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MULTIPLE USES OF IRRIGATION WATER IN THE HAKRA 6-R, DISTRIBUTARY COMMAND AREA, PUNJAB, PAKISTAN

By

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FOREWORD

Irrigation water, when supplied to rural communities, also meets their domestic, livestock and industrial needs. Such non-agricultural requirement of irrigation water is often not considered when decisions regarding operation and maintenance of the irrigation infrastructure are made. Recent awareness of this oversight led to one of the System-Wide Initiative on Water Management (SWIM) of the Consultative Group for International Agricultural Research (CGIAR). This study involved IIMI and the International Food Policy Research Institute (IFPRI) and was conducted in Sri Lanka and Pakistan.

This is the second activity related to rural health carried out by IIMI in Pakistan. (This first was to identify researchable tasks in rural health). This study was led by Dr. Waqar A. Jehangir and supported by Muhammed Mudasser, Mehmood ul Hassan and Zulfikar Ali. General guidance was provided by Mr. Flemming Konradsen from Colombo. Flemming has always supported and is part of health-related activities at IIMI Pakistan. We are grateful.

We believe that this report is the first of its kind in Pakistan. It has generated a lot of interest among the research community. The report is based on farmers' perceptions, rather than actual measurements. However, it does provide an insight into non-agricultural uses of irrigation water. We anticipate that the information contained in this report will lead to a number of detailed studies in rural health and sanitation in Pakistan.

S. A. Prathapar
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ABSTRACT

The main objective of the study is to document the multiple uses, and users, of irrigation water in the study area. The other objectives are: to identify the sources of water for various non-agricultural uses in the study area; to document users' perceptions about the quality of water for non-agricultural uses; to determine the incidence of water-borne diseases and their impact on human and livestock health, and environment in Hakra 6-R canal command, Haroonabad, irrigation sub-division, Punjab, Pakistan. The H-6-R Distributary is the sixth biggest distributary in Pakistan. Its total gross command area (GCA) is about 51,976 hectare. A multi-stage stratified random sampling technique was employed to select the sample from the study area. Out of 94 villages in the distributary command, 24 villages were selected for the study and the data were collected from 364 randomly selected households. A well-designed pre-tested questionnaire was used to collect the data.

The study revealed that village water tank (diggi) served as the major source of water as it provided around 44 percent of the daily water use. The water tank receives water from the canal on a weekly basis. The canal water allocation to the sample villages reveals that the average per capita daily water allowance varies between around 6-48 liters. Only a small proportion of the households had access to public water supply schemes. In total, the surface water sources accounted for 61 percent of the total water supplies (tank water, water supply scheme and canal).

Among the groundwater sources, most of the respondents reported obtaining water from either, a hand pump or an electric motor pump installed in the house. The results show that current domestic use meets only one third of the minimum daily water requirements of the households. About 58 percent of the respondents regarded the quality of seepage water, better as compared to that of the surface water. Almost 62 percent of the respondents (who used seepage ground waters) and almost half of the users of canal water and supply schemes were unaware of the type/source of contamination.

More than 55 percent respondents believed that dust particles and a mixture of dust, salt, sanitation wastage, insects, biological life, etc. contaminate the surface water. About 28 percent of the respondents opined that the groundwater was contaminated with salts. Estimates also, revealed that one or more members of about 90 percent of the households were suffering from water-borne diseases. The most prevalent diseases in the area are Malaria, Dysentery, Skin problems and Typhoid fever with the incidence was comparatively higher at the tail ends of the Distributary.

Besides the surface sources like minors and watercourses, the village water ponds are also used to supply water to the village livestock. About 60 percent of the livestock population with the sample households are affected from different water associated diseases like Diarrhea, Dysentery and Foot & Mouth disease, etc. It is estimated that about 48 percent of cattle, 70 percent of buffalo and 57 percent of goat population were affected from water associated diseases in 1997. Almost 89 percent of the respondents perceived wastewater as the cause of problems. For water purification majority of the households reported the use of a cloth filter for the surface waters. Only 37% of the sample households reported use of simple techniques such as boiling, chemicals (Alum or K2MnO4) and along with the use of a cloth filter.

MULTIPLE USES OF IRRIGATION WATER IN THE HAKRA 6-R DISTRIBUTARY COMMAND AREA, PUNJAB, PAKISTAN

1 INTRODUCTION

Of Pakistan's 140 million population, 69 percent live in rural areas (GoP, 1995). The irrigation water supplies for agricultural, and non-agricultural, purposes play multiple roles in their lives. The quantities of water used for non-agricultural purposes may be small, but in terms of household income, nutrition and health, command high values (Meinzen-Dick and Jackson, 1997). A literature review demonstrates that most of the studies conducted in Pakistan in the past revolved around the agricultural uses of irrigation water (Bhatti *et al.* 1991, Clark and Aniq, 1993 and Garces *et al.* 1994). Only a few research studies pertaining to rural water supplies have been conducted in Pakistan, and these were mainly focused on rural water supply policies, or evaluation, of the rural water supply program in the Punjab province (Altaf *et al.* 1993, World Bank 1993 and Rehman *et al.* 1988). Similar investigations have also been conducted in India (Griffin *et al.* 1995, Singh *et al.* 1993 and Bhatia, 1989). None of the studies in Pakistan provide any pragmatic estimates on the contribution of irrigation water to non-agricultural uses. Thus, in the absence of such estimates, these additional benefits are likely to be ignored when irrigation management practices, like the *warabandi* schedules, canal closures, etc. are modified to maximize the agricultural output per unit of water. For example, rotational water supplies in distributaries and minors result in water shortages for non-agricultural purposes. The closure of canals will result in lower water tables and dried up fresh water zones created due to the seepage from irrigation network.

The present study documents the spatial comparison of non-agricultural uses for irrigation water by different users located in the head, middle and tail reaches of the Hakra 6-R Distributary, Tehsil Haroonabad. Different sources of water in saline areas, its quality as perceived by the users and the impacts of alternative sources of water on the health of humans and livestock are investigated.

1.1 OBJECTIVES

The objectives of the study are:

1. to document different uses, and users, of irrigation water in the study area;
2. to identify sources of water, for various non-agricultural uses, in the study area;
3. to document users' perceptions about the quality of water for non-agricultural uses;
4. to document issues related to acquiring water in the study area;
5. to determine the incidence of water-borne diseases and their impacts on human, and livestock, population in the study area;
6. to study the relationship between different age groups and the prevalence of water-borne diseases; and

7. to study the relationship between the household's level of education and the prevalence of water-borne diseases.

1.2 METHODS

1.2.1 The Study Area

This study was conducted along the Hakra 6-R Distributary, Tehsil Haroonabad. The provision of water in the Hakra 6-R Distributary depends on a number of upstream irrigation link canals and barrages, as shown in Figure 1. The Eastern Sadiqia Canal originates from the left bank of the Sulemanki Headworks, and after approximately 46 miles (74 kilometers), splits into the Hakra Branch Canal, Malik Branch Canal and Sirajwah Distributary. Two distributaries originate near Head Mianwala Bangla from the main Hakra Canal, i.e., Hakra 2-L and Hakra 6-R Distributaries, while the main Hakra Canal flows towards the tail reaches. The Hakra 6-R Distributary covers a gross command and canal command area of about 51976 hectare and 42538 hectare, respectively. The main Hakra 6-R Distributary is about 45 kilometers long, with four minors (i.e., 1R, 2R, 1L and 2L) and two sub-minors (i.e., 1R/1L and 1L/1L). The Hakra 6-R Distributary has 283 outlets. The authorized discharge of the Hakra 6-R Distributary is 16.65 M3 in the kharif and 15.5 M3 in the rabi seasons. Of the 94 villages along the Hakra 6-R Distributary, 24 (i.e., 8 from each, head, middle and tail reaches) were selected for the current study (Figure 1).

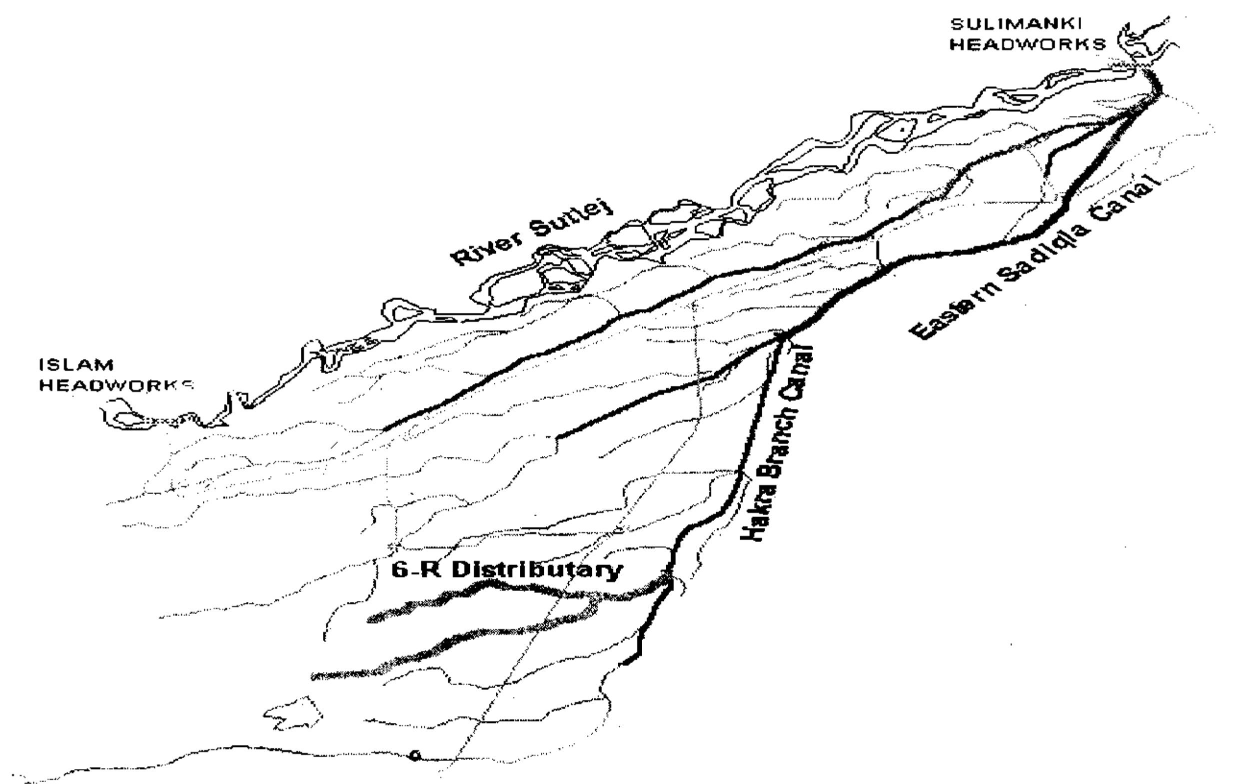

Figure 1. Irrigation Network below Sulemanki Headworks.

1.2.2 Sample Selection

A multi-stage stratified random sampling technique was used to select the sample from the study area. The 1st stage encompassed the spatial stratification of the Hakra 6-R Distributary into head, middle, and tail reaches. Eight villages from each reach were randomly selected during the 2nd stage. In the 3rd stage, a sample of 120 households from among the voters in each reach was randomly selected. Thus, the total sample size involved 360 respondents. Among selected households, the data were collected from both, the male and female heads of households, using a structured questionnaire, twice formerly pre-tested in the field.

1.2.3 Pre-testing Questionnaire and Training Enumerators

Before the actual data collection, the questionnaire was pre-tested in the field in order to evaluate its workability, and as a result, appropriate modifications were made. The revised questionnaire was pre-tested once more in another location among the non-sampled villages of the Hakra 6-R Distributary.

The purpose of imparting training, spread over several sessions, to the enumerators was to avoid conceptual biases in data collection (Memon et al. 1997). The first session served as an explanatory session, in which the procedure for selecting respondents was explained. The following session focused on commonly made mistakes when obtaining information using a structured questionnaire. Another session highlighted the concepts used in the questionnaire, background objectives, and the meanings of various questions.

Subsequently, respondents were asked to interview the trainers, so that their mistakes were immediately indicated for ratification. This exercise was repeated numerous times to ensure that the enumerators and trainers were in full understanding. The final session entailed coding procedures, in which the importance of using accurate codes was also discussed in detail. After these sessions, the enumerators were taken to the field, and trainers conducted two demonstration interviews. Later, each enumerator was asked to conduct one interview in the presence of the trainers. An exception was made for female enumerators, as the trainer was refused permission to interact with the female respondents. The enumerators' completed questionnaires were examined in another session, and mistakes made in data collection were discussed at length. Enumerators were also asked, and encouraged, to note responses considered deviations from coded responses. These were added to the coding list, and modified accordingly for distribution among enumerators.

The data entry person was also trained in the field, and was asked to defer any erroneous questionnaire to the concerned enumerator and to discuss it with field supervisors. Enumerators went back to verify responses from respondents. Initially, the data were recorded in spreadsheet format using Q-Pro software. Once data entry was complete, data processing consumed a significant amount of time and effort. The Statistical Package for Social Scientists (SPSS) was used to analyze data, and simple frequency distribution and cross tabulation were used for data analysis.

1.2.4 General Characteristics of the Users (Sample Households)

This section briefly discusses the general characteristics of the sample households so that the reader is able to understand the general socio-economic setting of the research area. Some important social variables are religion, residential and settlement patterns, assets owned by households, physical conditions of their residences, etc.. An overwhelming majority of the sample households (98.6%) was Muslim, and most (93%) were local residents who settled in the area during the early 1930's with the construction of the irrigation system in 1932. Other settlers migrated from India during Partition (1947), and purchased land for cultivation.

Among sample households, a vast majority (92%) was residing inside their village boundaries, around 5 percent outside the village and another 2 percent at their own farmhouses. Almost half of the sample households had mud-constructed (kachha) houses, and the rest, completely, or partially, concrete / brick-constructed houses. Kachha houses had no access to water for domestic cleaning purposes. Over half of respondent families (53.5%) had their own transport. Generally, they used bicycles, motorbikes, tractors, or motor cars. Around 22 percent of respondent families reported more than one mode of transport. Around one-third of households owned a television or radio, or both. Every two of three respondents owned a color television.

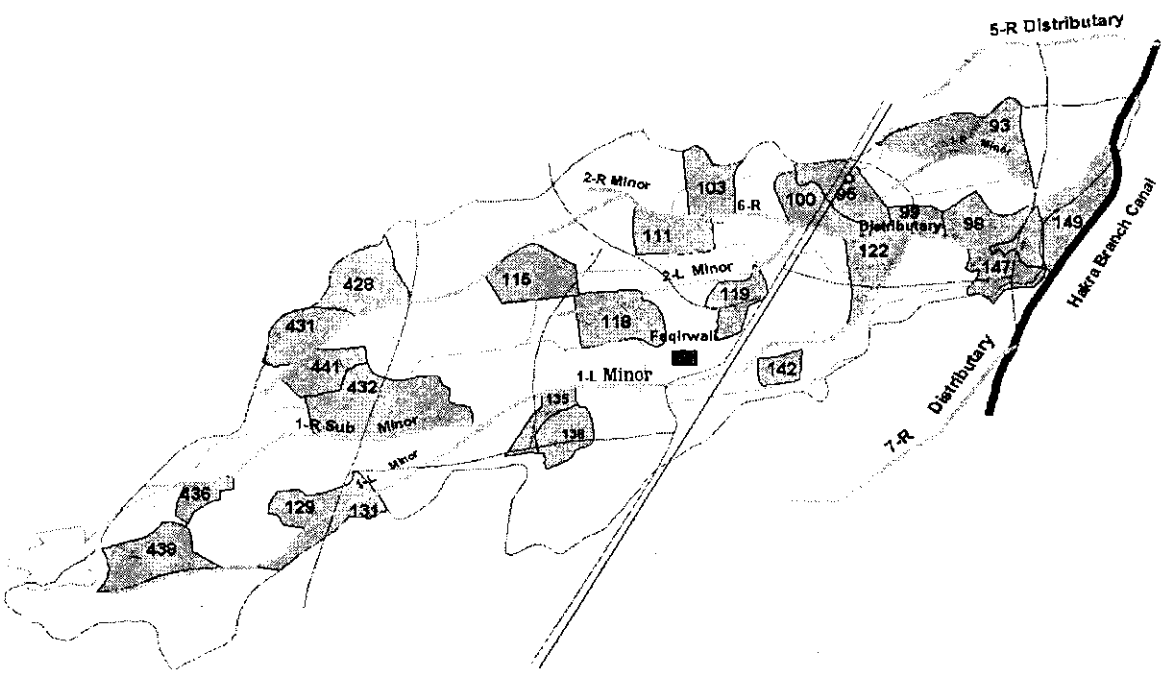

Figure 2. Locations of Sample Villages along the Hakra 6-R Distributary.

Female enumerators observed that around one-third of the houses were poorly cleaned, and reflected that poor hygienic conditions prevailed. Moreover, about half of the households did not have domestic sewerage disposal facilities, and generally, family members visit the fields when necessary. Every sixth house in the sample used pit latrines, enabling fecal waste to be dumped into deep pits. The high water table in the area increases the risk of groundwater pollution. The remainder of the households had poor flush latrines. The heads of the sample households had almost double the literacy level when compared to that of national and provincial averages. One out of every eight persons had attended school for more than 10 years. Only 37 percent of respondents were illiterate. There had been almost no difference in educational attainments between the head, middle, and tail reaches of the distributary. Over half of respondents had attended school for 10 years, or less.

2 NON-IRRIGATION USES OF IRRIGATION SUPPLIES IN THE HAKRA 6-R DISTRIBUTARY

This section entails a brief account of water availability for non-irrigation uses of water in the Hakra 6-R Distributary command (the research site for the present study). The research study at hand was exploratory, with an overall objective to document the uses. There are several non-irrigation uses of canal water in the Hakra 6-R Distributary, which satisfy various household, livestock, industrial, and aquaculture needs. Apart from these, the water is also used for brick making, construction, and vehicle washing activities. Except for the water used for industrial production, fish farming, and brick making, all other uses are household-oriented and one, or more, members of the household benefit from that use directly.

2.1 CANAL WATER ALLOCATION FOR NON-IRRIGATION USES

The canal water is usually allocated to the non-irrigation users to meet human and livestock needs. In general, two different conditions exist for water allocation. In the villages where the village water tanks (tank water serves human beings and pond water serves livestock needs) are connected to an existing watercourse, a separate time is allocated from the watercourse's irrigation roster for both tanks. The irrigation roster in the study area completes one cycle per week (168 hours), implying that each Giggi receives water once a week according to its water turn (2-5 hours). The distribution of water between the two tanks takes place on the decision of the community itself. In the other situation, where the village does not fall on the route of a watercourse, a separate water supply channel runs to the village water reservoirs (water tank / diggi) from the nearest canal (Figure 3). This is an exclusive watercourse, but the community can only open it for a specific duration each week.

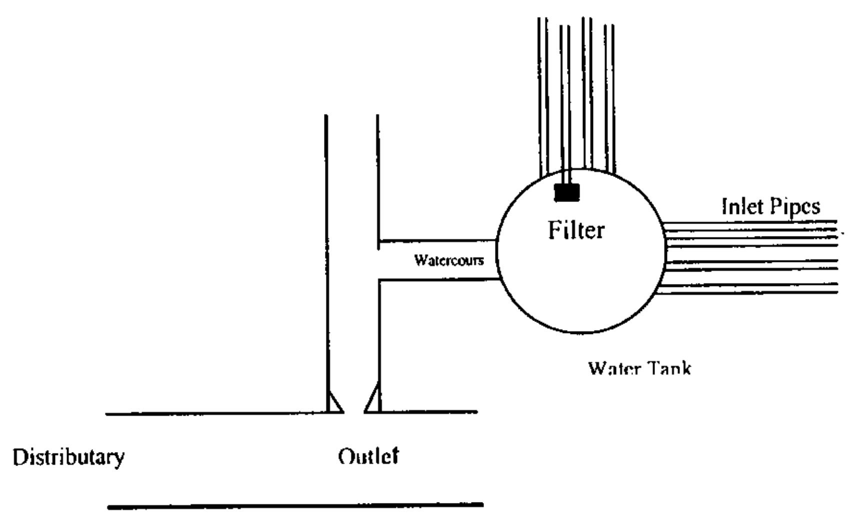

Figure 3. Layout of drinking water tank (*diggi*).

2.1.1 Availability and Daily Consumption of Water

The canal water allocation to the sample villages is presented in Table 1. The amount of water allocation has been calculated by multiplying the authorized discharge of the specific watercourse at full supply level, with the length of the turn allocated to the community water supply. The information reveals that the average per capita daily water allocation varies between around 6 liters in Chak No. 428/ 6-R to 48 liters in Chak No. 142/-R. A greater variation in allocation is evident within the villages of the head reach than that of the other reaches. This reflects that the size of the population does not act as a basis for water allocation. The water allocation is not fixed equally for every village, regardless of other influences. The canal water feeds all the surface water sources (water tanks, water supply schemes, etc.) in the area. Sometimes, the source of water is not readily accessible to the users. Only 12 percent of households have access to public water supply schemes. Another 19 percent of households had installed motor pumps in their homes to exploit groundwater (accumulated in the area through seepage from the irrigation network) to meet their daily water demands.

Table 1. Average Canal Water Allocation for Water Tanks and Village Ponds in the Sample Villages.

Distributary Reach	Chak No.	Population of the Village	Water Allocation for the Village	Average Allocation
		(number)	(cu. meter / week)	(liters / person / day)
Head	149	2000	281	20.1
	98	5500	277	7.2
	99	2000	230	16.4
	93	4800	289	8.6
	95	2200	410	26.6
	100	3500	220	9.0
	122	1300	212	23.3
	147	2400	381	22.7
Total	**8**	**23700**	**2300**	**13.9**
Middle	103	2000	465	33.2
	111	2200	312	20.3
	119	1500	228	21.7
	118	4000	283	10.1
	115	1500	234	22.3
	142	1500	508	48.4
	135	1350	291	30.8
	138	1540	251	23.3
Total	**8**	**15590**	**2572**	**23.6**
Tail	428	8000	322	5.8
	431	2800	371	18.9
	441	1500	204	19.4
	129	3000	291	13.9
	438	1100	334	43.4
	436	1150	359	44.6
	131	1200	318	37.9
	432	2800	361	18.4
Total	**8**	**21550**	**2560**	**17.0**
Grand Total	**24**	**60840**	**7432**	**17.5**

Table 1 presents a picture of water allocated to various villages from among the sample villages. The quantities reflect the amount of allocated water at the full supply level. However, important to note is that the distributary under consideration operates in rotation with other distributaries on the Hakra Branch Canal.[1] Very well possible is that the distributary may draw more than the allocated water for one week, and remains dry during the other. However, drawing double discharge in a week is impossible due to the design constraints of the distributary. In general, each distributary can accommodate almost 20 percent additional water than its designed allocation. An underlying assumption in the construction of the aforementioned table is that, on average, the distributary flows at the full supply level.

Two important conclusions glean from Table 1. Firstly, per capita allocation varies greatly between various reaches of the distributary, the maximum at the middle reach and the minimum at the head. This implies that the water allocation is not based on the size of the population to be served, but rather on some other criterion. Secondly, and most importantly, at all three of the distributary reaches, the allocation is far below the minimum daily water requirement for human beings (Shah and Ansari, n.d.)[2]. Even if assumed that the distributary always runs at the full supply level, the water allocation is not enough for human beings in all the areas. Besides, the allocated water does not always reach the water tank in full due to conveyance losses in the watercourse. The water requirement for the livestock and other needs has yet to be accounted for. This suggests that the exploitation of groundwater becomes unavoidable for the households to fulfill their daily water requirements.

The average daily water use for various household purposes has been estimated and is presented in Table 2. The information reveals that tank water is the major source of water as it provides around 44 percent of the daily water use. In total, the surface water sources account for 61 percent of the total water supplies (tank water, water supply scheme and canal). The canal provides all the surface water; a water channel connects the water supply schemes and the water tanks to the canal. When compared with the direct water use from the canal, the only difference is that some of the supply schemes provide somewhat clean water, which is either filtered or treated with chemicals. The supply scheme runs for a specified duration daily. The water tank receives water from the canal on a weekly basis and the stilling in the tank, to some extent, removes silt particles from the water.

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1 The distributaries on this branch canal have been grouped into three groups. There are three priorities. One group will be on one priority for one week. The group in the first priority gets demanded discharge. If some water still remains undistributed in the branch, it will be equitably distributed among the second group, in proportion to their demands. If still more water remains in the command, it will be distributed among the group with the lowest priority. In general, however, third preference distributaries seldom get water and remain closed.

2 According to them, the average minimum per day requirement for domestic consumption is 20 British Gallons, or 91 liters per person. Of this, 0.35 , 0.65, 8, 3, 3, and 5 gallons are required for drinking, religious, cooking, washing utensils, laundry and water closest, respectively.

Table 2. Quantity of Water Consumed by Sources and Uses of Water.

Water use	Average quantity of water used from the source (Liters/ Day/ Person)						
	Water Tank	Supply Scheme	Canal	Hand Pump	Electric Pump	Well	Total
Drinking	0.62	0.20	0.09	1.76	0.57	0.35	3.60
Cooking	0.36	0.11	0.03	0.72	0.29	0.14	1.65
Washing of Utensils	1.18	0.30	0.09	0.47	0.48	0.06	2.57
Laundry	3.65	1.03	0.80	0.70	1.33	0.03	7.54
Bathing	3.94	1.08	0.33	1.32	1.42	0.07	8.16
House Cleaning	1.51	0.51	0.05	0.11	0.68	0.00	2.87
Religious	1.16	0.31	0.03	0.59	0.48	0.05	2.62
Sanitation	1.77	0.52	0.07	0.64	0.67	0.08	3.74
Total (% of total)	14.19 (44)	4.06 (12)	1.48 (5)	6.31 (19)	5.93 (18)	0.77 (2)	32.76 (100)

Among the groundwater sources, most of the respondents obtain water from either, a hand pump or an electric motor installed in the house. In general, hand pumps are located closer to places where a greater possibility to recover the fresh recharge of the aquifer through seepage exists. Similarly, electric motors are usually installed in the house, but these draw seepage water from the vicinity of the water tank or livestock pond.

The canal water allocation forms almost half of the average water use in the area, and just 19 percent of the suggested minimum water requirement. The current water use meets 36 percent of the minimum daily water requirement. The assertion can be made that the research area is extremely scarce in water resources.

2.2 Effect of Other Uses of Water on Crops

Since canal-based water serves as the major source, there is a possibility that non-agricultural uses might have reduced water availability for crops. The majority of the respondents, however, thought that the other uses have not limited the water supply for agriculture. The most common reason quoted was that there was a separate water allocation for other purposes. Some of the respondents believed that when compared to agriculture, other uses consume much less quantities of water, which may not affect the crops. A few of the respondents believed that since there is an incidence of waterlogging, canal water is in excess of irrigation requirements. Around 11 percent of the respondents enlisted all of the mentioned reasons. One-third of the respondents did not respond to this question.

2.3 Consideration of Non-irrigation Uses in Water Allocation

The people in the villages generally use canal water from village water tanks to meet their household needs and from water ponds for livestock. Generally, these two sources have a water turn in the irrigation roster of the watercourse it emanates from. Nevertheless, in some areas, separate allocations are also present for communal graveyards, schools, and hospitals to meet various other needs. While more than 80 percent of the respondents believed that their water tank and village pond had an allocation of water in the irrigation roster, around 14 to 18 percent did not believe so. Some respondents were not living in the village, but elsewhere. Their water tanks and ponds are personal, not communal. There is no water allocation arrangement for these personal tanks. Similarly, one-third of the respondents believed that the schools located in the village had no legal water allocation from the canal.

2.4 Consideration of Non-irrigation Uses during Irrigation System O&M (Closure, Lining, Rotation, etc.)

While the allocation of water for other purposes appear to be less than the requirement, operation and maintenance of the irrigation system may altogether cut off water supply for other purposes, temporally. According to the opinion of an overwhelming majority (96%), the Punjab Irrigation Department (agency responsible for canal operation and maintenance) has no consideration for other uses when closing the distributary for maintenance. The entire water supply to the canal system in Pakistan is, necessarily, turned off for a minimum period of 25 days during December and January each year. In practice, this closure may last more than 40 days or so, implying that the villagers would drain their water tanks and ponds and eventually have no water if the canal is turned off for longer periods.

Besides the annual closure, canals may experience several breaches during a year, and consequently, the water supplies would be temporarily disconnected. Such constraints are due to negligent maintenance or farmers' deliberate efforts to cut the canal bank to secure more water for irrigation. Repairing a breach may sometimes take several days. Since the distributary is operated under a rotational program consisting of three weeks, it gets full supply in only one of the three weeks. If the water is abundant, it may possibly receive water in the second and third week; but practically, the distributaries do not receive any water during the second and third week of rotation. Almost one-third of the respondents believed that their service was cut off for at least one to more than ten times during last year.

Another important feature of the study area is that the distributary is lined. Due to lining, the recharge of the shallow aquifer has diminished seriously. Though this may have some positive effects for crops, it also has some negative effects for other uses. The majority of the respondents believed that the canal lining was unfavorable for crops (due to more breaches on upstream unlined patches), but had no effect on household or livestock uses (due to exploitation of seepage water from nearby fields/diggi/pond etc).

2.5 Availability of Irrigation Water for Other Uses

In the situation where groundwater is generally unsuitable for human consumption, the users consider a number of factors before choosing their major source for domestic water supply. They select their source owing to a multitude of criteria, ranging from its quality to the mere fact that it is the only source that could provide enough water for domestic consumption. Other reasons related with the choice of the source are its comparative low cost, easy accessibility, reliability of water supply, etc., or a combination of many of these considerations. The following sections discuss the underlying reasons behind the choice of the major source for various domestic uses. The source of information is the female respondents of the survey. The major reason for limiting the analysis to the female householders is because they are responsible for undertaking most of the household activities that require water.

2.6 Source of Water for Household Needs and Reasons for Preference

The scarcities of water from canal sources forces the people to exploit both, the surface and seepage from the irrigation water network in to the groundwater. The choices of the source for various uses are presented in Tables 3 and 4.

Table 3. Sources of Water Used for Various Purposes by Households.

Household Uses	Surface Water	Groundwater	Both	Number of Respondents
Bathing	65.1%	33.0%	1.9%	364
Cooking	37.1%	62.9%	0.0%	364
Drinking	17.6%	81.9%	0.5%	364
House Cleaning	73.6%	26.4%	0.0%	148
Laundry	74.7%	22.5%	2.8%	364
Sanitation	59.4%	38.7%	1.9%	364
Washing Utensils	63.7%	34.1%	2.2%	364
Religious	55.5%	42.6%	1.9%	364

Table 4. Reasons Considered in Choosing Water for a specific Use.

	Low Cost	Quality	Easy Access	Quantity	Availability	Many Reasons	Total	
	%	%	%	%	%	%	No.	%
Bathing	3.6	17.6	8.2	0.0	24.2	46.4	364	100
Cooking	0.0	48.6	0.0	0.0	15.9	35.4	364	100
House Cleaning	0.0	14.3	12.9	0.0	30.6	41.5	147	100
Drinking	0.0	57.7	0.0	0.0	19.0	23.4	364	100
Laundry	3.8	14.8	7.7	7.7	14.3	51.6	364	100
Religious	3.8	8.9	21.3	0.0	27.5	38.2	338	100
Sanitation	4.1	4.7	23.9	0.0	28.8	38.5	364	100
Washing Utensils	4.1	20.3	10.2	0.0	21.2	44.2	364	100

2.6.1 Source for Drinking Water

Table 5 reveals that almost half of the households were using hand pumps to obtain seepage water for drinking purposes. The canal water, as such, was the least used source (only 2%). Another one-sixth of the households used the communal village tank water. Almost three-fourths of the households used seepage groundwater (from hand pumps and electric motors) for drinking purposes. Only 28 percent of the households used surface water (from village tanks, water supply schemes, and canals). The water supply schemes need a special mention. Most water supply schemes in the selected area are nothing more than a special buried pipe running from the canal into a tank, from where the water is supplied into the houses. Thus, it is also a canal-based source protected from local contamination during conveyance. A few of the water supply schemes, however, have the facility of slow sand filters, which makes it safer for human consumption.

Table 5. Source of Drinking Water by Perceptions and Reason for Preferences over Other Sources.

Source	Reasons for Preferences				
	Quality	Availability	Many Reasons	Total %	Number of Respondents
Canal	42.9%	14.3%	42.9%	100.0%	7 (2)
Water Supply Scheme	10.7%	21.4%	67.9%	100.0%	28(8)
Motor Pump	70.9%	9.1%	20.0%	100.0%	55(15)
Hand Pump	76.1%	6.1%	17.8%	100.0%	180(49)
Water Tank	9.4%	68.8%	21.9%	100.0%	64(18)
Well	73.3%	6.7%	20.0%	100.0%	30(8)
Total No.	210	69	85		364(100)
Total %	57.7%	19.0%	23.4%		

Note: Figures in parenthesis are the percentages out of total respondents.
* = More than one reason, including combinations of cost, quality, access, reliability, quantity, and availability consideration.

The reason why the majority of households in the area choose groundwater as the source for drinking water is to recover the seepage water from the watercourses/canals. Hand pumps were installed along watercourses in these areas. This keeps the water quality relatively better than other surface or groundwater sources. Similarly, electric motor pumps draw water from bore holes dug into the land near the water tank. At a few places, the dug wells are located either close to the water tank, or at a sweet water pocket.

2.6.2 Source for Cooking Water

For cooking water, the source of water and reasons for preferences over other sources are presented in Table 6. Out of the sample households, many were using hand pump water for cooking, followed by water from the village water tank. Some others used groundwater extracted through electric motor pumps. Almost two of the three households used groundwater for cooking purposes. Only a few households used water from wells or canals. Almost 66 percent of the respondents who used hand pumps to obtain water for cooking reported that they had opted for the hand pump because of the relatively superior quality of water. Only 6 percent chose this option because it was the only available source. Around one of every four respondents chose it for a combination of reasons. Almost 50 percent of the households using tank water for cooking preferred its water because of a combination of reasons. To another one-third of the respondents, surface water was the only available source. One of five respondents opted for the quality of water.

Respondents who used canal water as their basic source for cooking clearly used a multi-criteria approach for selecting canal water. In general, water from the canal or the watercourse is used in very special cases. For instance, if the user is residing away from the main village, he will opt for the nearest source that can supply water for his needs. Under such circumstances, water from canals and watercourses will be free of cost and easily accessible. From this discussion transpires that users are as cautious about water for cooking purposes as they are about drinking water. The majority of users opted for the specific groundwater source because of its quality.

Table 6. Source of Cooking Water by Perceptions of Reason for Preferences over Other Sources.

Source	Reason For Preferences				
	Quality	Availability	Many Reasons	Total %	Number of Respondents
Canal	33.3%	11.1%	55.6%	100.0%	9 (2)
Motor Pump	56.6%	11.3%	32.1%	100.0%	53 (15)
Hand Pump	67.3%	6.0%	26.7%	100.0%	150(41)
Water Tank	19.0%	31.7%	49.2%	100.0%	126(35)
Well	73.1%	7.7%	19.2%	100.0%	26(7)
Total No.	177	58	129		364(100)
Total %	48.6%	15.9%	35.4%	100.0%	

Note: Figures in parenthesis are the percentages out of total respondents.
* = A combination of preferences based on the cost, quality, accessibility, reliability, quantity, and availability.

2.6.3 Source for House Cleaning

For cleaning the house (Table 7), which was being done by only 41 percent of the total respondents, 72 percent used water from the village water tank. The reasons for cleaning the house with tank water were many; more specifically, the availability of water. Beside many reasons, those using water from electric motors (another 18%) opined that they chose it owing to easy access. The use of tank water by the majority implies that the quality of water attached to house cleaning is meaningless. Moreover, for this purpose, water is also required in relatively larger quantities. If one has to fetch water from a hand pump, or directly from the canal, it becomes an uphill task.

Table 7. Source of Water for House Cleaning by Perceptions and Reasons for Preferences over Other Sources.

Source	Reason for Preference					
	Quality	Easy Access	Availability	Many reasons*	Total %	No.of respondents
Canal			50.0%	50.0%	100.0%	3 (2)
Motor Pump	3.8%	30.8%	19.2%	46.2%	100.0%	27(18)
Hand Pump	33.3%		41.7%	25.0%	100.0%	12 (8)
Water Tank	15.2%	10.5%	31.4%	42.9%	100.0%	106(72)
Total No.	21	19	45	61		148(41)
Total %	14.4%	13.0%	30.8%	41.8%	100.0%	

Note: Figures in parenthesis are the percentages out of total respondents.
* = A combination of preferences based on the cost, quality, accessibility, reliability, quantity, and availability.

2.6.4 Source for Bathing Water

About two-thirds (65%) of households used surface water for bathing purposes (Table 8). Most took a bath with water obtained from a water tank. The majority of those who used groundwater for bathing obtained it from hand pumps. Noteworthy is that many males in the rural areas take a jungle-bath right at the source. Therefore, they do not fetch water for bathing. Preferences for bathing water, as revealed by the users, depict that around one-fourth of households used hand pumps, water tanks or motors, and 83 percent of those who used well water, chose their source because of availability. Over half the users chose canal water for bathing owing to a multitude of reasons. They would have taken a jungle-bath in the canal.

Table 8. Source of Water for Bathing by Perceptions and Reasons for Preferences over Other Sources.

Source	Reasons for Preference						
	Low Cost	Quality	Easy Access	Availability	Many reasons*	Total %	Number of respondents
Canal	.0%	30.8%	.0%	11.5%	57.7%	100.0%	27(7)
Water Supply Scheme	.0%	7.0%	7.0%	9.3%	76.7%	100.0%	43(12)
Motor Pump	.0%	8.0%	20.0%	22.0%	50.0%	100.0%	50(14)
Hand Pump	3.3%	23.3%	10.0%	28.3%	35.0%	100.0%	64(18)
Water Tank	6.6%	19.9%	6.6%	28.9%	38.0%	100.0%	166(46)
Well	.0%	.0%	.0%	83.3%	16.7%	100.0%	6(2)
Combination of Any Two Sources	.0%	28.6%	.0%	.0%	71.4%	100.0%	7(2)
Total No.	13	64	30	88	163	100.0%	364(100)
Total %	3.6%	17.9%	8.4%	24.6%	45.5%	100.0%	

Note: Figures in parenthesis are the percentages out of total respondents.
* = A combination of preferences based on the cost, quality, accessibility, reliability, quantity, and availability.

2.6.5 Source of Water for Religious and Laundry Purposes

A similar picture to that of bathing can be witnessed for the use of water for religious purposes and washing utensils (Tables 10 and 11). Water for religious use is limited to ablution for prayers. For religious purposes, the users' perceptions appear to be the options of easy access, availability and a combination of several reasons. Easy access and availability in this case might have been considered synonymous to each other, as most of the males perform their ablutions in the mosque, where water is available and accessible. Some changes are noticeable in the perceptions for choice of the source between the two uses. Converse to the choice of source for drinking and cooking water uses, almost two-thirds of respondents preferred using surface water for laundry purposes.

Table 9. Source of Water for Laundry by Perceptions and Reasons for Preferences over Other Sources.

Source	Reasons for Preference							
	Low Cost	Quality	Easy Access	Quantity	Availability	Many reasons*	Total %	Number of Respondents
Canal	2.7%	14.9%	1.4%	18.9%	.0%	62.2%	100.0%	74(20)
Water Supply Scheme	.0%	7.1%	7.1%	2.4%	9.5%	73.8%	100.0%	42(11)
Motor Pump	.0%	6.7%	22.2%	11.1%	11.1%	48.9%	100.0%	45(12)
Hand Pump	5.4%	27.0%	10.8%	.0%	18.9%	37.8%	100.0%	37(10)
Water Tank	6.4%	17.3%	6.4%	5.1%	23.1%	41.7%	100.0%	156(43)
Combination of Any Two Sources	.0%	.0%	.0%	.0%	.0%	100.0%	100.0%	10 (3)
Total No.	14	54	28	28	52	188	100%	364
Total %	3.8%	14.8%	7.7%	7.7%	14.3%	51.6%		

Note: Figures in parenthesis are the percentages out of total respondents.
* = A combination of preferences based on the cost, quality, accessibility, reliability, quantity, and availability.

Table 10. Source of Water for Religious Use by Perceptions of Reason for Preferences over Other Sources.

Source	Reasons for Preference						
	Low Cost	Quality	Easy Access	Availability	Many reasons*	Total %	Number of respondents
Canal	.0%	.0%	50.0%	.0%	50.0%	100.0%	6(2)
Water Supply Scheme	.0%	4.7%	14.0%	9.3%	72.1%	100.0%	43(12)
Motor Pump	.0%	6.7%	24.4%	15.6%	53.3%	100.0%	51(14)
Hand Pump	2.6%	25.6%	10.3%	26.9%	34.6%	100.0%	93(25)
Water Tank	7.5%	1.4%	29.3%	33.3%	28.6%	100.0%	152(42)
Well	.0%	27.3%	9.1%	63.6%	.0%	100.0%	11(3)
Combination of Any Two Sources	.0%	.0%	.0%	71.4%	28.6%	100.0%	7(2)
Total No.	13	30	72	93	129	100.0%	364
Total %	3.9%	8.9%	21.4%	27.6%	38.3%	100.0%	

Note: Figures in parenthesis are the percentages out of total respondents.
* = A combination of preferences based on the cost, quality, accessibility, reliability, quantity, and availability.

Table 11. Source of Water for Washing Utensils by Perceptions and Reasons for Preferences over Other Sources.

Source	Reasons for Preference						
	Low Cost	Quality	Easy Access	Availability	Many reasons*	Total %	Number of respondents
Canal	5.6%	11.1%	5.6%	.0%	77.8%	100%	18(5)
Water Supply Scheme	.0%	4.8%	7.1%	11.9%	76.2%	100%	43(12)
Motor Pump	.0%	14.0%	24.0%	16.0%	46.0%	100%	50(14)
Hand Pump	2.7%	27.0%	5.4%	21.6%	43.2%	100%	74(20)
Water Tank	7.1%	24.9%	10.1%	27.2%	30.8%	100%	170(47)
Combination of Any Two Sources	.0%	12.5%	.0%	25.0%	62.5%	100%	8(2)
Total No.	15	74	37	77	158	100%	364
Total %	4.2%	20.5%	10.2%	21.3%	43.8%	100.0%	

Note: Figures in parenthesis are the percentages out of total respondents.
* = A combination of preferences based on the cost, quality, accessibility, reliability, quantity, and availability.

The choice of water source for sanitation (Table 12) shows that many households used either water tanks (47%) or hand pumps (22%). Others used water from water supply schemes (12%) and motor pumps (14%). The choice depended on, in most cases, either availability or a combination of availability, quality, quantity, accessibility, cost, etc..

Table 12. Source of Water for Sanitation by Perceptions and Reason for Preferences over Other Sources.

Source	Reason for Preference						
	Low Cost	**Quality**	**Easy Access**	**Availability**	**Many reasons***	**Total %**	**Number of respondents**
Water Supply Scheme	.0%	4.7%	16.3%	9.3%	69.8%	100.0%	43(12)
Motor Pump	.0%	2.2%	31.1%	20.0%	46.7%	100.0%	51(14)
Hand Pump	6.0%	11.9%	17.9%	38.8%	25.4%	100.0%	79(22)
Water Tank	6.7%	2.4%	31.5%	31.5%	27.9%	100.0%	172(47)
Well	.0%	9.1%	18.2%	72.7%	.0%	100.0%	11(3)
Combination of Any Two Sources	.0%	14.3%	.0%	85.7%	.0%	100.0%	7(2)
Total No.	15	17	87	105	114	100.0%	364
Total %	4.4%	5.0%	25.7%	31.1%	33.7%	100.0%	

Note: Figures in parenthesis are the percentages out of total respondents.
* = A combination of preferences based on the cost, quality, accessibility, reliability, quantity, and availability.

The majority of respondents used ground water sources for drinking and cooking. The reason is that although the groundwater is brackish, there are fewer chances of other types of pollution. Besides, small pockets of comparatively sweet water do exist in the command areas where people have the ability to capture the fresh recharge to aquifer due to seepage from the canal, watercourse, water tank, etc.. The users appear to be conscious about the quality of water, which they have to consume. For all other household uses, such as bathing, sanitation, and religious, the majority of respondents preferred to use surface water. Some of the uses, such as laundry, house cleaning and bathing need adequate water that is only available from surface water sources. The conjunctive use of water appears to be minimal for all purposes, and its exploitation seems to be limited for when the major source is temporarily unavailable.

Another transpiration is that the majority of households using groundwater opted for these sources because of their perception that the quality of groundwater was comparatively better (as it may have less contaminants) than that of the surface water. The surface water users did not opt for the source due to quality; rather, their choice was guided either by the fact that it was the only available source, or a multitude of reasons including relative cost, accessibility, reliability, availability, quality and quantity.

2.7 WATER USE FOR LIVESTOCK

Livestock is an important consumer of water. In the rural areas, people raise livestock as an essential enterprise that supplements their family income. Livestock is kept at home as well as at the farm. If livestock is kept at home, they are fed by bringing fodder and other feeds to the home from elsewhere. The domestic water supply source is used for livestock drinking and bathing. On the contrary, livestock kept on the farm is generally driven into the canal or the watercourse, whichever is nearer, for consumption and bathing purposes. In some instances, a ditch dug on farm premises is filled with irrigation water once a week for livestock use. Since most of the water for livestock use takes place at the source, measuring the water used was not possible. However, as a proxy to availability, farmers' perceptions on adequacy of water for livestock were recorded and analyzed. Table 13 presents the results.

The perceptions among households on the adequacy of water for livestock reveal that in general, respondents regarded water supplies to be adequate for their livestock. Comparatively however, more respondents regarded the water supplies insufficient for farmyard livestock when compared with livestock kept at home. The reason is that groundwater supplies for livestock at the farm are either limited, or non-existent. This implies that the surface water supplies alone are insufficient, whether the animals are kept at home or on the farm. Augmentation of water availability for livestock by supplementing it with groundwater supplies makes enough water available for livestock kept at home.

Table 13. Users' Perceptions about Adequate Water Supplies for Livestock.

Livestock	At Home			On the Farm		
	Enough	Not Enough	No.	Enough	Not Enough	No.
	%	%		%	%	
Cattle	95%	5%	57	71%	29%	65
Buffalo	93%	7%	159	71%	29%	129
Goat	96%	4%	189	72%	28%	98
Poultry	98%	2%	112	92%	8%	29
Donkey	-	-	-	64%	36%	22

Another revelation is that at home, the inadequacy of water supplies for livestock is more pronounced for buffaloes and cattle, and on the farm, this also includes donkeys. Therefore, inadequacy becomes more pronounced only in the case of livestock that needs a higher daily intake of water. Table 14 reflects the situation of sources of water used for livestock, for drinking and bathing, purposes. Table 14 exhibits that the tendency to use surface water for livestock is higher among respondents who keep livestock on the farm than those kept at home. The reason is because surface water supplies are higher on the farm than in the village due to the spatial proximity of the farmhouse to the canal or the watercourse. As already mentioned, people dig water ponds for livestock, adding canal water to these during their own irrigation water turns whenever deemed necessary. Moreover, in the case of bigger animals needing more water, such as cattle, buffaloes, and donkeys, drawing the required amount of water from the well or the hand pump is a tough job.

Table 14. Livestock Water Use at Home.

	Type of Livestock	Surface Water	Groundwater	Both	Total	
At Home		%	%	%	%	No.
	Cattle	75.5	24.5	0	100	57
	Buffalo	76.1	22.6	1.3	100	159
	Goat	58.2	39.7	2.1	100	189
	Poultry	53.6	43.8	2.6	100	112
On the Farm	Cattle	84.6	7.7	7.7	100	65
	Buffalo	89.2	2.4	8.4	100	129
	Goat	80.6	8.1	11.3	100	98
	Poultry	68.9	10.5	20.6	100	29
	Donkey	81.8	0	18.2	100	22

For livestock kept at home, the second major source of water appears to be groundwater. Usually, the village pond is situated on alternate corners of the village on the outskirts of the dwelling area, and many women, as custodians of livestock kept at home, find it difficult to take livestock to the pond to drink and bathe twice a day. Besides, in many villages all the sewer and village wastewater is drained to the village pond, polluting and making it unfit for animal consumption. Animals usually do not drink this water. Compared to the availability on the farm, groundwater from hand pumps, motor pumps and wells further fosters the use of groundwater for livestock at home.

Table 15 reflects that for larger breeds of livestock kept at home, the single major reason of preference for the source is the quantity of water, followed by easy access, as cattle and buffalo need larger quantities than goat and poultry. Moreover, they are usually given water twice a day. For goat and poultry, easy access is the major reason. Their daily water need is relatively low. Poultry birds kept at home are left to roam free in the precincts of the house and usually select its own water source, thus owners do not have to bother much about this provision of water.

Table 15. Reason for Preference for Livestock Water Use.

Place	L/stock	Low cost	Quality	Easy Access	Reliability	Availability	Proximity	Quantity	Many reasons	Total	
At Home		%	%	%	%	%	%	%	%	%	No.
	Cattle		5.3	17.5	1.8	0	3.5	29.8	42.1	100	57
	Buffalo	1.3	6.9	17	2.5	0	2.5	31.4	38.4	100	159
	Goat	.5	4.8	41.8	1.6	0	5.8	2.1	43.4	100	189
	Poultry	1.8	3.6	34.8	0	0	8.9	0	50.9	100	112
On the Farm	Cattle	4.6	21.5	30.8	1.5	23.1	1.5	1.5	15.5	100	65
	Buffalo	2.3	22.5	29.5	1.6	28.7	1.6	2.3	11.5	100	129
	Goat	3.1	19.4	32.7	1.0	31.6	2.0	1.0	9.2	100	98
	Poultry	6.9	13.8	51.7	17.2	3.4	0	0	7	100	29
	Donkey	4.5	13.6	36.4	4.5	27.3	0	4.5	9.2	100	22

For cattle, buffaloes, donkeys, and goats kept on the farm, easy access and availability are the major considerations, followed by the quality of water. The reason for some respondents' consciousness for good quality water for animals is that usually, draught and milk animals are kept on the farm. If one falls ill, much-needed animal power and milk supplies may become unavailable. During the annual canal closure, the canal water supply is suspended and whatever source is available, is exploited. For poultry, easy access is the sole-most important factor. As the water requirement is very small, whatever is easily accessible is considered fine.

2.8 Water Use for Industrial Purposes: Ice Manufacturing

Ice manufacturing factories in the study area generally use canal water. This water is stored in a tank in large capacities. The average storage capacity was around 92000 liters. Beside invisible pollutants, water flowing into the storage tanks contains silt and sedimentation. After two to three days, the sediments settle down. This water is then poured into another tank where it is treated with limestone and alum salt. These two chemicals make the water crystal clear. From here, the water is pumped into steel blocks, which have an average capacity of 140-160 liters. The filled blocks are hung in a freezing tank. The housing for the blocks in the freezing tank is partially filled with Brine Solution. Compressed ammonia gas is circulated through steel pipes, which flows through the freezing tank. The gas absorbs the heat from the tank and expands. This gas then transports to the cooling unit where it is passed through sprinkled water, which absorbs heat from the gas. The gas is compressed with a compressor. On average, the process of freezing water consumes about 54 hours. The quality of the product largely depends on the duration of time it has been kept in the freezing tank. A freezing time of 72 hours is considered best, but during the peak season, actual freezing may reduce to 30 hours due to higher demand.

The ice-manufacturing season starts in March-April and continues until September. March and September are relatively cool months. Therefore, the demand is low. During March, April and September, only 7.4 percent of the capacity were utilized. The maximum demand is observed during the month of June, when 79 percent of the installed capacity is exploited. The seasonal nature of demand enforces under-utilization of the installed capacity during relatively cooler months. Even during the hot months, full utilization of the installed capacity is not possible because of widespread poverty among families residing in the locale. Consumption of ice is not yet considered to be a necessity. The majority of families is only prompted to use ice when they have guests. Families with relatively higher incomes usually consume ice, but their demand is more or less constant. Similarly, the demand for ice from ice-cream manufacturers and restaurants is rather fixed. Exploitation of the installed capacity in the off-season is constrained by the fact that farmers do not store their products in cold storage due to the absence of paying power. This under-utilization constrains the producers' profits, as per unit overhead costs cannot be minimized.

2.8.1 General Characteristics of Ice Factories in Hakra 6-R Distributary Command Area

The first ice factory in the area was installed during 1975 in Faqirwali town, and the latest one was erected during 1993. The average age of factories was about 13 years. Factories that operated during 1997 were evenly spread among the head, middle, and tail reaches of the distributary. All were using canal water for ice manufacturing, but three of six factories (50%)

also used groundwater for cooling purposes. The spatial distribution with regard to groundwater use for cooling was even among the head, middle and tail reaches. Only one factory was supplying ice to Faqirwali, as it was located in the town. The remaining supply was consumed in the rural areas. The average investment per metric ton of ice production capacity is Rs 26,750.

Out of the six operating factories, five were obtaining water supplies from the watercourses meant for irrigation, while only one, located in the town, had a special watercourse for its canal supplies. These five factories located in the rural areas had a specified water turn in the watercourse irrigation roster (warabandi), but they were not following the roster strictly. In four of these factories, a pipe led into the factory could be closed when the storage tank was full. The length of the water turns of these factories had been divided among other water users based on allocation principles prescribed by the Irrigation Department. Consequently, other users had no objection to a regulated water supply to factories from the watercourse. The major material inputs that were used directly during the ice-manufacturing process included water, alum salt, sodium chloride, ammonia gas, and limestone. Indirect material inputs used were compressor and Mobil oil for lubrication purposes. The non-material inputs included electricity, repairs, labor, and management. Other costs included formal and informal tax payments, etc.. The composition of the average cost of production per metric ton for ice manufacturing is presented in Table 16. Note that the interest on investment is not included in the cost of production. The average interest at a 10 percent annual rate forms another Rs 34.37 per metric ton of ice produced.

Electricity forms the major part of production costs (77%), followed by labor and management (8%), maintenance and repairs (7%), taxes, etc. (7%), and costs for materials other than water (6%). Canal water forms the major part in terms of quantity used, but only forms a small proportion of the total costs (2%). This reflects that the cost of water is not rationalized in terms of its relative importance. Since the groundwater is unsuitable for ice manufacturing and consumers have a clear preference for canal water, groundwater cannot be regarded as a close substitute for canal water. Canal water pricing for ice- manufacturing is also interesting to study. The official annual schedules for water rates issued by the revenue administration do not include ice-manufacturing activities (Mahmood, 1996, Iqbal, 1996). The factories were to pay the Irrigation Department (ID) different rates for water. No knowledge about the basis for assessment of water cost exists. Some factories reported that payments were based on the area of the factory, while others were paying a fixed seasonal amount (Table 16). The ID does not issue any official receipt at the time of assessment or payment. One factory owner pointed out that payments, for water received from ice factories were unofficial payments, and does not form part of the government revenue.

There are at least three possibilities for water allocation is evident. The most common one is that from the supply of water from a watercourse to irrigators, a water turn is allocated for the factories. Two-thirds of the factories has this arrangement. Factory owners have entered into an agreement with other users that enables water to be extracted as and when desired to ensure water supply. In return, other users, in proportion to the duration of their respective water turns, can utilize the factory's water turn. The basis for water tax assessment was completely unknown to factory operators.

Table 16. Arrangements for Water Allocation and Water Rates for Ice Factories 1997.

Location of the Factory	Arrangements for Canal Water	Length of Water Turn (Minutes/ Week)	Amount of Money Paid as Water Rate (Rs/ year)
Faqirwali	Water Turn in irrigation watercourse	180	250
Chak 93/6-R	-do-	132	1600
Chak 93/6-R	-do-	120	1500
Latifabad	-do-	420	n.a.
Rehmat Chowk	-do-	210	n.a.
Yateemwala	Use water for command area of the factory owner	720	n.a.
Yateemwala	Special Watercourse	Not applicable	Rs 50/ operating day

Another arrangement is that factory owners have allocated individual water turns for agriculture over to the factory, fully or partially. Since the contractor was operating the factory under this arrangement, there had been no information about water rates. Nevertheless, given the fact that water rates in Pakistan are charged on the basis of crops grown, canal water, if used exclusively for ice manufacturing, will be free of cost, as water rates cannot be assessed where no crops are grown (Hassan, 1997).

The third arrangement is the installation of an exclusive factory watercourse. The water pricing is done on the basis of a daily water charge. Compared to the other arrangements for water pricing for ice, this arrangement seems to be more transparent. All that transpires from this discussion is that there is no clear-cut method to price water for industrial use.

2.9 AQUA CULTURE AND OTHER USES

Apart from domestic, livestock, and industrial uses, some other uses were also noticed during the fieldwork. These uses included vehicle washing, construction, brick making and fish farming. The sources of water for these uses are presented in Table 17. Vehicle washing, the most prevalent other use was reported by about 59 percent of respondents. Around 38 and 34 percent, respectively, of those washing vehicles were using water from the canal or the water tank. The use of groundwater was limited to only 13 percent of respondents. Similarly, another important use of water was for the construction of houses etc., which was reported by around half of the respondents. Out of these, around 40 and 23 percent, respectively, used water from the water tank and canal. The exploitation of groundwater was only reported by around 16 percent of such respondents. Less than one percent of respondents reported fish farming and brick making.

Table 17. Other Uses and Sources of Water in Hakra 6-R, 1997.

Water Use	Canal	Supply Scheme	Motor Pump	Hand Pump	Village Pond	Water Tank	Many Sources	Total	
	%	%	%	%	%	%	%	No.	%
Brick Making		66.7				33.3		3	100
Construction	22.8	9.4	6.1	9.4	6.7	42.2	3.5	180	100
Fish Farming	100.0							2	100
Vehicle Washing	33.6	9.3	6.1	7.0	3.3	37.9	2.8	214	100

The major reason for the choice of the specific source was the quality of water. Since groundwater is saline, vehicles become rusted if washed with groundwater. Similarly, construction undertaken with groundwater starts getting salts soon after construction. Fish cannot survive in groundwater, as the species, generally, are unsuitable for saline waters. Therefore, respondents prefer to use water from the canal or water tank.

3 FARMERS' PERCEPTIONS ABOUT NON-IRRIGATION USES

3.1 AWARENESS ABOUT QUALITY OF AVAILABLE WATER

The residents of the study area consume surface and groundwater from various sources to serve various purposes. In general, the quality of water in the area is not appropriate for human consumption. While the groundwater is saline, the surface water carries pollutants that are hazardous for human and livestock health. The electric conductivity (EC) of various sources was measured, as it can be regarded as an approximation of the taste. The higher the EC, the more brackish the taste of the water. The results are summarized in Table 18.

Table 18. Electric Conductivity of Water Available for Domestic and Livestock Use (% of Sources).

Source of Water	**Electric Conductivity (µs / cm)**				
	< 500	**501-1000**	**1001-2000**	**>2000**	**Total**
Water Tank	95	5			22
Supply Scheme	75	25			4
Village Pond	4	4	42	50	26
Well	28	14	29	29	7
Hand pump/Seepage-water		20	45	45	20

According to WHO guidelines, the EC values less than 1500 µs/cm is considered acceptable for human consumption (WHO, 1996). However, the taste of the water with EC > 400 µs / cm is considered to be poor. Measurement tests indicated that compared to remaining sources, the majority of water tanks and supply schemes had an EC ranging from 0-500 µs / cm and, therefore, supplied water with better taste. Almost all the water from all the village livestock ponds had a relatively higher EC (above 1000 µs / cm). The reason for this higher EC is that most of the village ponds also contain the village sewerage water. The taste of groundwater sources was found poorer compared to that of surface sources, as none of the groundwater sources had an EC below 400 µs / cm.

Only a small proportion of respondents opined that they had no knowledge about the quality of water from their respective source(s) (Table 19). A higher percentage of the respondents regarded the quality of seepage water, among different water sources, better compared to that of surface water. There could be two reasons for this response. Firstly, the users generally evaluate the quality with respect to the specific use of water from a particular source. For instance, if tank water is used for cleaning the house, its quality is good. Similarly, since there is no odor in hand pumped water, it is also regarded fit for human intake. Secondly, since salts are dissolved in water and cannot be seen with the naked eye, seepage water is ranked better in quality than that of surface water.

Table 19. Users' Perceptions about the Quality of Water Consumed from Various Sources.

Source	Don't Know		Good		Not Bad		Bad		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Water Tank	4	2.2	14	7.8	46	25.7	115	64.2	179	100
Supply Scheme	1	2.4	22	52.4	14	33.3	5	11.9	42	100
Well	4	10	21	52.5	5	12.5	10	25.0	40	100
Canal	0	0.0	22	30.6	20	27.8	30	41.7	72	100
Hand Pump / Seepage Water	3	1.6	146	77.2	25	13.2	15	7.9	189	100

The information contained in the above two tables implies that the users preferred to use seepage water, despite its higher EC over the surface water.

3.2 PERCEPTIONS ABOUT TYPE AND SOURCE OF CONTAMINATION

Water from both, ground and surface sources, is contaminated with visible or invisible pollutants. The most noticeable contaminants are dust particles, human and animal excreta, biological life, salts, and chemicals. In the case of groundwater, most salts are present in the parent material of the soil. The salts are dissolved in water present in the aquifer, or are added to water while the groundwater is being recharged.

Surface water sources, generally, contain waste materials that are added to water while flowing from catchment areas to the place of use. Pollution sources are, therefore, both remote and local. From Table 20 gleans that the majority of groundwater users appear unaware of the source of contamination. This might be because they believe that their seepage water source supplies is clean water as the salt contents cannot be seen. A sizeable proportion of the respondents also seems unaware of the source of contamination in the surface water sources. The majority of the water tank users perceived that much of the contamination in the water was local in nature. Since the water tanks and the water channels taking water in are open, the respondents see many pollutants entering the tank in one way or another.

Table 20. Users' Perceptions about Sources of Contamination by Source of Water.

Source of Water	Location of the source of contamination					
	Local (%)	Remote (%)	Both (%)	Don't Know (%)	Total	
					No.	%
Canal	40.3	12.5	1.4	45.8	72	100
Hand Pump	1.6	2.6	11.1	84.7	189	100
Motor	5.8	1.4	2.9	89.9	69	100
Supply Scheme	28.6	26.2	0.0	45.2	42	100
Well	25.0	2.5	32.5	40.0	40	100
Water Tank	87.2%	0.0	3.9	8.9	179	100

The majority of respondents who used groundwater, and almost half of those using canal water and supply schemes, were also unaware of the type of contamination (Table 21). Among those who perceived that there were contaminants in surface water sources, a higher percentage of respondents believed that the surface water was contaminated by dust particles and a mixture of all the mentioned pollutants. A vast majority of water tank users was of the view that the water tank was polluted with a combination of dust, plant and animal excreta, and biological life and sanitation water. A high proportion of the groundwater users who were aware of the type of pollution opined that the groundwater was contaminated with salts.

Table 21. Type of Contamination by Source of Household Supply.

Source of Water	Dust	Salts	Animal / Human Excreta	Others*	Many Mentioned Types	Don't Know	Total	
							No.	%
	%	%	%	%	%	%	72	100
Canal	13.9	0	4.2	1.4	34.7	45.8	189	100
Hand Pump	0	17.5	0.5	0	0	82	69	100
Motor Pump	7.2	4.3	0	0	0	88.4	42	100
Supply Scheme	11.9	0	0	7.1	35.7	45.2	40	100
Well	17.5	7.5	0	5.0	7.5	62.5	179	100
Water Tank	15.1	0	0	2.8	81.6	0.6		

* Others include sanitation wastage, insects, biological life, etc.

3.3 Perceived Impact of Domestic Water Supply on Human Health

Water-related diseases are caused due to one, or more, of the pollutants in the water. Households that experienced one or more incidents of various water- related diseases during the last year were asked to identify the source they thought had caused a specific disease. Table 22 shows that in total, 88 of the respondents regarded water as the main cause of disease. Islam and Karim (1992) also documented the incidence of intestinal diseases and diarrhea due to the usage of bad quality groundwater. To the majority of users, surface water was the main cause for cholera, jaundice, kidney stones, malaria, typhoid and skin diseases. On the other hand, only one respondent regarded groundwater as the main cause for diarrhea. The respondents' opinion about the surface or groundwater causing dysentery was equally divided.

Table 22. Perceptions pertaining to Domestic Water Supply Causing Diseases.

Disease	Seepage water (%)	Surface Water (%)	Number	%
Cholera	23	77	13	100
Diarrhea	100	0	1	100
Dysentery	49	51	34	100
Jaundice	20	80	5	100
Kidney Stone	33	67	6	100
Malaria	28	72	8	100
Skin Diseases	20	80	5	100
Typhoid	0	100	11	100
Total	29	59	88	100

A large majority of respondents (around 75%) were consuming seepage water for drinking purposes, which also points to their perception that surface water, more so than the seepage water, caused diseases.

If the reasons for preference to use groundwater for drinking are studied together with water shortage periods, then it becomes evident that their meanings of the quality of water for drinking purposes were closer to clear and odorless water. The groundwater was regarded to be of better quality by the majority of respondents because of it being colorless and odorless. The unavailability of alternate sources during extreme shortages of surface water further accentuates the intake of groundwater. Some skin diseases are spread by contact with polluted water. Households are always vulnerable to this because of being forced to use polluted water to wash utensils, and for sanitation and bathing needs.

3.4 SEASONALITY OF DISEASES

Surface water sources require that users use water from one of the sources where water has to be stored under sub-optimal hygienic conditions. Thus, there are more chances that in certain seasons, water becomes more polluted when compared to others, because some seasons provide more congenial conditions for the growth of microorganisms that cause diseases. In order to know whether respondents feel that the incidence of diseases in the study area exhibits a seasonal pattern, their perceptions were documented. Of course, the respondents base their perceptions on their experience. Therefore, it can be regarded as a good approximation for the actual observation. The users' perceptions about seasonal occurrence of various diseases are documented in Table 23. The information reveals that three-fourths of the diseases were thought to occur in the summer season, while around 13 percent of respondents believed that these occur in the winter season. The incidence of diseases in the rainy season was perceived to be the lowest.

Table 23. Users' Perceptions about the Seasonality of Disease Incidence.

Disease	Season in which Disease Generally Occurs				Total	
	Summer	Winter	Rainy	No Seasonality	No.	%
Cholera	83.3	6.7	6.7	3.3	30	100
Diarrhea	50.0	16.7	16.7	16.7	6	100
Typhoid	71.6	22.4	6.0	0.0	67	100
Dysentery	85.5	10.1	0.0	4.3	69	100
Jaundice	82.4	11.8	0.0	5.9	17	100
Kidney Stones	52.0	20.0	0.0	28.0	25	100
Malaria	84.5	7.1	8.3	0.0	84	100
Skin Diseases	48.4	12.9	12.9	25.8	31	100
Total No.	250	42	18	21	331	100
Total %	75.5	12.7	5.4	6.3	100	

To most households where family members experienced dysentery during the reference period (around 86%), it emerged to be associated with the summer season. Similarly, the majority of respondents associated malaria, jaundice, typhoid, kidney stones, and diarrhea with the summer season. This finding is similar to the results of Amerasinghe (1993). Winter and rainy seasons have not been associated to the occurrence of disease, as only 13 and 5 percent of respondent families experienced a disease in these seasons, respectively. Over one-fourth of respondents believed that kidney stones and skin diseases had not been associated with any particular season.

As for other diseases, people are more vulnerable to jaundice (82.4%) in the summer season, as perceived by households. As households use surface water, or recover groundwater-recharge taking place through seepage from the canal, they claim that sanitation and waste water, along with animal and human excreta, etc. are mixed in this water. About half the respondents believed that skin diseases experienced were associated with the summer season.

The foregoing discussion concludes that the respondents' perceptions regarding the seasonal nature of various diseases reflect that they associated occurrence of most of the diseases with the summer season. They are well aware of the fact that summer is more conducive to the spread of diseases.

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4 CONSEQUENCES OF NON-IRRIGATION USES

4.1 IMPACT ON HUMAN HEALTH

Surface water used in the sample area was reported to have serious consequences on the health of household members. The study highlights the most common diseases prevalent in the area.

4.1.1 Water-related Diseases in *Tehsil* Haroonabad

In order to determine the extent of water-related diseases, disease data for three years (1994-1996), as well as water-related diseases, were collected from Tehsil Hospital, Haroonabad. The patients registered in hospital during that three-year period were classified under the following seven types of water-related diseases.

(1) Dysentery
(2) Diarrhoea
(3) Enteric fever
(4) Malaria
(5) Stomach diseases (other than diarrhoea and dysentery)
(6) Trachoma
(7) Skin diseases

Figure 4 shows patients of water-related diseases registered from 1994-1996. The most prevalent diseases are stomach diseases, i.e., dysentery and diarrhoea. Malarial patients were not registered as in or out patients, and have likely been registered under Pyrexia of unknown origin (PUO). The people in the study area generally purchase commonly known tablets for malaria from nearby shops and dispensaries (run by skilled medical practitioners) in the villages or medical stores (if available). Out of seven diseases mentioned earlier, 88 percent of respondents reported the incidence of the following four diseases.

(1) Dysentery
(2) Diarrhoea
(3) Malaria
(4) Skin diseases

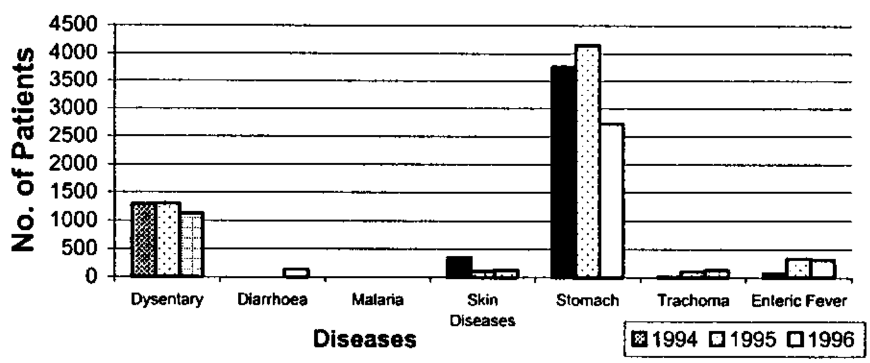


Figure 4. Water-related diseases registered in *Tehsil* Hospital, Haroonabad, 1994-96.

4.1.2 Water-related Diseases in the Sample Households

The prevalence of water-related diseases in the study area is shown in Figure 5. The graph illustrates that the percentage of patients that suffered from malaria was higher (32%) when compared to other water-borne diseases in the study sample. Other most important water-borne diseases in the study sample were dysentery (17%), skin diseases (13%), typhoid fever (11%), cholera (9%) and diarrhea (8%). About 12 percent of respondents reported the incidence of the other three diseases, i.e., jaundice, kidney stones and cancer, were very low in percentage when compared to the incidence of other water-borne diseases in the sample study.

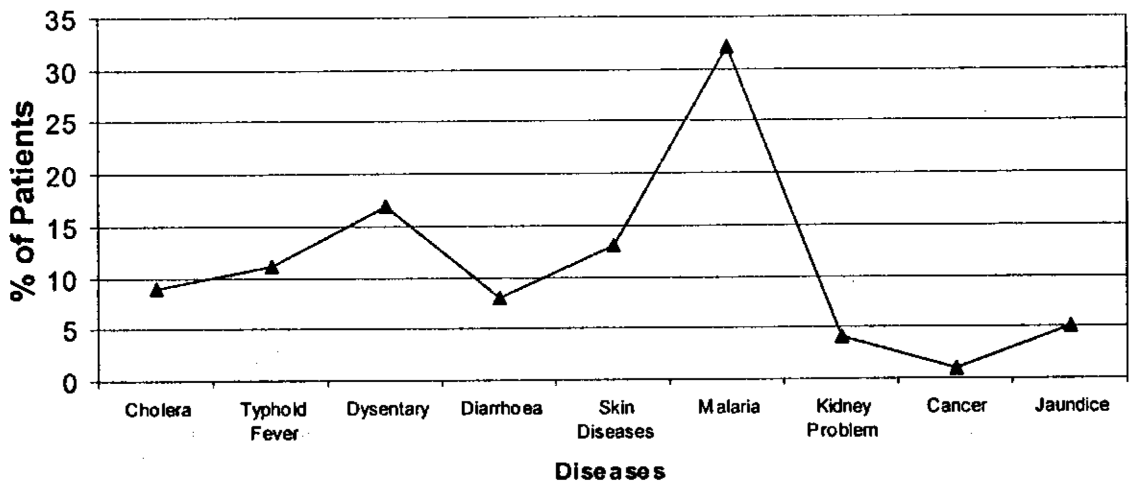


Figure 5. Water-related Diseases in the Sample.

The overall comparison of water-related diseases prevailing in the head, middle and tail reaches of the Hakra 6-R Distributary is revealed in Figure 6. The graph shows that the incidence of malaria was higher in the tail and head reaches when compared to that of the middle reach. The second-most prevalent disease in the study area, as reported by respondents, was dysentery. Incidence of this disease was higher in the middle reach (22%) when compared to the head (18%) and tail (12%). Skin diseases affected 13 percent of respondents in the middle and tail reaches, while 12 percent of respondents reported patients in the head reach. Typhoid fever was the most reported disease in the head and tail reaches, where 14 and 11 percent of patients were found, respectively. In the head reach, about 9 percent were infected with this disease.

Diarrhea was recorded as the most prevalent disease in the tail and middle reaches (12 and 9%, respectively), as is clear from Figure 6. Only respondents in the head reach reported the incidence of diarrhea. This may be because people at the head reach are using hand pumps, thus, using a higher quantity of canal and seepage water. On the other hand, people in the middle and tail reaches are not enjoying such recharge or seepage due to the shortage of canal water. So they have to depend on low quality seepage or ground water, and are using direct canal water in worse quality. Respondents infected with cholera ranged from 9-10 percent in all three regions. Patients suffering from the other two diseases, kidney stones and jaundice were thought significant in percentage, but relative to other water-related diseases; their percentage was very low. The percentages of patients at the head, middle and tail reaches, for jaundice, were 6, 5 and 4, respectively; whereas the percentages of patients among respondents at the head, middle and tail reaches for kidney stones were 5, 4 and 2, respectively. The graph shows that cancer patients were only found at the middle reach (1%) of the Hakra 6-R Distributary.

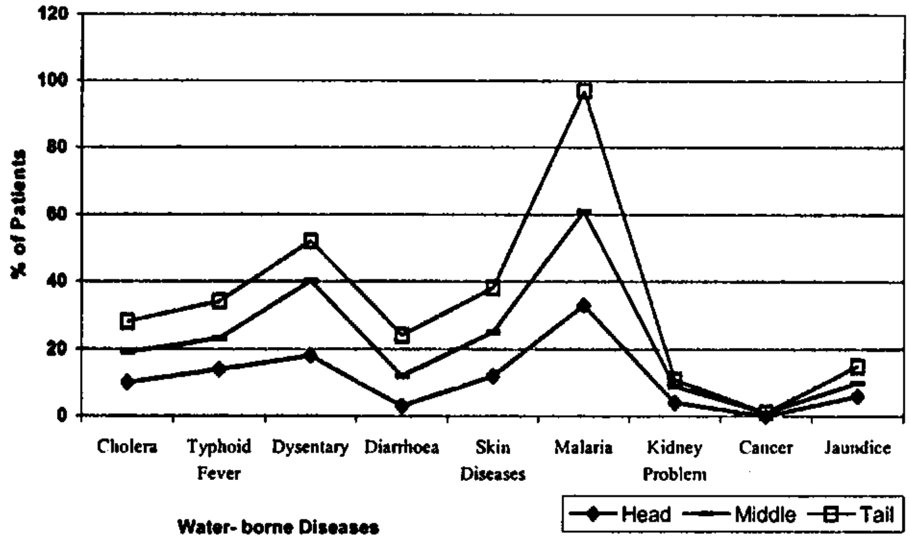


Figure 6. Spatial Distribution of Water-borne Diseases

4.1.3 Water-related Diseases among Different Age and Gender Groups

Table 24 indicates the incidence of water-related diseases among different age and gender groups in the study area. The finding was that 581 male adults, 241 female adults, 376 male children and 182 female children suffered from water-related diseases. The highest percentage of respondents (more than 31%) reported the incidence of malaria, in which adults and children, regardless of gender aggregation, were approximately equal in percentage. Dysentery, ranked second, in which 20 percent of male children were affected, followed by 18 percent of female children, 16 percent of female adults and 15 percent of male adults. The third water-related disease, which scored high, was skin-related. For this category, the percentage of infected adults and children ranged from 12-14 percent. Table 24 shows that there is no significant difference among adults and children (male / female) infected with cholera and typhoid fever. The incidence of these two diseases ranged from 9 to 13 percent in all age and gender groups. Kidney-related problems were also recorded in the area, where the incidence of this disease in female adults was higher (6%) when compared to male adults (5%). In the case of children, about 2 percent of households reported the incidence of kidney-related diseases. The incidence of jaundice was reported to be higher in male adults and male children (6 percent and 4 percent, respectively) when compared to female adults and children (3 percent).

The majority of respondents also consider cancer as a water-related disease. The incidence of this disease was only found in adults (1%). Percentages presented in Table 24 make it clear that male adults and male children affected by water-related diseases are higher when compared to female adults and children. Overall, during 1997, the total number of male and female patients infected by water-related diseases were 1380, of which 957 (69%) were male and 423 (31%) were female patients. This does not mean that the diseases are more prevalent for males than females. The fact is that male members of the household are considered to be more worthy assets for the household (being a patriarchal society). Males are thus more looked-after in the family, whereas females are overlooked. Moreover, female members may have under-reported their prevalence. This implies that the low disease incidence in females may be because of poor reporting by household members.

Table 24. Water-related Diseases among Different Age and Gender Groups.

Diseases	Male Adult	%	Female Adult	%	Male Child	%	Female Child	%	Total
Cholera	52	9	21	9	34	9	19	10	126
Typhoid fever	69	12	32	13	39	10	16	9	156
Dysentery	91	15	38	16	76	20	32	18	237
Diarrhea	41	7	13	5	39	10	22	12	115
Skin problems	75	13	33	14	45	12	25	14	178
Malaria	187	32	81	33	123	34	56	31	447
Kidney problems	28	5	14	6	4	1	5	3	51
Cancer	2	1	1	1	0	0	0	0	3
Jaundice	36	6	8	3	16	4	7	3	67
Total	581	42	241	18	376	27	182	13	1380

Data presented in Table 25 reveals that out of 120 sample households at the head reach of the Hakra 6-R Distributary, 107 (89%) suffered from water-related diseases, of which 439 family members were affected. Out of the total financial loss (i.e., amount spent for treatment, plus wages lost) among these families, Rs 122949 (as reported by respondents) was due the amount spent on treatment. For affected households, the average treatment cost per household was estimated to be Rs 1149 in the study year.

Table 25. Water-related Diseases and Money Spent on Treatment.

Location	Total No. of Households	No. of Households Affected	No. of Households Not Affected	Number of Persons Suffered in those Households	Amount spent on Treatment (Rs.)
Head	120	107 (89)	13 (11)	439	122,949 (23)
Middle	120	108 (90)	12 (10)	469	165,938 (32)
Tail	124	111 (90)	13 (10)	472	236,666 (45)
Total	364	326 (90)	38 (10)	1380	525,553 (100)

Note: Figures in parentheses indicate percentages.

Out of 120 sampled households at the middle reach of the distributary, 108 (90%) suffered from water-related diseases, of which 469 family members were affected. Out of the total financial loss of these families, RS 165938 was due to the amount spent on treatment. For affected households, on average, the treatment cost per household amounted to RS 1536 in the study year. Out of 124 sampled households at the tail reach, 111 (90%) suffered from water-related diseases, of which 472 family members were affected. The total amount spent on treatment was Rs 236666. On average, treatment cost per household amounted to RS 2132 in the study year. On the whole, treatment cost per person amounted to RS 380 during 1997.

The location-wise ratio of households suffering from water-related diseases was approximately equal at head, middle and tail reaches of the Hakra 6-R Distributary, i.e. 90 percent. However, the treatment cost for households suffering from water-related diseases was higher at tail-end villages (45%), followed by middle- (32%) and head-end villages (23%). This difference in treatment cost in each of the reaches may be because most respondents at the tail reach of the distributary had to travel a long distance to visit a doctor, followed by the middle and head reaches.

4.1.4 Sources of Domestic Water Supply Causing Diseases

There are so many factors responsible for spreading water-related diseases in the study area. Respondents were asked about the cause of various diseases. In order to assess their awareness about the factors responsible for spreading diseases, their responses were recorded. Figure 7 shows that out of 364 respondents, only 88 provided answers, while the remaining 276 were unaware of any of the causes for disease. Out of 88, the majority of the respondents (55) were of the view that the cause of water-borne diseases was tank water (diggi), with groundwater and canal water following close behind. This confirms the results of Puntakey et al. (1996) that in rural areas, the main health problems are due to the direct use of polluted canal water for domestic uses. As already mentioned, the quality of water tanks in the area is not acceptable due to the addition of contaminants like dust / silt, tadpoles, insects, dead animals, plants and even sewage water. That is why people perceived tank water to be a major contributor towards diseases.

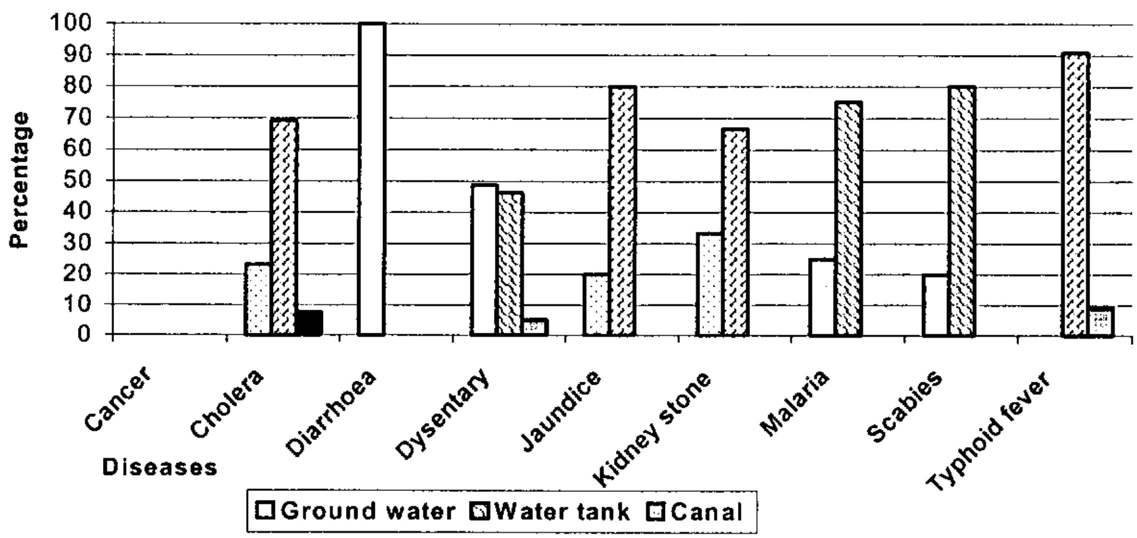


Figure 7. Sources of Domestic Water Supply Causing Diseases.

Since ground water in the entire study area is brackish (except for the pockets of seepage water near irrigation network), the people use canal water to fulfil their water needs. But, during times of canal closure, people have to depend on brackish ground water. Most times people try their best to exploit seepage water for drinking and cooking purposes. This seepage water, exploited through hand pumps, etc., was also not free from salts or other contaminants. That is why a considerable number of respondents perceived ground water as a disease-causing factor. Figure 7 clarifies that a higher percentage of respondents perceive groundwater to be the sole cause of diarrhea and dysentery. The reason is the higher concentration of salts in ground water.

Skin diseases need a special mention. Most people thought tank water to be the cause of skin disease problems. This is because ground water is hard and doesn't rinse soap when used for bathing purposes. Households have to use polluted water from water tanks, which was considered good to rinse soap off with, but was the cause of skin diseases. A higher percentage of respondents perceived tank water as a cause of cholera. The reason is that bacteria growing in water causes cholera. In the case of malaria, a higher percentage of respondents perceived that stagnant, open polluted tank and canal water contributed towards it. Also, mosquitoes cause malaria and open surface water sources are breeding sites for mosquitoes (Punthakey et al. 1996). The conclusion is that all water sources are not providing good quality water to respondents from a health point of view. They have to switch from one source to another, although the best does not mean more appropriate from a health point of view.

4.1.5 Diseases and the Source of Treatment

Different types of treatment are used to cure various diseases. Some people use traditional cures, while others consult doctors. Figure 8 shows various types of treatment adopted by respondents in the study sample. The figure displays that most people sought treatment from doctors for all the water-borne diseases, except malaria, during the study year. In times when medical facilities are not accessible (due to income or distance away from doctors' facilities), people mostly go to a nearby medical store to buy medicines without prescriptions.

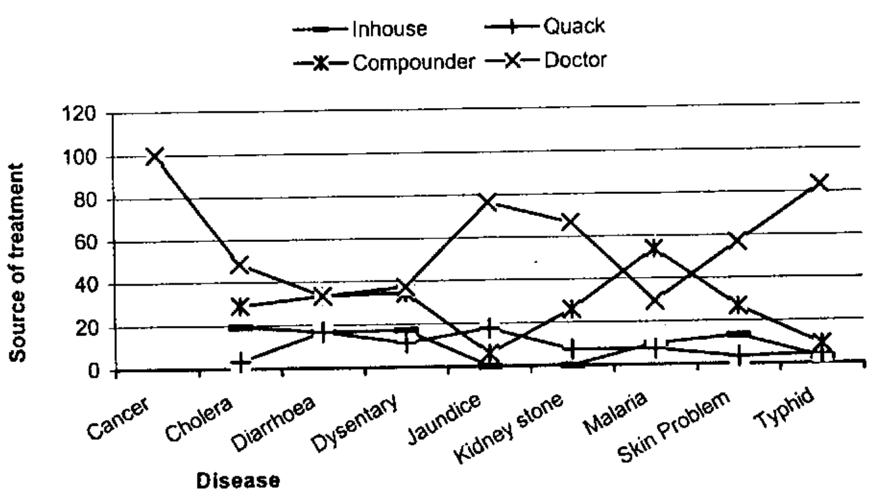


Figure 8. Diseases and the Source of Treatment.

In the case of malaria, respondents reported that they generally prefer to purchase commonly known tablets from medical stores, but in acute cases, they visit to a nearby doctor. For diseases like jaundice a considerable number of people also opt for "spiritual treatment" from a quack (traditional medicine man). Other alternatives respondents reported are in-house, homeopathic doctors and the use of their own knowledge based on previous experiences.

4.1.6 Measures Adopted to Improve Water Quality

Several ways are used to improve water quality, especially for drinking and cooking purposes. Only 37 percent of sample households reported using simple techniques, such as boiling, chemicals (Alum or K2MnO4) and cloth filtering. According to Haturusinha (1994), it was noted that the frequency of using remedial measures, particularly boiling water and chemicals (mentioned above), was higher among educated households than those with less education. Table 26 shows that the frequency of households using boiled water is higher in the tail reach than in the head and middle reaches of the distributary. One possibility is that the literacy ratio was higher in the tail than in the other two reaches. The use of Alum or KMnO4 is as common.

Table 26. Measures to Improve Water Quality.

Location	Boiling	Chemicals(Alum or K2MnO4)	Filter (Cloth filtering)	Total
Head	2 (4)	11 (22)	38 (74)	51
Middle	1 (2)	8 (19)	34 (79)	43
Tail	5 (13)	8 (20)	26 (67)	39
Total	8 (6)	27 (20)	98 (74)	133

Note: Figures in parenthesis indicate percentages.

Table 26 shows that out of 133 households, the majority (74%) use surface water (water tanks, supply schemes, etc.) after applying plain methods, like cloth filtering. To some extent, this is to avoid dust / silt and tadpoles, which can be seen floating in water from tanks or supply schemes. Tank water is the major source that requires some type of treatment, as this source is more prone to being polluted by dust / silt etc.. A small percentage of sample households were using cloth filters to get rid of visible dust particles from water for drinking and cooking purposes. This water was not free from other chemicals and biological contamination, which is why the use of cloth filters does not effectively control the spread of water-borne diseases in the area.

From the above discussion it can be concluded that the majority of sample households in the area are using chemically and biologically polluted water without prior formal chemical / biological treatment.

4.1.7 Reasons for not Adopting Remedial Measures

Most respondents assume that they don't need to treat water with heat or chemicals since the water is supposed to be clean already. They placed more confidence in relative visual cleanliness of the water, while it still contained the presence of salts or contaminants. Respondents knew that the groundwater in the area was brackish, and tried to exploit the seepage by using hand pumps or motors installed in the vicinity of the water tank, in the fields, or near the watercourses. This water source (seepage water) is used only for drinking and cooking purposes. Physically, this water looks clear. Table 27 shows that a notable percentage (32.9) of households do not feel the necessity to treat such water. There are households (16 %) which are unaware of the methods of making water potable. This illustrates the rural peoples' low level of awareness pertaining to the presence of chemicals and biological contaminants in the water, and the related health hazards.

Table 27. Reasons for not Adopting Remedial Measures in Water for Domestic Use.

Reasons	Frequency	Percentage
Water is already clean	110	47.62
Not important to treat	76	32.90
Do not know how to treat	37	16.02
Does not have time to treat	2	0.86
High cost	6	2.60
Total	231	100

4.2 IMPACT ON LIVESTOCK HEALTH

Like human beings, livestock also face various diseases caused by any disturbance to their natural environment. These may be the chemical / biological pollutants in potable water, contaminants in feed, etc.

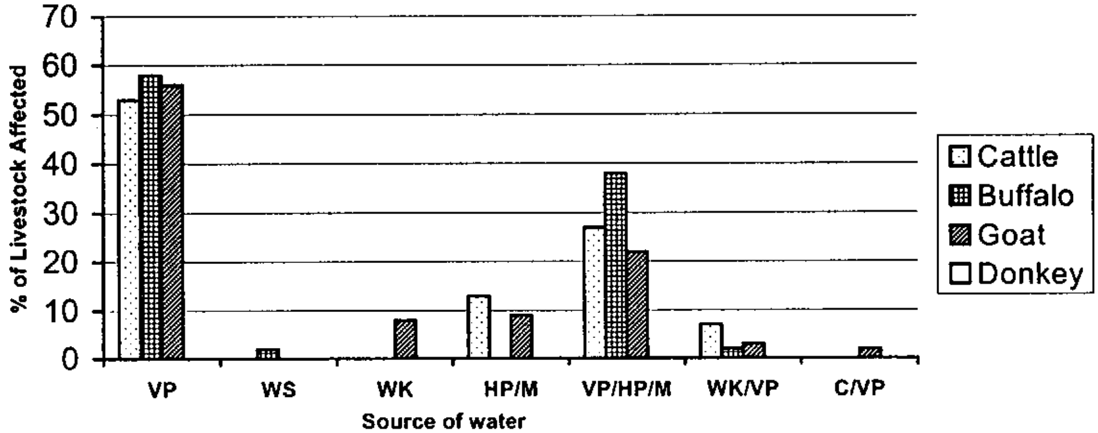
4.2.1 Livestock Affected by Water-borne Diseases

Sixty percent of livestock in the sample households are affected by different water related diseases, as shown in Table 28. The table shows that 48 percent of cattle, 70 percent of buffalo and 57 percent of the goat population are affected by water related diseases.

Table 28. Livestock Affected during 1997.

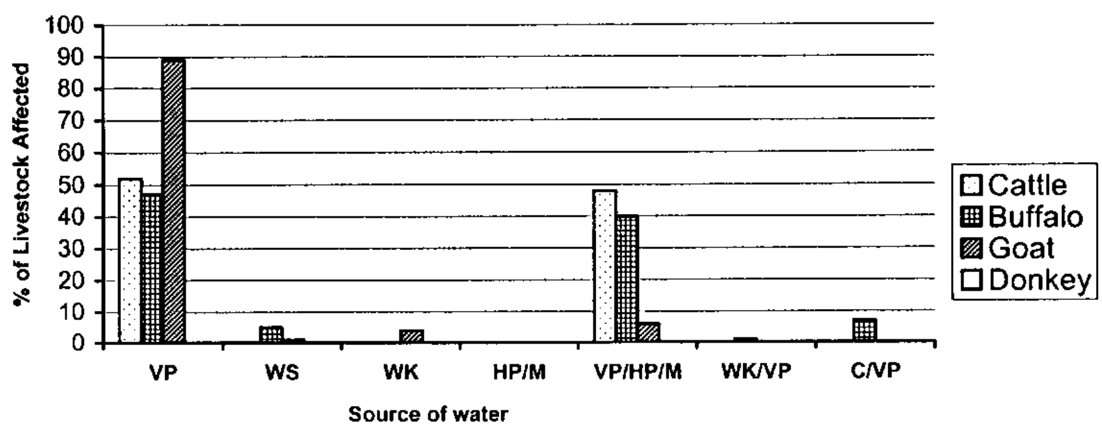
Livestock	Count	%	Total
Cattle	105	48	217
Buffalo	427	70	611
Goat	562	57	986
Total	1094	60	1814

Figures 9 to 11 describe different types of water sources used for livestock in the Hakra 6-R Distributary command area during 1997. Also, it shows the incidence of water-borne diseases to livestock for respective sources of water used in the head, middle and tail reaches of the distributary. These figures show that village ponds were the major sources of drinking water for livestock in all three reaches. These were also found to be the major source for diseases caused in the animals owned by respondents. Figures 9 to 11 show that a high percentage of animals consuming water from village ponds was most affected at the tail, followed by the middle and head reaches. The most probable reason is that since there was a scarcity of water at the tail end, people dumped domestic sewage into the village pond. Animals drinking this water have more chances of acquiring water-borne diseases. On the other hand, where canal water was sufficient in quantity at the head reach when compared to the middle and tail reaches, the quality of village pond water was comparatively good.



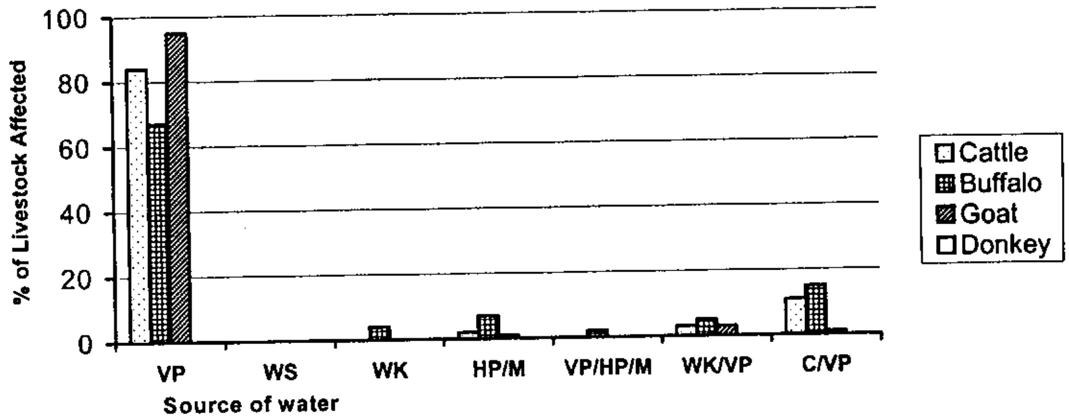
Key: VP= Village pond; WS= Supply Scheme; WK= Water tank; HP= Hand pump; M= Motor; C= Canal.

Figure 9. Percentage of Livestock affected at the Head Reach of the Hakra-6-R Distributary During 1997.



Key: VP= Village pond; WS= Supply Scheme; WK= Water tank; HP= Hand pump; M= Motor; C= Canal.

Figure 10. Percentage of Livestock affected at the Middle Reach of the Hakra-6-R Distributary during 1997.



Key: VP= Village pond; WS= Supply Scheme; WK= Water tank; HP= Hand pump; M= Motor; C= Canal.

Figure 11. Percentage of Livestock affected at the Tail Reach of the Hakra 6-R Distributary during1997.

The contribution of water from canals and village ponds, and from water tanks and village ponds, toward the spread of water-borne diseases was more than 60 percent in middle and tail reaches, whereas in the head region, this percentage was less than 60, as shown in Figures 9 to 11.

From the above discussion it can be concluded that livestock in the study area mainly relied on polluted village ponds for water. The main sources of village pond water pollution are domestic sewage, chemicals (soaps, agricultural waste material), animal excreta and physical pollutants. Among these sources, chemicals and domestic sewage seems to play an important role in polluting the village pond water in the study area.

4.3 Impact on Environment

In this section, the environmental conditions in the villages of the study area in the Hakra 6-R Distributary are discussed. Unpaved streets are full of stagnant sewage water that is visible from a distance. There are absolutely no drainage arrangements. Heaps of dirt are lying in the streets. Dirty water flows into the lanes and provides a breeding place for mosquitoes. During the rainy seasons the situation become even worse. Stagnant rainwater becomes smelly. According to respondents, they find it extremely inconvenient to pass through the streets. Almost every village has a village pond for livestock. In most cases, village pond water contains a high concentration of salts, because sewage, as well as cow dung, etc., is mixed with the village pond water. Village ponds are not lined. Nobody cares about cleaning these ponds. These also encourage mosquito breeding. The watercourse intended for domestic and livestock water supply is also an important consideration. Here, the village urchins bathe, women wash clothing and utensils, and animals quench their thirst. This polluted water (mixed with soaps, chemicals, animal and human excreta) is then poured into the village pond and water tank, and used for livestock and domestic needs, respectively. This might be one of the reasons for the incidence of cholera, malaria, typhoid fever, skin diseases, etc., which are common in the villages of the Hakra 6-R Distributary.

Table 29 shows respondents' responses to problems caused by wastewater disposed of into the streets or under ground pits, etc.. The majority of respondents (88.5%) pointed out the reality of wastewater being the cause of various problems for them. Table 29 shows that the percentage increases from the head to the tail region. Perhaps this is due to the head and middle reach farmers having comparatively better self made sewerage systems when compared to the tail end villagers of the Hakra 6-R Distributary.

Table 29. Waste Water Disposal Problems.

	No Response	Yes	No	Total %	Total No.
Head	0.8%	75.8%	23.3%	100.0%	120
Middle	0%	92.5%	7.5%	100.0%	120
Tail	0.8%	96.8%	2.4%	100.0%	124
Total No.	2	322	40		364
Total %	0.5%	88.5%	11.0%	100.0%	

The majority of respondents think of mosquito breeding or stagnant litter as big problems caused by wastewater flowing into the streets (Table 30). A considerable number of respondents complained about more than one problem, as mentioned in Table 30. The above situation speaks about rural dwellers having become accustomed to their natural habitats. The majority of respondents did not take elements necessary for good health into account.

Table 30. Wastewater Disposal Problems Perceived by Respondents in the Hakra 6-R Distributary during 1997.

	One problem*	Two problems**	None	Total %	Total No.
Head	75.8%	20.8%	3.3%	100.0%	120
Middle	83.3%	16.7%	0%	100.0%	120
Tail	86.3%	11.3%	2.4%	100.0%	124
Total No.	298	59	7		364
Total %	81.9%	16.2%	1.9%	100.0%	

Note: *Any one of mosquito breeding, litter, pollution, water logging, cause of diseases, or quarrelling.
** Any two of mosquito breeding, litter, pollution, water logging, cause of diseases, or quarrelling.

4.4 Impacts on Socio-Economic Life of Study Population

4.4.1 Difficulties Faced by Those Fetching Water

Since ground water is brackish and surface water is the only source for domestic use in the study area, people utilize these in different ways and for various purposes. In the head and middle reaches of the distributary, people generally use seepage water for drinking and cooking purposes. This water is fetched from hand pumps, motors or wells located in the fields near the water tank and the watercourses. On the other hand, in the tail region where canal water is limited, polluted tank water is the major source of water, even for drinking and cooking purposes. When fetching water for the home, people face many difficulties. Figure 12 depicts the difficulties faced by those fetching water in the head, middle and tail reaches of the distributary. Major difficulties, according to its intensities, are quarrels, rush at source, located far from the home, garbage and litter, dogs barking and boys teasing ladies (Table 30-a). As the majority in the head and middle reaches fetches water from hand pumps, the extent of difficulties is comparatively more in these reaches.

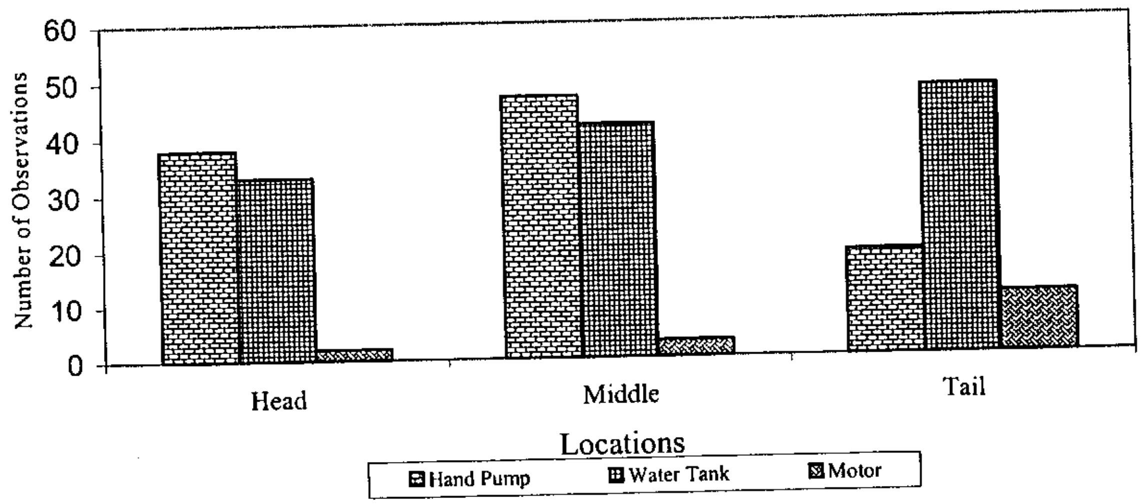


Figure 12. Difficulties Faced by the Study Population when Fetching Water From Sources.

This is because of the easy availability of canal water, as well as of seepage water via hand pumps, in the head and middle reaches of the distributary. This situation is in direct contrast with the tail reach, which is why the extent of difficulty is more in the case of water tanks located in the tail reach. This is based on water availability / scarcity being a bigger problem in the tail reach, when compared to the head or middle regions of the distributary.

Table 30.A. Difficulties Faced When Fetching Water.

Difficulties	Frequency	%Age
Rush at source	98	33
Far away from the house	70	24
Garbage in the way	65	22
Quarrel	25	8
Dogs barking	20	7
Boys teasing the ladies	17	6
Total	295	100

4.4.2 Willingness to Pay

Based on the social constraints mentioned above, similar to those by Altaf *et al.* (1992), families in the study area are willing to pay more for improved water sources (Table 31). The table shows that female household representatives are more willing to pay for improved domestic water supplies than their male counterparts. This is because much of the burden of fetching water falls on women's shoulders (Table 32). The majority of respondents (females) are willing to pay more than Rs 75 per month (Table 33).

Table 31. Willingness to Pay for Improved Water Supplies.

Location	Female				Male			
	Willing to pay				Willing to pay			
	No	Yes	Total%	Total No.	No	Yes	Total%	Total No.
Head	.8%	99.2%	100.0%	120	30.0%	70.0%	100.0%	120
Middle		100.0%	100.0%	120	44.2%	55.8%	100.0%	120
Tail	.8%	99.2%	100.0%	124	22.6%	77.4%	100.0%	124
Total	2	362		364	117	247		364
Total%	.5%	99.5%	100.0%		32.1%	67.9%	100.0%	

Table 32. Individuals Responsible for Fetching Canal Water.

Location		NA	Adult Male	Adult Female	Child Male	No Specific	Total No.
Head	Landless	78.8%		9.1%		12.1%	33
	Owner	85.0%		5.0%	1.7%	8.3%	60
	OCT	90.9%		9.1%			11
	Tenant	68.8%		25.0%		6.3%	16
Middle	Landless	88.05		12.0%			25
	Owner	95.2%		4.8%			62
	O-CTt	88.9%		11.1%			27
	Tenant	100.0%					6
Tail	Landless	83.3%	8.3%	8.3%			12
	Owner	98.4%		1.6%			64
	OCT	100.0%					27
	Tenant	90.5%		9.5%			21
Total No.		328	1	24	1	10	364
Total %		90.1%	.3%	6.6%	.3%	2.7%	

Table 33. Ability to Pay for Improved Water Supply.

Location	No Response	1 to 25	26 to 50	51 to 75	Not Willing	>75	Total No.
Head	.8%	20.0%	32.5%	20.0%	13.3%	13.3%	120
Middle		10.0%	11.7%	9.2%	11.7%	57.5%	120
Tail	.8%	12.1%	16.9%	12.9%	24.2%	33.1%	124
Total No.	2	51	74	51	60	126	364
Total %	.5%	14.0%	20.3%	14.0%	16.5%	34.6%	

Table 34 shows that for most respondents, water quality is the major reason for being willing to pay more. Other reasons are proximity, availability, quantity, reliability, timeliness and low cost. With regard to water quality, women have placed a higher value on having access to water (irrigation water) which is clear enough to be used for domestic purposes. Also, the health hazard presented by the use of irrigation water for domestic purposes may be felt among women more, since they are often responsible for caring for the sick.

Table 34. Reasons for Paying for Improved Water Supplies in the Hakra 6-R Distributary during 1997.

	NA	**Quality**	**Any Other Reason**	**Many Reasons***	**Total**
Head	.8%	38.3%	8.3%	52.5%	120
Middle		27.5%	0.8%	71.7%	120
Tail	.8%	33.9%	4.0%	61.3%	124
Total No.	2	121	16	225	364
Total	.5%	33.2%	4.3%	61.8%	

Note: *Combinations of quality, proximity, availability, quantity, reliability, timeliness and low cost.

Women displayed more willingness to pay for improved water supplies, but the majority did not have enough money to pay (Table 35). Without improved water supplies, they have no spare time for income-generating activities. Without extra income, they may not be able to pay for new facilities (improved water supplies or others). From Table 36 it is clear that the majority of women in the area do not have time to engage in some productive income-generating micro-enterprise. This is because they have to spend much of their time fetching water for drinking and cooking purposes. Conclusively, productive skills mentioned in Table 36 may be an income-generating micro-entrepreneurial option that could enable females to pay for improved water supplies if they are provided with potable water at the doorstep.

Table 35. Money in Hand Last Month (Rs.)

Amount (Rs.)	**Frequency**	**%Age**
0	188	52
1 to 500	38	10
501 to 1000	55	15
1001 to 1500	83	23
Total	364	100

Table 36. Women's Skills and Reasons for not utilising these to Earn Money.

Skills	No spare time	Not allowed by the family	Total
	%	%	Count
Making Cow Dung Cakes	66.1	33.9	62
Chick-rearing	90.9	9.1	44
Carpet-making	90.5	9.5	21
Embroidery	77.5	22.5	80
Collection of Fuel Wood	29.7	70.3	91
Ghee-making	98.8	1.2	81
Goat-raising	100.0		18
Home Gardening	98.1	1.9	52
Knitting	75.8	24.2	66
Reed Mat Making	100.0		5
Sewing	78.9	21.1	71
String Weaving	86.5	13.5	74

4.5 IMPACT ON AGRICULTURE

On account of the scarce availability of canal water from the head to tail reaches of the distributary, it seems logical that other uses of irrigation water have some impact on the water supply for crops. At critical stages of crop growth, less water availability has a direct effect on the yield when considering the separate allocation of water for other uses. The household's perception is a comparative concern about whether they prefer more water availability for crops (income earning), or for other uses (non-income earning) (Table 37).

Table 37. Other uses that limit the Water Supply for Crops.

Location	Yes	No	Do not know	Total
	%	%	%	Count
Head	69.0%	12.6%	18.4%	87
Middle	65.3%	28.4%	6.3%	95
Tail	57.1%	24.1%	18.8%	112
Total	63.3%	22.1%	14.6%	294

5 OTHER ISSUES

5.1 GENDER

Like in many other fields of life, the women are deprived of playing an active role in the irrigation and water sector. Activities requiring more strenuous physical work are responsibilities males take on. Although the women may irrigate the fields, the timing of the water turn poses a threat to this objective (irrigating the field at night is not considered safe for women irrigators). With this in view, the water sector (non-irrigation uses) is where they may actively participate. Women are responsible for the provision of water for almost all types of domestic household needs.

Comparatively, women are more inclined to exploit sweet / seepage ground water sources than surface water sources. At present, males are responsible for managing surface water sources (water tank, etc.), but the quality of water is not satisfactory from a health point of view. Women have to boil water, they use cloth filters, chemicals, etc., depending on their perceptions, education, economic conditions, access to these measures, and needs. This condition leads towards an active role for women to exploit water from non-irrigation resources used for household purposes. Moreover, it is common practice for livestock to be kept at home and women are responsible for looking after these. The provision of water to livestock forms part of their responsibility.

Figure 13 shows that the majority of males conceive that the water quality is not good when compared with females. This does not mean that females are less bothered about the water quality; rather, it implies that they are more cautious about the quality in terms of its source and with reference to the specific use of that water.

Table 31 shows that an overwhelming majority of female household respondents in the study area are willing to pay for improved domestic water supplies than males are. This is explained by much of the burden of fetching water for domestic, as well as livestock purposes, falls on women (Table 32). Altaf *et al.* (1992) supports this finding that households with livestock were very keen to pay more for domestic water connections if for improved water supplies. The majority of female respondents are willing to pay more than Rs 75 per month (Table 33). Most respondents find water quality to be the major reason for paying more. The incidence of diseases by using bad quality water may be more of a concern for women, since they are often responsible for caring for the sick. In the case of illness, females have limited access to doctors or hospitals when compared to the male population.

Women are willing to pay more for improved water supplies, but the majority of females in the study sample did not have enough money to pay (Table 35), as they have to spend several hours fetching water everyday. Additionally, they also have to manage the provision of water for livestock. They reported that this hampered their ability to become involved in some income-generating activities. This is right in line with Stanbury (1981), that the change from extensive to intensive livestock-rearing decreased women's ability to get involved in various activities like fuel procurement, etc.. Table 36 throws light on those women who have skills, but who are unable to utilise these to earn because of being unable to spare time, or are not allowed by the family due to certain reasons. This is partly attributed to the time women spend fetching and queuing for water for domestic uses. Rehman *et al.* (1988) found that in brackish water zones, women were spending 6 to7 hours every day to fetch water, but that after the introduction of improved rural water supply schemes, they allocated that time to other household jobs. Table 36 shows that for fuel wood collection, the majority of women was not allowed to do so because of several reasons.

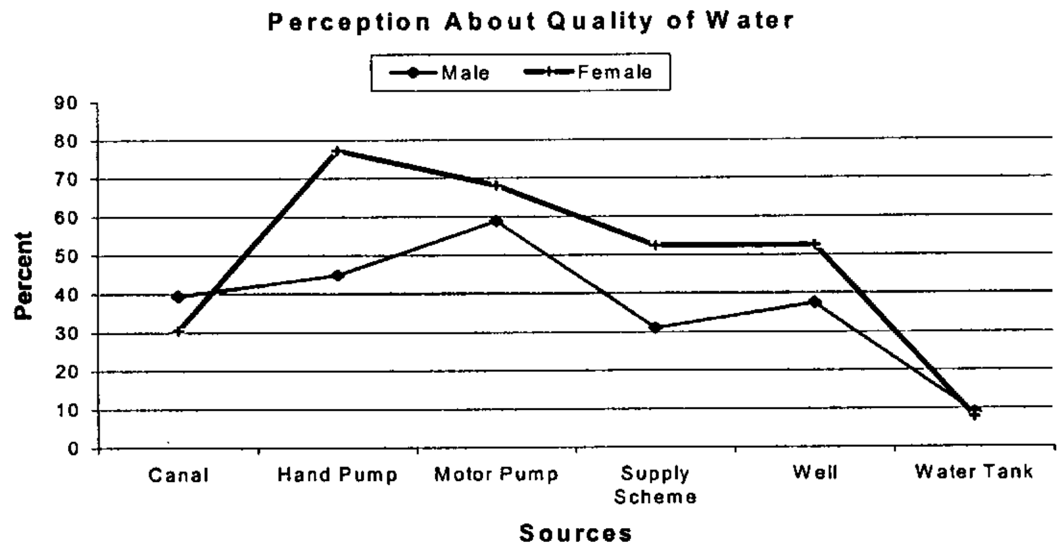


Figure 13. Gender Disaggregation for Perception about Quality of Water by Source.

As discussed earlier, the main diseases prevalent in the area are water-related and only by providing improved quality water can the incidence be decreased. Traditionally, looking after ill household members is considered to be concerns for females in the household. Thus, illness in the household means additional responsibilities for females. Females' willingness to pay more, when compared to males, can also partly be ascribed to this factor.

These facts suggest that women may not be ignored in water management for domestic and livestock purposes. For this purpose, it is necessary to find out:

- types of roles that women can play in water resources management for household and livestock;
- types of sources (other than for irrigation) for which women should be involved in the management of;
- factors which prevent women from participating in such activities;
- whether women think they should participate in water resources management for household or livestock purposes, or both; and
- whether men should also be asked about the type of activities they may participate in to improve the water resources management, and so on.

5.2 AQUA-CULTURE

Along with ice factories, aqua-culture is another important enterprise, and has the potential of not only fulfilling the demands for food, but also of being a good income-generating enterprise. Table 38 shows that the majority of farmers (57.5%) keep the area fallow only because of scarcity of water. The scarcity of water does not mean that water is always short of requirement, but conveys that it becomes a scare when crops reach critical stages of its growth. Another 39.5 percent of respondents attribute it to a blend of scarcity of water, waterlogging and salinity, and sodicity. As the ratio of fallow land area to net operational holdings changes from season to season, less fallow area may be spared for fish farming.

Table 38. Reasons for Keeping the Area Fallow.

	Frequency	Percent
Scarcity of Water	135	57.5
Waterlogging and Salinity	7	3.0
Many Reasons*	93	39.5
Total	235	100

Note* Includes scarcity of water, waterlogging and salinity, and sodicity.

For fish farming, the government of Pakistan is providing technical, as well as financial, support for construction and operation of fish farms. Therefore, to construct a fish farm means having land on which to construct it. Table 39 shows that almost 62.9 percent of farmers have landholdings less than 12.5 acres. A common myth is that small farms are hard to run economically. Fish farming may prove to be a good income-generating enterprise, with little effort involved. Special water allocation rates for these farms are also being offered. Much less water than raising crops is required. Moreover, owing to the large variety of fish that can tolerate low to high levels of salt concentration in the water, the inception of fish farming is practicable in almost all types of lands. Farmers need to be educated to divert their attention towards every possible extent for fish farms in order to utilize their unemployed resources efficiently.

Table 39. Distribution of Respondents according to Farm Size (n=294).

Size of Holdings	Frequency	Percent
Small (up to 12.5 acres)	185	62.9
Medium (between 12.5 - 25 acres)	64	21.8
Large (above 25 acres)	45	15.3
Total	294	100

In this respect, it is important to identify:

- the factors that encourage, or prevent, fish farming as an enterprise; and
- strategies to be developed to divert peoples' attention in this direction.

5.3 Literacy and Health

The relationship of literacy and health is also found very interesting. Table 42 shows that the average number of patients per household is maximum in the case of households in which at least one member has completed more than 10 years of schooling, and the minimum average number of patients is among families where nobody is literate.

Table 40. Average Number of Patients and Literacy Rate.

Category	Head	Middle	Tail	Average
Zero Literacy	3.7	3.9	3.8	3.8
At least one member has education up to 10 years of schooling	3.7	4	4	3.9
At least one member has above 10 years of schooling	4.6	4.5	4.6	4.6

This seems strange. In fact, it implies that:

- Households where literacy is non-existent do not report minor health problems, whereas educated households do.
- In cases with a limited choice of sources for domestic purposes, literacy has little effect. Since respondents are using polluted surface water or saline groundwater (although diluted due to seepage water) for their domestic needs, one can merely switch from best to second best source. More important is that none of the surface or groundwater sources is providing water of a quality conducive to health.
- The general household literacy is insufficient to change the scenario until and unless females responsible for fetching and using water are made aware of the merits and demerits of using certain water sources. Moreover, these females must be made aware of possible solutions to optimum cleaning of water. Additionally, they must have the willingness to treat the water, and the ability to treat the low quality polluted water through some procedure to make it hygienic.

In this regard, it is important to study:

- who is responsible for water management for household purposes;
- what type of guidance (education) is needed to make people more responsive towards good quality water;
- what are the possible measures that can be adopted in order to make the poor quality water harmless by knowledge dissemination;

5.4 Water Marketing

In the middle reach villages, the average water allocation per person for other uses is higher than in the head and tail reaches of the Hakra 6-R Distributary. The water allocation is meant for both the water tank and the village water pond. In most cases, the storage capacity of the water tank is enough for 10 to 15 days, but the water turn is fixed on a basis of certain hours per week. The time allocated for other uses is different from village to village. As the villages in the middle reach of the distributary are getting more water than they need, they sell the water turn meant for other uses. The water turn is sold on seasonal (*rabi* or *kharif*) or six-monthly bases, and is used to irrigate the fields of the purchasers, in addition to his water turn meant for irrigation purposes. There is a loose organizational set-up for the auction of this surplus water allocated for other uses. The money received by this action is used for some community works in that specific village. So it is interesting to find out:

- the factors that encourage, or prevent, water marketing;
- the type of organizational set-up that prevails for selling water meant for other uses; and
- the basis of water allocation for fulfilling the needs of the village community for uses other than irrigation

6 SUMMARY AND CONCLUSIONS

Following conclusions are made based on survey results. Readers are reminded that no physical measurements were made during the study, and respondents' answers were taken at their face value.

- In total, surface water sources account for 61 percent of the total water supplies (water tank, water supply scheme, and canal).
- The current water use meets 36 percent of the minimum daily water requirement.
- Canal water was the least used source (only 2%). Only 28 percent of households used surface water (water from village tank, water supply scheme, and canal).
- More than two-thirds (65%) of households used surface water for bathing purposes. Most took a bath in the water obtained from a water tank. For sanitation, many households used water from either, a water tank (47%) or hand pump (22%). Some used water from the water supply scheme (12%) or the motor pump (14%).
- Beside domestic uses, irrigation water was also reported to be used for livestock, industry, aqua-culture, construction, etc..
- The majority of users did not know about the source of contamination in their water supply. Those who knew perceived that much of the contamination in the surface and groundwater was either local by origin, or a combination of both local and remote pollutants.
- Many users (45% to 88%) held no knowledge about the types of contaminants. Those who knew opined that the surface water contained dust, animal and human excreta, sanitation water, insects and biological life. The main pollutants in the groundwater were salts.
- The frequency of water-borne diseases was high (75%) during the summer seasons when compared to the other seasons.
- Malaria, dysentery, skin problems and typhoid fever are the most prevalent diseases in the whole area; the incidence was comparatively higher in the tail region of the distributary.
- The percentage of male adults and children infected by water-related diseases were higher when compared to that of females.
- Around one-third of sample households reported the adoption of remedial measures.
- The frequency of using remedial measures, particularly the use of cloth filters and Alum salt, etc., was higher among educated households than those less educated.
- About 60 percent of the livestock population among sample households were affected by water borne diseases during 1997.
- Major difficulties reported by those fetching water were quarrels, distance from the house, rush at source, stagnant garbage and boys teasing the ladies.

- More females showed a willingness to pay for improved water supplies than males, water quality being the major reason for paying more.
- Many females reported a variety of skills they had, but were unable to use due to lack of time.
- In a few of the middle reach villages (with higher average water allocation than other reaches), the marketing of water allocated to other uses have been reported.
- Water marketing is being facilitated by a loose organizational set up in the aforementioned villages.

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GLOSSARY OF TERMS

Disease:

A disease represents maladjustment of human and livestock organism to their environment.

Water-related diseases:

Refers to diseases which are defined as water-borne diseases (diarrhea, dysentery, cholera, gastroenteritis, typhoid), water-washed diseases (skin diseases, trachoma.), water-based diseases (cyclops.) and water-related diseases (malaria).

Education level:

Education level refers to formal years of schooling completed. Education level is classified as:

1)	No schooling
2) 1 to 10	Secondary education
3) 11 +	College or University education

Sources of water supply:

The following are the main sources of water for all non-agricultural uses in the study area:

- **Canal water:** Main source of water in the study area is irrigation canals.
- **Tobas or *diggies*:** Water is diverted directly from irrigation canals to the *tobas* or *diggies* (water tanks) without sedimentation and filtration tanks. Most often, these *tobas* are brick-lined with cement plaster. Water is pumped to houses from these *tobas*. The layout of *diggies* or *tobas* is shown in Figure 3.
- **Water supply scheme** (Surface water treatment plant): Initially, water is diverted from irrigation canals to sedimentation tanks. Subsequently, it enters another tank with slow sand filter (SSF). Finally, the clean water enters a third tank, which is supplied through a distribution system.
- **Ground water**: Ground water in the study area is saline, but due to seepage, a sweet water layer may be found near the canals, watercourses, water tanks and irrigated fields. This layer may be exploited through dug wells, hand pumps or electrical pumps.
- **Village pond** (livestock pool): Water is diverted directly from a watercourse to the village pond without any filtration or treatment. Villagers bring their animals to the village pond for watering and bathing purposes.

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