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Abstract

In large areas worldwide, groundwater cannot be used for drinking due to high levels of salt, iron, fluoride or arsenic. In many of these areas, irrigation water is an important, and sometimes the only, source of water for all domestic water needs.

In Pakistan, over 40 million people are currently dependent on irrigation water for their domestic water needs. From 1998 to 2002, the International Water Management Institute (IWMI) conducted different studies on the linkages between irrigation water management and health in the southern Punjab, Pakistan. This paper presents the findings of the studies on water quality and domestic water use.

Irrigation canal water was found to be of poor quality but many households exploited seepage water from irrigation canals for drinking purposes and this was generally of good quality. Water stored inside houses in clay vessels was of poor quality, irrespective of the quality at the source, suggesting a considerable contamination within the household.

Surveys on water use showed big differences in the availability of water between households, depending on the presence or absence of a water connection to the house and a large storage reservoir. Over 70 percent of households did not have enough water available to guarantee healthy conditions, and domestic water use went down to as low as 10 liters/capita/day during the yearly canal closure period.

The utilization of seepage water could be optimized and should become part of strategies to improve the drinking water supply in rural areas affected by brackish groundwater. In irrigated areas with few seepage water sources special arrangements should be made to overcome canal closures to make sure that enough water is available for domestic water needs.

Future changes in irrigation water management could have an important impact on health. It is therefore important to consider domestic uses of irrigation water when changes in irrigation water management are proposed.

Domestic Use of Irrigation Water in Brackish Groundwater Areas

Over a billion people worldwide lack access to sufficient water of good quality. Most of these people live in Africa and Asia. Poor access to (clean) water, together with poor sanitation and hygiene, facilitate the transmission of bacteria, parasites and viruses to a new host. Diarrhea—with around 4 billion cases and 2.2 million deaths, especially among children below the age of 5—is the most serious public health concern related to poor domestic water supply (UNICEF 2001).

The provision of drinking water through water supply schemes and hand pumps has been given top priority by many organizations worldwide. Groundwater has always been considered the best way to provide sufficient clean (bacteria-free) drinking water. However, in large areas worldwide, groundwater is unfit for consumption and other domestic uses due to high levels of salt, iron, fluoride or arsenic.

Most of Sindh Province and large parts of Punjab Province of Pakistan have brackish to saline groundwater. The origin of this groundwater goes back 70 million years, to the end of the continental drift of the subcontinent, which resulted in the formation of the Himalayan mountain ranges and subsequent formation of several basins. The Indus basin is considered to be a rift valley, converted into a flat plain by centuries-long alluviation. Frequent intrusions by the sea and an alluviation process that took place in seawater have led to brackish groundwater in most parts of the Indus plain.

Data on groundwater in Pakistan show a gradual increase in groundwater salinity from north to south. The North-West Frontier Province (NWFP) has the smallest area (< 1%) affected by groundwater salinity while the Sindh Province has the largest area, with over 85 percent of its total land area, affected by brackish groundwater (Zuberi 1999). Fresh groundwater in Sindh and large parts of Punjab is often found only in wide belts paralleling the major rivers of Indus, Jhelum, Chenab, Ravi and Sutlej, in old riverbeds and close to irrigation canals and reservoirs.

The Indus Basin Irrigation System (IBIS), taking water from the Indus river and its tributaries, is the world's largest contiguous irrigation system and its command area the most densely populated in Pakistan. Agriculture without irrigation is virtually impossible due to the semiarid to arid conditions in most of the country. In areas with brackish groundwater, irrigation water is also the only source of water for all domestic needs, including drinking (van der Hoek et al. 1999). A survey by IWMI in the southern Punjab documented the different nonagricultural (multiple) uses of irrigation water. Water seeping out of irrigation canals was the most important source of drinking water (Jehangir et al. 1998)

Number of People Dependent on Irrigation Water for Domestic Uses

The total number of people dependent on irrigation water for domestic purposes in Pakistan is unknown. Based upon a compilation of results of groundwater research in Pakistan (Zuberi 1999) and the provincial reports of the 1998 nationwide census (Population Census Organization 2000a, b and c) an estimate was made of the number of people dependent on irrigation water for domestic uses. A prediction was made for 2025 using the annual district population growth figures. The province of Baluchistan, the Federal Administered Tribal Areas, Northern Areas and Pakistan-administered Jammu and Kashmir were not included because these areas generally have fresh groundwater resources or limited irrigation infrastructure.

In the estimation, all groundwater with a Total Dissolved Solids (TDS) value over 1,000 mg/l was considered as unpalatable and unfit for drinking purposes according to guidelines for drinking water quality of the World Health Organization (WHO 1995). The assumption was then made that people will rely on irrigation water if no other sources of freshwater are available. Irrigation water was defined as water taken directly from irrigation canals or water seeping out of irrigation structures and settling on top of brackish groundwater.

Table 1 presents those areas in Punjab affected by brackish groundwater and gives estimates of the number of people dependent on irrigation water for domestic needs in 1998 and 2025. In Punjab and Sindh, it is not just the rural areas that are dependent on irrigation water; a large number of small and even large cities are either partially or completely dependent on irrigation water for their water supply. Faisalabad city with a population of over 2 million and Bahawalpur with nearly 0.5 million are good examples of this urban dependency on irrigation water.

Table 1. Estimated number of people dependent on irrigation water for domestic uses in some key areas of the Punjab Province in 1998 and 2025.

	Area affected (km²)	Area affected (%)	Number of people dependent on irrigation water for domestic use	
			1998	2025
Bahawalpur division	9,500[1]	56.2[1]	4,290,000	7,700,000
Bari *Doab*[2]	6,400	22.6	5,020,000	8,820,000
Chai *Doab*[3]	2,800	27.8	1,790,000	2,780,000
Indus right bank	10,300	40.6	1,200,000	2,250,000
Rechna *Doab*[4]	8,250	35.5	7,320,000	12,230,000
Thal *Doab*[5]	5,650[1]	35.1[1]	2,500,000	4,430,000
Punjab, total	42,900	21.1	22,120,000	38,210,000

[1]Desert areas are not included.
[2]Land between Ravi and Sutlej.
[3]Land between Jhelum and Chenab.
[4]Land between Chenab and Ravi.
[5]Land between Indus and Chenab/Jhelum.

Sindh has the most serious groundwater salinity problem; salinity varies from 200 mg/l close to the Indus river and old courses of the Gaja river, to 150,000 mg/l in the delta of the Indus river and interior Sindh. The rural areas of Sindh are mainly dependent on the IBIS or smaller irrigation systems for their domestic water supply and over 14.5 million people live in this area.

Karachi, with almost 10 million people, obtains its supply of drinking water from the Indus and Hub rivers. Although the barrages at Gudu, Sukkur and Kothri regulate the Indus river for irrigation purposes, Karachi was not classified as being dependent on irrigation water for domestic needs. Hyderabad (1 million people) partly depends on irrigation water, while the majority of the other smaller cities and towns are dependent on irrigation water, adding another 3 million people. This would bring the total population dependent on irrigation water in Pakistan to almost 40 million, which is likely to increase to 75-80 million in 2025.

The estimate of 40 million people who depend on irrigation water for domestic needs is subject to discussion. Data on groundwater were collected at irrigation command level and compared with population figures at district level. This might have led to an overestimation or underestimation

because irrigation commands cross the district boundaries and, in many cases, different irrigation commands are located in one district. The difference between water that is fit and that is unfit for drinking is not as sharp as it may seem on a map. The same applies to the 1,000 mg/l TDS threshold for drinking water. Whether the water is perceived as unpalatable depends on personal taste and on the taste and quality of alternative drinking water sources. The extent to which the Punjabi and Sindhi cities depend on irrigation water is hard to estimate. In Faisalabad, 10 percent of the water supplied by the local utility is irrigation water, but with only a 70 percent coverage, irregular supply and frequent breakdowns, many people rely on an unknown number of private water vendors selling irrigation seepage water to an unknown number of households.

Quality of Drinking Water Obtained from Irrigation Systems

The 1960 Indus Basin Treaty between the Governments of India and Pakistan assigned the right of use of water of the three western rivers, Indus, Jhelum, Chenab to Pakistan while water rights to the three remaining rivers, Ravi, Sutlej and Beas were assigned to India. To ensure the continuation of water supply to irrigation systems in Pakistan that received water from the Ravi and Sutlej, a number of link canals were constructed between the different rivers. Irrigation water is therefore transported over long distances making it vulnerable to contamination by urban centers and industries. This is shown in table 2, which presents river-water quality from north to south within the IBIS for the period 1997-1999.

Table 2. Average river-water quality in the IBIS for the period 1997-1999.

	BOD[1] (mg/l)	COD[2] (mg/l)	DO[3] (mg/l)	Fecal Coliform (No./100 ml)	NH$_3$ (mg/l)	TSS[4] (mg/l)
Rawal reservoir	1	14	7.8	967	0.00	81
Chenab	2	20	7.6	4106	0.00	241
Ravi (Upstream Lahore)	3	17	7.5	5291	0.02	274
Ravi (Downstream Lahore)	3	22	6.5	6700	0.08	251
Indus (Kotri, Sindh)	10	31	2.9	4315	0.23	629

[1]Biological Oxygen Demand.
[2]Chemical Oxygen Demand.
[3]Dissolved Oxygen.
[4]Total Suspended Solids.
Source: Global Environment Monitoring System (GEMS), http://www.cciw.ca /gems

Hakra-6/R Study

Figure 1 shows the location of the Hakra-6/R distributary where IWMI conducted different studies on linkages between irrigation water management and health from 1998 to 2002. For this study, 200 households in 10 villages were selected and water quality, water use and different water-related diseases were monitored. With a length of 45 km, Hakra-6/R is the sixth largest distributary in Pakistan and serves an irrigated area of approximately 50,000 hectares with 94 villages and an estimated population of 160,000.

Figure 1. Schematic diagram of Ravi-Sutlej and Hakra 6/R.
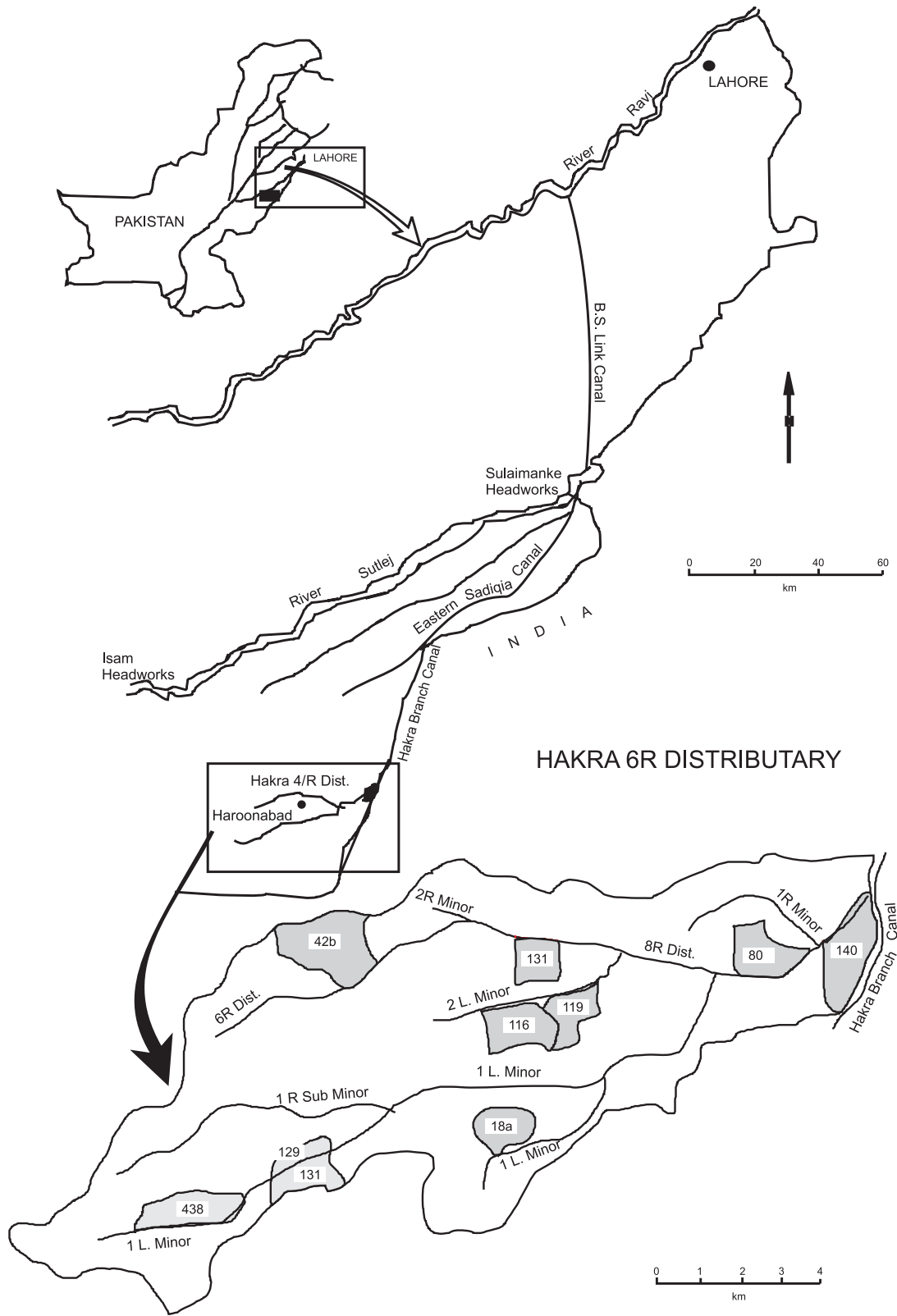
Water is provided to Hakra-6/R by a barrage on river Sutlej, connected by the Balochi-Sulaimanke link canal with the Ravi river. In the early 1900s, distributaries like Hakra-6/R were built to open up new areas for cultivation and so to overcome recurrent famines on the Indian subcontinent. *Diggis (*village water tanks) were constructed as part of the irrigation system to provide drinking water in areas where groundwater was brackish. In the rotational schedule of the irrigation system special time is allocated to provide the diggis with water. The dependency on irrigation water becomes obvious during the annual closure of the irrigation system in January. For at least a month, no water is available and users are compelled to identify other sources since the seepage water sources and diggis dry up.

All the villages in Hakra-6/R had a similar layout (figure 2). They were connected to a main road on one side of the village and the infrastructure within the village consisted of a pattern of roads going north-south and east-west. The center of the village was a large square where the diggis (used for domestic water) and the mosque were located. At the outskirts of the village an animal pond (water for livestock) was dug.

Although all members of the family were, to some extent, involved in fetching water for one activity or the other, the women in the household were primarily responsible for obtaining water for domestic purposes. The majority of the population was Muslim (98.6%) and the average family size was 7.4. The main source of income was agriculture, with cotton and wheat as major crops. Schooling was basic and an estimated 80 percent of the women were illiterate.

The annual average rainfall in Hakra-6/R is 160 mm, concentrated in the monsoonal period from June to August. The potential evaporation was 2,500 mm/year and temperatures ranged from 0 °C in January to 48 °C in July.

Irrigation Canals

The results of a 6-month water quality sampling in Hakra-6/R at 6 different points showed a deterioration of water quality along the canal as reflected by increasing BOD and *E. coli* counts (table 3) (Amin 2002). Washing, bathing, defecation, livestock watering, and small-scale industrial activities take place close to or in the irrigation canals and this could have caused the pollution.


Drinking Water Sources

Although all water sources originate directly or indirectly from the Hakra-6/R irrigation canal, five different sources of drinking water can be distinguished: diggis, seepage water, deep well, public water supply scheme and irrigation watercourse. The diggis are circular or rectangular and the volume ranges from 350 m^3 to over 1,000 m^3. Many households have PVC pipes directly inserted in the tanks and connected to the houses from which water is drawn either with electric pumps or by hand pumps. Seepage water is pumped from a depth of between 10 and 25 meters close to all permanent and temporary freshwater bodies like the diggi, irrigation watercourse, agricultural fields and animal pond. The irrigation watercourses are, in most cases, lined and approximately 30 cm wide and 30 cm deep. All the water supply schemes have a similar setup with a large sedimentation tank, two slow sand filters and a clear water well from where the water is pumped to the village. The deep wells are brick-built and, on average, 10-15 meters deep.

Table 3. Water quality at six different points along Hakra-6/R (standard deviation within brackets).

Distance from head of canal (km)	BOD (mg/l)	DO (mg/l)	E.coli (No/100 ml)		NH$_3$ (mg/l)	pH	EC (dS/m)
			Geometric mean	95% CI*			
0	5.8 (1.8)	6.1 (0.7)	1,237	1,022 – 1,452	9.2 (4.5)	8.0 (0.2)	0.32 (0.15)
12	6.4 (1.6)	6.2 (0.6)	1,642	1,416 – 1,868	8.1 (2.4)	8.0 (0.2)	0.31 (0.15)
25	6.0 (1.5)	6.1 (0.5)	1,770	1,476 – 2,064	8.2 (2.9)	8.1 (0.2)	0.30 (0.13)
34	6.8 (2.2)	6.1 (0.7)	1,696	1,436 – 1,954	9.4 (3.4)	8.1 (0.2)	0.31 (0.15)
47	7.5 (2.6)	6.1 (0.8)	1,956	1,680 – 2,231	10.0 (4.6)	8.2 (0.2)	0.32 (0.14)
52	8.4 (2.7)	5.9 (0.8)	2,284	1,947 – 2,621	10.3 (5.2)	7.9 (0.3)	0.31 (0.14)

* 95% confidence interval.

Figure 2. Cross section of a typical village in the southern Punjab.
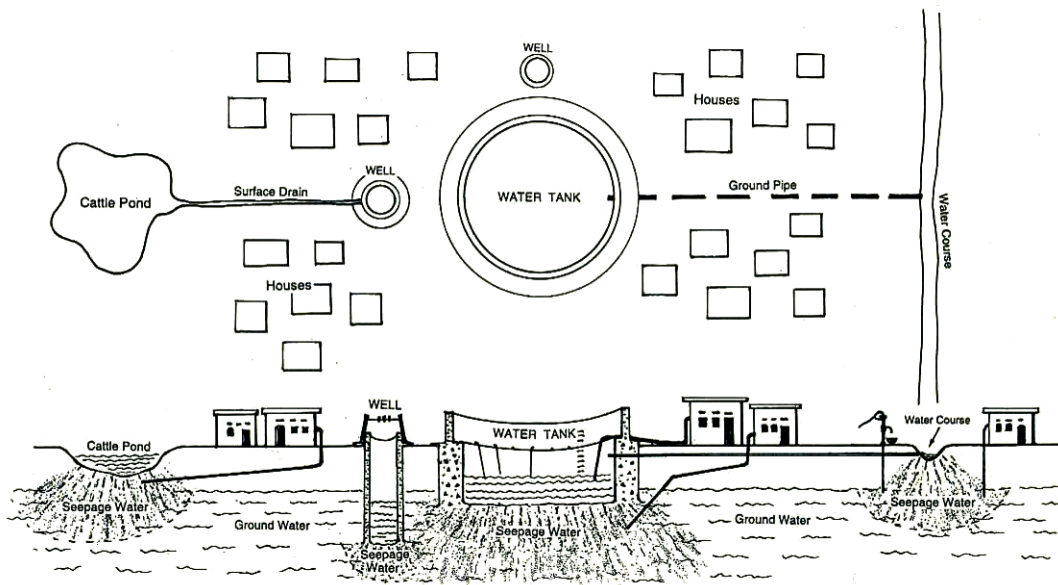
Most of the villages have at least three of these five sources. Households can opt for any of these different water sources that differ with respect to seasonal availability, quality, taste and cost of extraction. These factors, together with the purposes for which the water is intended, determine the choice of the water source. Only a few villages have access to water supply schemes that pump water from larger irrigation canals. However, most of these systems are only partially functional.

Over a period of 2 years, the different drinking water sources were sampled and analyzed according to a fixed routine and standardized methodologies (Jensen 2001; Jensen et al. 2001); the results are summarized in table 4.

Table 4. Average water quality of different drinking water sources in the Hakra-6/R command area (standard deviation within brackets).

Source	BOD (mg/l)	DO (mg/l)	E.coli (No./100 ml)		Turbidity (NTU)	EC (dS/m)
			Geometric mean	95% CI*		
Seepage water	-	5.0 (2.1)	2.0	1.8 - 2.2	-	0.21 (0.15)
Water supply scheme	4.6 (2.2)	5.7 (1.5)	33.1	21.2 – 51.3	10 (8)	0.33 (0.21)
Deep well	-	3.8 (0.3)	96.2	76.0 – 121.8	-	1.20 (0.50)
Diggi	9.6 (3.3)	5.8 (2.2)	128.6	107.4 – 153.9	141 (158)	0.44 (0.15)

* 95% confidence interval.

In-House Storage

In 55 households divided over the 10 selected villages in the Hakra-6/R command, in-house drinking water storage vessels, in most cases traditional clay pitchers, were tested on a weekly basis for the presence of *E.coli*. The households were selected in such a way that all different sources of drinking water within the villages were represented. On average, 29.7/100 ml *E. coli* were found in the pitcher samples. This was irrespective of the source of water used. Figure 3 shows that there was a large discrepancy between the source and the corresponding pitcher, indicating a considerable amount of in-house contamination.

Quantities of Water Available for Domestic Use

For many years, it has been the general belief that better water quality would result in less diarrheal disease and better health. More recently, the importance of water availability and use has been stressed (Cairncross 1997). The general consensus now seems to be that the quantity of water used by people is at least as important, and often more important, for diarrheal disease control than the quality of that water (Kolsky 1993).

Whereas there are strict and comprehensive WHO guidelines for drinking water quality, no such guidelines exist for water quantities. This lack of attention for water quantity is also reflected in the lack of methodologies for estimating water use in rural areas, especially in cases where more than one drinking water source is available for households.

Figure 3. Average monthly E. coli *count (No./100 ml) of drinking water source and corresponding household pitchers.*
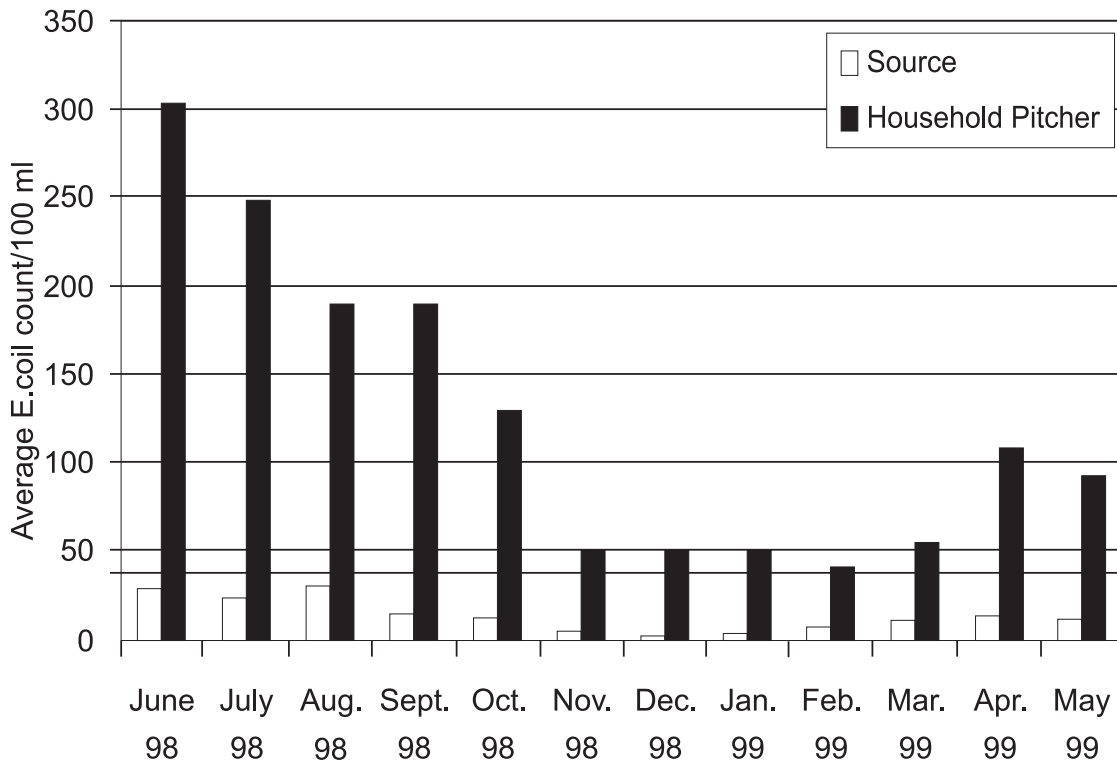
For the work in Hakra-6/R a rapid methodology was developed to estimate domestic water use in a rural multiple source and use setting. The methodology adopted needed to be nonintrusive because many households in the study area observed *purdah*, a system of female seclusion. An additional aim was to assess the divergence in the water use at the household level according to the type of main supply and to determine the differences in the consumption of water at household level in different seasons.

Water Use in the Household

Water is obtained in different ways: directly from the source, indirectly from a clay pitcher or a bucket that is filled at the source and brought back to the homestead or from a storage basin in the house connected to the source via a pumping system. Sources of direct use of water can be divided into two groups: irrigation canals and hand pumps. Irrigation canals are mainly used for washing clothes, utensils and bathing.

Data were collected from the 200 selected households on how water was brought to the household and how it was stored and used. This information was gathered through simple survey sheets, short observation lists and family interviews. The 200 selected households were classified into three categories according to their access to water.

Group A. No water connection in the house and therefore the need to obtain water directly from the source.

Group B: Access to water within the homestead via a hand pump or motor pump connected to a water source.

Group C: Access to water within the homestead via a motor pump and the presence of a water storage basin (tank) in the house.

Ten households from each group were selected to monitor their water consumption in two periods. The selection of the households was based on permission from the male head of the household. The first monitoring was in the cold season (January 1999) during the period of canal closure when very little water was available in the irrigation system. The second was in the beginning of the hot season (May 1999) when water was flowing abundantly in the irrigation canals.

Estimation of Water Use—Methodology

Different methodologies had to be adopted to quantify water use to determine the different ways in which water was used. As irrigation canals were mainly used for washing and bathing it was impossible to come up with an estimate of the quantity of water used. Therefore, direct use of the irrigation canal was noted down as one event. The other direct or indirect uses of water were systematically estimated.

Hand pumps were used for personal hygiene, drinking and washing of clothes and utensils. The design and discharge of the pumps were found to be more or less similar throughout the area and these were calibrated according to the number of strokes pumped and volume of water extracted. This relationship was used to measure the direct water use from a hand pump. Each household was provided with a wooden box and stones while the household was asked to place a stone in the box after every ten strokes pumped. The clay pitchers were used to fetch and store water for drinking and cooking. The pitchers varied in size and often more than one pitcher was used within a household. Each household was provided with a standard (20.5-liter) clay pitcher as well as a wooden box and small stones to count the number of pitchers used. Water from buckets was used for washing, bathing and cleaning of the household. The buckets were locally fabricated and not of a standard size. The width at the bottom and top and depth were measured and the volume of each of the buckets was calculated. Again, a wooden box and stones were provided to each household to record the number of buckets used. For the overhead tanks and other storage basins, the length, width and depth were measured and the maximum volume of water calculated. The depth of water in the water storage basin was recorded at 0 hours and again after 24 hours. Since all households had only one tank, it was not necessary to monitor the taps in the households but only the water level in the tank.

After 24 hours, the different boxes with the small stones were collected and counted and the amount of water consumed from the overhead tanks/basins was calculated. If agreed by the household members, the volume of water remaining in the pitchers was also estimated. Staff from the research team interviewed the family members to verify that the study had been understood and procedures were correctly followed. Finally, the household was questioned if clothes had been washed over the past 24 hours and how many people had taken a bath outside the house. The activity where a person washed clothes or bathed in an irrigation canal was recorded as one event.

The number of people within the household using water over the 24-hour period was also recorded. Those households where nobody was available after 24 hours were excluded from the survey.

Water Use in the Household

Average daily per capita water use is presented separately in liters and in number of events. The differences in liters of water used per capita per day between the three groups were dramatic (table 5). However, these differences are partly evened out when the larger number of water contact events for group A are taken into account (table 6). Still it is clear that group C with the overhead tank and with a direct connection to the water source had a higher water consumption. This can be explained by the fact that houses with an overhead tank had easy access to water and had a secure supply even when the source ran dry for a shorter period. Also, the plumbing system connecting the overhead tank with taps within the household increased the use of water.

Table 5. Water use per capita per day (in liters).

Period	N	Group A	Group B	Group C
Canal closure (January)	23	10	16	48
Peak crop water demand (May)	27	15	29	113

Table 6. Water use per capita per day as number of events of water contact for washing of clothes and utensils and bathing.

Period	N	Group A	Group B	Group C
Canal closure (January)	23	4	0	0
Peak crop water demand (May)	27	3	1	0

The results show a marked difference between the hot and cold seasons with respect to per capita water use. The reason for the increase in water use during the warmer period could be explained by the easy availability of water close to the settlements in May due to the irrigation water releases. Also, the high temperatures will make people bathe more frequently.

Discussion

We estimated that in Pakistan alone more than 40 million people depend on irrigation water for domestic water supply, a number that is likely to double in the coming 25 years. The use of irrigation water for domestic water needs has also been reported from Morocco (Laamrani et al. 2000), India (Yoder 1981), Sri Lanka (van der Hoek et al. 1999) and Nepal, Jordan and Mexico (Ault 1981), and seems to be common in all semiarid and arid countries. Irrigation systems are often associated with negative impacts on human health, especially because of vector-borne

diseases like malaria and schistosomiasis (Oomen et al. 1990) but in Pakistan and elsewhere there are substantial health benefits of irrigation water, which are generally underestimated or even completely ignored.

The high *E.coli* counts in rivers and irrigation canals in Pakistan exceed the limits of WHO guidelines for unrestricted irrigation (Mara and Cairncross 1989; Blumenthal et al. 2000), let alone the limits of guidelines for drinking water (WHO 1995). Likely explanations for these high fecal contamination levels are direct disposal of fecal material by cattle and/or disposal of wastewater by urban centers directly into irrigation canals. The use of wastewater for agriculture, already widely practiced in many cities in Pakistan could potentially improve the quality of irrigation water as it would lead to less discharge of wastewater into irrigation canals.

Water from seepage sources was of good quality and in most cases up to WHO standards for drinking water. However, regardless of the source used, contamination levels in pitchers were very high. Poor awareness of hygiene among mothers in the households under study (Nielsen et al. 2001) and contamination of the pitcher during filling and cleaning (Jensen et al. 2002) would underscore the assumption that it is contamination through hand contact that deteriorates the quality of water at the household level.

From the 200 selected households in the Hakra-6/R command only 58 (29%) had a per capita water use of more than 50 liters per day. A per capita water consumption of 50 liters was suggested by Gleick (1998) as a minimum water requirement to maintain hygienic conditions, a value confirmed by the outcomes of the epidemiological study undertaken in Hakra-6/R (van der Hoek et al. 2001). The presence of a storage tank in the house led to a larger water consumption and was one of the key factors for the lower incidence of diarrheal diseases (van der Hoek et al. 2001). However, overhead tanks require a diesel or electric pump and these are too expensive for many households.

Dependency on irrigation water becomes clear during the canal closure period in January, as water consumption for some households went down to as low as 10 liters per capita per day. During canal closure, most of the seepage sources turn brackish and, therefore, water has to be fetched from far away, which means that less water can be brought back to the household. The lack of water is most severely felt in the end reaches of the irrigation canals.

The methods used to quantify water use cannot provide more than a rough estimate. The results from the overhead tanks are the most reliable since it is a closed system and can, therefore, be estimated easily from the water levels in the tank. The method to estimate the use from hand pumps is the least accurate. Although the pumps are of the same model each pump is of a different age, i.e., newer pumps could have higher discharges. The method of using boxes and stones to record frequencies was successful and the respondents took to the idea enthusiastically following a brief introduction. This approach was especially useful to record water used in households observing *purdah* since it was seen as less invasive. The period of 24 hours used for measuring is a short time span and large fluctuations could be expected throughout the year. However, this short period was deliberately chosen in order not to be a burden to the family and to prevent loss of interest in the study.

Recommendations

Irrigation water, direct from canals or indirect as seepage, is and will become an even more important source of drinking water for rural and urban communities in Pakistan and other semiarid countries. It is unrealistic to expect that irrigation canals can deliver bacteriologically safe water. However, water from seepage sources is of good quality and an important source of clean drinking water. It is important that the use of seepage water for domestic purposes is considered in the planning and management of irrigation systems. For example, when canals are lined with concrete close to settlement areas, people could be deprived of a clean source of water and be forced to use a more polluted source of water with all its attendant health risks. In areas with brackish groundwater where canal lining is considered, the cost of constructing water supply schemes, treatment of drinking water and increased health costs due to the loss of seepage water must be included in a cost and benefit analysis of canal lining.

The effects of management of irrigation systems on the availability and use of water have become particularly clear during the period of canal maintenance. The canal closure led to a considerable drop in water use, which is the key determinant for incidence of diarrhea. Future water scarcity due to droughts or increasing demand for water outside agriculture could lead to extra canal closures. During these periods, it is important that special provisions are made for domestic water needs. Close to permanent canals seepage use could be optimized and become part of strategies to improve drinking water supply. In areas where canals are subjected to regular rotational closures the construction of water supply schemes with large storage tanks, capable of overcoming these periods, should be considered.

Per capita water use and average duration of canal closures would be of vital importance for the proper design and functioning of new water supply schemes. Rough indicators such as type of household connection and size of overhead tanks seem to be useful to estimate water consumption per household. Both water use surveys took a period of 2 weeks to complete most of which time was spent explaining the study to the households and obtaining their permission to conduct the surveys. The short duration and the total cost of US$15 for clay pitchers and US$10 for wooden boxes make surveys of this type a rapid, inexpensive and simple exercise for future estimations of water use.

The considerable contamination of household pitchers calls for interventions at the household level. Improving awareness of hygienic matters among mothers improved sanitation, and simple water treatments like chlorination could help improve the quality of water at the household level and lead to improved health. In these initiatives community awareness and participation are a must.

The need for closer collaboration between the Public Health Department in charge of drinking water supply and sanitation and the Provincial Irrigation and Drainage Departments seems evident and urgent.

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