J HEALTH POPUL NUTR 2002 Mar;20(1):77-84
ISSN 1606-0997 $ 5.00+0.20

Availability of Irrigation Water for Domestic Use in Pakistan: Its Impact on Prevalence of Diarrhoea and Nutritional Status of Children

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ABSTRACT

This study assessed whether availability of water for domestic use had any impact on nutritional status of children in an area where people depend on irrigation water for all their domestic water needs. During May 1998-April 1999, data on the occurrence of diarrhoea among 167 children aged less than five years were collected from 10 villages in the command area of the Hakra 6R canal in southern Punjab, Pakistan. Anthropometric measurements were taken at the end of the study period. Additional surveys were conducted to collect information on the availability of water, sanitary facilities, hygiene, and socioeconomic status. Height-for-age and longitudinal prevalence of diarrhoea were used as outcome measures. Quantity of water available in households was a strong predictor of height-for-age and prevalence of diarrhoea. Children from households with a large storage capacity for water in the house had a much lower prevalence of diarrhoea and stunting than children from families without this facility. Having a toilet was protective for diarrhoea and stunting. Increased quantity of water for domestic use and provision of toilet facilities were the most important interventions to reduce burden of diarrhoea and malnutrition in this area. An integrated approach to water management is needed in irrigation schemes, so that supply of domestic water is given priority when allocating water in time and space within the systems.

Key words: Diarrhoea; Diarrhoea, Infantile; Infant nutritional status; Child nutritional status; Irrigation; Water supply; Pakistan

INTRODUCTION

Malnutrition is a major problem in Pakistan. In the last nationwide survey carried out during 1990-1994, 36.3% of children aged less than five years were stunted (too short), 14.2% wasted (too thin), and 40.0% underweight (too light) (1). The mean per-capita intake of calories and protein in Pakistan in 1997 was above the recommended dietary allowance (2). Gross inequalities in intake of food between population groups are, of course, not reflected in aggregate national figures, but factors other than insufficient availability of food may play a role in causing malnutrition. Infectious diseases, especially diarrhoea, are considered direct causes of malnutrition. A child aged less than five years in a developing country typically suffers from several episodes of diarrhoea each year.

Results of a national survey in Pakistan showed that the number of annual episodes of diarrhoea was as high as 12 for male children aged less than two years (1). These episodes of diarrhoea can cause malnutrition for decreased intake of food resulting from anorexia or food withholding, decreased absorption of nutrients, increased

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metabolic requirements, and direct loss of nutrients (3). Malnutrition, in turn, can impair the immune system, making malnourished children more vulnerable for diarrhoea (4). Association of malnutrition with diarrhoea has also been documented in Pakistan, with infants with poor nutritional intake having a higher incidence of diarrhoea and malnutrition than infants receiving nutritional supplementation (5).

One way of breaking the vicious malnutrition-diarrhoea cycle is to improve supply of water and sanitation. This can reduce the transmission of pathogens, thereby decreasing the incidence of diarrhoea, and would lead to improved nutritional status and lower mortality among children. The most effective way of obtaining health benefits from water and sanitation programmes is to increase quantities of water for personal and domestic hygiene. Simple measures, such as frequent hand-washing, are very effective in interrupting faecal-oral transmission of pathogens that cause diarrhoea. The best results are obtained when increased quantities of water are combined with improved facilities to dispose of human faeces in a sanitary way (6).

Large areas of Pakistan have brackish groundwater and very low rainfall. Improving water supply in such an environment is problematic since people depend completely on water from irrigation canals that are managed primarily to satisfy water requirements for crops (7). The same areas are often affected by irrigation-induced waterlogging, making it very difficult to provide low-cost onsite sanitation.

The International Water Management Institute is implementing a study in southern Punjab, Pakistan, aiming at analyzing the linkages between irrigation and domestic supply of water. This should lead to recommendations for improvements in supply of water and sanitation in irrigation schemes. Results of a previous study in this area showed that poor availability of water contributed to the high incidence of diarrhoea and was found to be more important than quality of water used for drinking (8). The present study was done to estimate the prevalence of malnutrition among children in this area and to assess its possible association with diarrhoea and with quantity of water supplied to households. The specific research question was "To what extent does availability of water for domestic use have an impact on nutritional status in an area where people obtain their water from an irrigation system?"

MATERIALS AND METHODS

Study area

The study was conducted in the area irrigated by the Hakra 6R canal, located in Bahawalnagar district of southern Punjab, Pakistan. The length of the canal is 45 km, and the size of the command area is about 50,000 hectares. It is part of the largest irrigation system in the world, using water from the river Indus and its tributaries. This part of the Indus River Irrigation System was built in the 1920s and 1930s to open up desert areas for cultivation to overcome recurrent famines in the Indian subcontinent. The annual average rainfall in the area is below 200 mm concentrated in the monsoon period from June to August. Because of low rainfall and brackish groundwater, most fresh water in the study area originates from the irrigation canals.

Water reservoirs in villages 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 drinking water to the village water reservoirs. The rotation system with an on/off supply and extended periods of canal closure for maintenance interrupts the supply of water to village water tanks. During the annual canal closure period, no water is supplied for 4-8 weeks. Water from village water reservoirs is used for drinking and other domestic purposes either directly or after passing through a simple filter. To supplement water supply from the village reservoirs, people have installed PVC pipes linked to hand- and motor-pumps in places where seepage water is available, for example next to canals, village water reservoirs, animal ponds, and in irrigated fields. The pumps capture water that has seeped out from these fresh-water bodies to form a fresh-water layer on top of saline groundwater. However, availability of this fresh water is governed by irrigation water releases, and pumps quickly run dry or start producing saline water when irrigation canals are closed. While many families have made a connection with PVC pipes to their house from the drinking water source, others have to carry water to their homes from the village reservoirs or hand-pump. A few villages in the Hakra 6R area have a piped water-supply system with sedimentation tanks and slow sand-filters. However, all slow sand-filters are dysfunctional, and untreated canal water is provided to these villages.

Study population

Of 94 villages in the Hakra 6R area with a population of 160,000, ten were selected in 1998 for an epidemiological research project. These 10 villages were evenly distributed over the area representing the tail, middle, and head of the Hakra 6R irrigation scheme. In these 10 villages, a random sample of 200 households, proportionally distributed over 10 villages, was taken. For households with more than 10 family members, only one core family, consisting of husband, wife, their children, and parents, was selected. Before starting the epidemiological study in May 1998, all individuals were given identification numbers, and basic demographic and socioeconomic data of households were collected. To study the nutritional status of children in this area, the population of children, aged less than five years, in selected households, was surveyed.

Data collection

Nutritional status: Two trained female personnel visited all selected households in April/May 1999 to measure height and weight of all children aged less than five years. Age of child on the day of measurement was obtained from birth certificate, if available. In other cases, the mother was asked to report the date or month of birth of her child. Sometimes, the date had to be estimated using yearly events and seasons. If a mother was unable to give the date of birth for a child aged less than approximately three years, the number of teeth was recorded to estimate the age. Children were weighed to the nearest 100 g with an electronic weighing scale provided by the United Nations Children's Fund in Lahore. This scale calculates weight of a child by subtracting weight of mother alone from the combined weight of mother and child. Height of children was measured to the nearest 0.1 cm with a portable wooden measuring board. The board was put as straight as possible against a wall in the house. Height was measured while the child was standing on his/her feet against the board. If the child was too young to stand against the board, height was measured in supine position.

Diarrhoea: One or two trained research assistant(s) visited each of the 200 sample households in 10 villages once a week during May 1998-April 1999. During each weekly visit, illness episodes since the previous visit of the interviewer were recorded for each day for all individuals in the household. Diarrhoea was defined as three or more non-bloody loose stools or one or more bloody loose stool(s) in a 24-hour period. The methodology is described elsewhere (8).

Supply of domestic water: A previous study in the area had shown that the quantity of water available to each household for domestic use was dependent upon the presence or absence of a water connection to the house and the presence or absence of a large water-storage facility (to be reported elsewhere). Households with a private water connection in compound (either a piped connection or a tubewell) and with a water-storage facility (mostly an overhead tank) were classified as having good availability of water with a consumption of 48-113 litre of water per capita per day depending on the season. Households with a connection, but without storage facility used only 16-29 litre per capita per day because of non-availability or insufficient water during the non-supply periods. Households without a private connection had no possibility to store enough water and had to fetch water from a public water-supply point or directly from canals. They were classified as having poor availability of water, and their per-capita water consumption was estimated to be 10-15 litre per day.

Other variables: If a household in the area had a toilet facility, it was generally a flush toilet with a septic tank. Some houses lacking a flush toilet had a 'female' toilet, which is a designated place within compound where mainly female family members take baths and which drains directly into street. However, a distinction was made between households having a flush toilet and those not having such a facility, which in most cases, indicated no toilet facility at all.

To collect information on socioeconomic status and hygiene, a short-structured questionnaire was administered to 200 households during the year in phases. The questionnaire was administered to females, if possible, except for the socioeconomic survey where any reliable adult member of the household was questioned about ownership of land and other assets. During each survey on hygiene behaviour and sanitary practices, a male enumerator interviewed one of the household members with a structured questionnaire, while a female enumerator scored general hygiene standards of compound according to a structured observation checklist. Pictures were used in the questionnaire surveys as a communication tool. Two female anthropologists supervised the surveys. To score each household according to hygiene standards, several topics were selected based on literature and local situation. Each hygiene topic, on which the household showed or reported a good knowledge or practice, was scored to have one point. The topics in the questionnaire focused on means of disposal of children's faeces, hand-washing at critical times, and food-storage practices. Knowledge was tested by asking opinions of respondents on three stories illustrated with pictures. Direct observations in compound focused on presence of faecal material, availability of soap, food-storage practices, and general cleanliness of compound. In the end, each household obtained a total score for the 41 items. Those with a score below the median were classified as poor and those above the median were classified as good with respect to hygiene status.

The socioeconomic status of each household was determined with a similar composite scoring system and classification whereby each of the following 13 situations qualified for one point: good overall physical appearance of house construction; five or more acres of land under cultivation in the *Rabi* (winter) agricultural season; three or more acres of land under cultivation in the *Kharif* (summer) season; ownership of at least one cow; buffalo; goat; camel; poultry; tractor; car; family members with off-farm employment; sale of home-based non-agricultural produce; and receipt of income from relatives overseas.

Data analysis

Anthropometric indices were compared with the United States National Center for Health Statistics (NCHS) reference values as recommended by the World Health Organization (9). Height-for-age, weight-for-height, and weight-for-age were expressed in terms of standard deviations (SD) from the median of reference population (z-scores). Children were classified as stunted, wasted, or underweight, if z-scores of height-for-age, weight-for-height, and weight-for-age respectively were below -2SD from the NCHS median. Height-for-age is considered the best indicator of chronic undernutrition reflecting cumulative effects of socioeconomic, environmental, health and nutritional conditions (9). Z-scores of height-for-age were, therefore, used as outcome measures in analyzing the relationship between different explanatory variables and nutritional status. Z-scores were calculated using Epi Info software, and further analyses were done with SPSS version 8.0. The other outcome measure used was longitudinal prevalence of diarrhoea, defined as the number of days of diarrhoea divided by the number of days of observation for each individual (10).

RESULTS

There were 186 children, aged less than five years, in the 200 selected households. Weight and height measurements could be obtained for 167 (90%) of these children. There were no differences in age and sex distribution between the examined children and the children who were not available for examination. In Table 1, levels of malnutrition in the study area are compared to the percentages found for the whole of Pakistan in the National Health Survey of 1990-1994. Boys had slightly higher rates of stunting than girls, but there were no gender differences in the prevalence of underweight and wasting. Height-for-age z-score among the children ranged from +4.99 to –5.18 with a mean value of -1.40 (SD 1.47). Poor availability of water in the house was strongly associated with height-for-age z-score (Table 2). Analysis of variance with a multiple comparison test showed no significant difference in the mean height-for-age z-score between the categories 'connected, no storage' and 'not connected' (Tukey HSD, p=0.910). This indicated that the availability of a storage facility was the critical issue. Lack of a toilet facility, illiteracy of mothers, and, to a lesser extent, low socioeconomic status were also associated with low height-for-age z-scores. No clear association was found between height-for-age z-score and hygiene, gender, and family size. Table 3 shows the results of logistic regression analyses in which stunted/not stunted were used as a binary outcome variable. There was a strong effect of availability of water, adjusted for age of children, socioeconomic status of households, and educational level of mothers on stunting. Not having a toilet facility was also a strong risk factor for stunting, but hygiene was not a significant variable. In the full model, effects of availability of water and sanitary facilities were low. Hygiene and availability of a toilet were determined by quantity of water available at a household and, therefore, have to be considered as mediating factors, not confounders. Effect of availability of water on stunting in the full model represented the effect of quantity of water that was not mediated through sanitation and hygiene.

On an average, the children suffered from 3.9 episodes of diarrhoea over the one-year period, and diarrhoea was reported, on an average, for 6.6% of child-days of observation. The mean duration of a diarrhoeal

Table 1. Nutritional status of children in Hakra 6R area, compared with figures from National Health Survey 1990-1994 (1)

Indicator	Male	Female	Total	National Health Survey 1990-1994
Underweight (low weight-for-age)	35.7	36.1	35.9	40.0
Wasted (low weight-for-height)	11.9	12.0	12.0	14.2
Stunted (low height-for-age)	39.0	34.6	36.8	36.3

Figures indicate percentages

episode was 6.2 days. As expected, burden of diarrhoea was specially high among children aged less than three years (Table 4). Not having a water-storage facility in the household and lack of a toilet were risk factors for diarrhoea (Table 5). The male children had a higher risk for diarrhoea than the female children. Surprisingly, the children of educated mothers had a higher risk for diarrhoea than the children of illiterate mothers. Confidence intervals (CIs) in this analysis have to be interpreted with caution, because days of diarrhoea in the same child are not necessarily and statistically independent events.

To determine the association of diarrhoea with stunting, the longitudinal prevalence of diarrhoea was categorized. The children who had diarrhoea on more than 5% of days of observation were more likely to be stunted than those who had suffered from less diarrhoea

Table 2. Potential risk factors and confounding variables for stunting among children in 200 households in Hakra 6-R, Pakistan, with proportion of children stunted (height-for-age below -2SD of median of reference population), mean z-score of height-for-age, and p values resulting from one-way analysis of variance

Household characteristics	No. of children	% stunted	Mean z-score of height-for-age	p value
Water availability				
Connected, storage	58	15.5	-0.71	
Connected, no storage	73	47.9	-1.73	
Not connected	36	50.0	-1.84	<0.001
Sanitary facilities				
Toilet	60	16.7	-0.92	
No facilities	107	48.6	-1.67	0.001
Hygiene				
Good	96	36.5	-1.36	
Poor	71	38.0	-1.44	0.741
Socioeconomic status				
High	76	25.0	-1.15	
Low	91	47.3	-1.61	0.044
Mother literate				
Yes	36	22.2	-0.79	
No	131	41.2	-1.56	0.005
Gender				
Female	83	34.9	-1.29	
Male	84	39.3	-1.51	0.330
Family size				
≤6	44	36.4	-1.35	
>6	123	37.4	-1.41	0.817

Table 3. Results of multivariate logistic regression analysis of association between stunting and water availability, sanitary facilities, and hygiene

Household	Partial model		Full model	
characteristics	Odds ratio	95% CI	Odds ratio	95% CI
Water availability				
Connected, storage	1	-	1	-
Connected, no storage	4.06	1.69-9.74	2.95	1.08-8.03
Not connected	3.28	1.12-9.58	2.48	0.72-8.56
Sanitary facilities				
Toilet	1	-	1	-
No facilities	3.47	1.46-8.23	2.41	0.86-6.72
Hygiene				
Good	1	-	1	-
Poor	0.64	0.31-1.31	0.50	0.23-1.07

CI=Confidence interval

The column with partial model shows separate effects of availability of water, sanitary facilities, and hygiene on stunting, adjusted for age of children, socioeconomic status of household, and educational level of mothers. The full model includes all variables in one single model in the previous year (Table 6). The relative risk for stunting, if the longitudinal prevalence of diarrhoea was equal or more than 5% in the previous year, was 1.67 (95% CI 1.12-2.49).

Table 4. Age group-specific number of episodes of diarrhoea and longitudinal prevalence (%) of diarrhoea over a one-year period with SD for 167 children in Hakra 6R area, Pakistan

Age (in years)	No. of children	No. of episodes	SD	Prevalence of diarrhoea	SD
Below 1	26	5.84	5.70	9.87	12.35
1	38	5.18	4.33	9.35	8.42
2	37	5.14	4.44	8.52	7.88
3	29	2.06	2.14	3.12	3.34
4	37	1.61	1.82	2.26	3.14
Total	167	3.94	4.23	6.59	8.17

SD=Standard deviation

DISCUSSION

We found a high prevalence of stunting and diarrhoea among children aged less than five years in an area where people used irrigation water for domestic needs. Poor availability of water for domestic use was the most important risk factor for diarrhoea and stunted growth in this community in Pakistan. Among the children of households having no water connection and no storage facility, a large part of the longitudinal prevalence of diarrhoea and of the prevalence of stunting could be attributed to supply of insufficient water. Improving the availability of water for domestic use could, therefore, have an important impact on health of children in this area, especially when combined with improvements in sanitary facilities. We have shown before that when sufficient quantities of water and sanitary facilities are available, improvements in quality of water would have additional health benefits (8).

Several studies have reported complementary effect of increased availability of water and improved sanitary facilities, the study of Esrey *et al.*, for example (12). Other studies have not been that conclusive. A study in

Table 5. Univariate analysis of potential risk factors and confounding variables for diarrhoea among children in 200 households in Hakra 6R, Pakistan, with person-days of observation, longitudinal prevalences, relative risks, and 95% CI for relative risks

Household characteristics	Person-day	Prevalence of diarrhoea	Relative risk	95% CI
Water availability				
Connected, storage	21,028	4.18	1	
Connected, no storage	27,079	6.50	1.55	1.43-1.68
No connection	13,771	8.87	2.12	1.94-2.31
Sanitary facilities				
Toilet	21,587	5.27	1	
No facilities	40,291	6.76	1.28	1.20-1.38
Hygiene				
Good	36,160	5.85	1	
Poor	25,718	6.79	1.16	1.09-1.24
Socioeconomic status				
High	28,132	5.77	1	
Low	33,746	6.63	1.15	1.08-1.23
Mother literate				
Yes	13,051	7.00	1	
No	48,827	6.04	0.86	0.80-0.93
Gender				
emale	31,103	4.53	1	
Male	30,775	7.96	1.76	1.64-1.88
Family size				
≤6	16,637	6.35	1	
>6	45,241	6.20	0.98	0.91-1.05

CI=Confidence interval

Table 6. Association between stunting and longitudinal prevalence of diarrhoea over the previous year among children in Hakra 6R, Pakistan

Prevalence of diarrhoea	Stunted (n=62)	Not stunted (n=105)	Total (n=167)
≥5%	35	38	73
<5%	27	67	94

Stunted was defined as height-for-age below –2SD from median of reference population

Sri Lanka found no association between use of larger quantities of water and reduced prevalence of stunting (13). However, burden of diarrhoea and malnutrition is higher in Pakistan than in Sri Lanka, and it is likely that effect of availability of water on diarrhoea and growth depends on the existing environmental conditions and presence or absence of other related factors that influence exposure to pathogens. Several studies in development economics literature have examined the impact of 'safe' water on child growth; the results are inconsistent (14). However, in most of these studies, only quality of water was considered, not availability of water.

Anthropometric measurements of Pakistani children were compared with a standard developed in a western industrialized country. This is appropriate, since it has been shown that children from Pakistani parents, who recently migrated to the United Kingdom, closely followed international and local reference parameters for weight and length (15). This indicates that low height-for-age in a population of children is not due to constitutional or ethnic factors but can entirely be attributed to the socioeconomic and environmental conditions prevailing in the country.

We used the longitudinal prevalence of diarrhoea as one of the outcome measures. This measure has been proposed as a better predictor of subsequent weight gain and mortality in children aged less than five years than the number of episodes of diarrhoea experienced by each child over time—the incidence of diarrhoea (10). Obtaining reliable data on the incidence and prevalence of diarrhoea is difficult and time-consuming. Anthropometric measurements have the advantage that they do not rely on perceptions of mothers and are, therefore, perhaps more objective, although the exact age of children is often not known and height can be difficult to measure in small children. Weight-for-height (wasting) has been recommended as an appropriate indicator in health-impact evaluations of water and sanitation projects (16). However, the proportion of children who are wasted is generally much lower than the proportion stunted, and, therefore, larger sample sizes are needed.

We repeated analyses with weight-for-height as the outcome measure (data not shown). The pattern of risk factors was similar to that when using height-for-age as an outcome measure, but the differences between groups did not reach statistical significance for most variables. This could at least partly be explained by the much lower prevalence of wasting (12.0%) than stunting (36.8%) in the study population. Our findings strongly support the use of stunting as an outcome measure in cross-sectional studies when the health impact of different levels of water supply and sanitation is of interest. In cross-sectional studies, exposure and outcome are measured at the same point in time, and these studies are generally not considered appropriate to draw causal inference. However, stunting is relatively stable over time, and if we assume that level of exposure, for example having good water supply or having a latrine is also stable, we could validly draw causal inference from such studies.

The present study was efficient for a number of reasons. First, the prevalence of stunting and diarrhoea was very high in the study area. Secondly, there was a clear contrast between children in availability of water and in other environmental variables. Despite the small sample size, an effect of availability of water on stunting could be shown. Elsewhere, under different conditions, a much larger sample size might be needed. Also, in our study area, a larger sample size might have shown a significant independent effect of sanitation on stunting, which now did not come out as a significant variable in the full multivariate model.

The high prevalence of diarrhoea among children whose mothers were literate was unexpected, because female literacy is generally considered one of the strongest determinants of child health. Education of mothers had a strong positive effect on height of children. It could be that the well-educated women reported episodes of diarrhoea more accurately. The higher prevalence of diarrhoea among the children of educated mothers could also have been due to the shorter duration of breast-feeding and earlier introduction of potentially contaminated weaning food. The male children were at a higher risk of diarrhoea than the female children. This could be related to differences in freedom of movement with the male children more likely to come in contact with a larger number of people leading to increased exposure to people with diarrhoea (17).

The results emphasize the strong link between the availability of irrigation water and the health status of children in Pakistan. Unfortunately, management of irrigation water is based entirely on requirements of crop-water, not on requirements of domestic water. Therefore, if decisions of water allocation are taken, domestic uses are generally not taken into account. With looming fresh water crisis, there is an increasing pressure on the irrigation sector to make water use in agriculture more efficient. One of the key strategies of the irrigation sector to limit amounts of water that are 'lost' through seepage is to line irrigation canals with concrete. Others include changing the cropping pattern to less-water-demanding crops and changing rotational supply of water. Such measures could have serious effects on the availability of water for domestic use and could negatively impact on health of children. An integrated approach to management of water resources in irrigation systems, in which all water uses are considered and in which basic human needs for drinking water would be given a priority, would, on the other hand, provide important health benefits.

Malnutrition is a complex problem, and in a country like Pakistan, there are many unfavourable interacting factors responsible for high prevalence of malnutrition and burden of diarrhoea, the more fundamental one being poverty. Single measures may not solve the problem. Poor supply of water and sanitation play an important role, and improvements in this field could contribute to breaking the vicious cycle of poverty, poor nutritional status, and disease.

ACKNOWLEDGEMENTS

We thank the staff of the Haroonabad field station of the International Water Management Institute, Mr. Muhammad Mudasser, Ms Asia Batool, and Ms Nuzhat Nasira, in particular, for their data-collection work. The Canadian International Development Agency and the Government of Japan provided financial support for irrigation and health work of the International Water Management Institute in Pakistan.

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