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Water Supply, Sanitation and Hygiene Education

Report of a Health Impact Study in Mirzapur, Bangladesh

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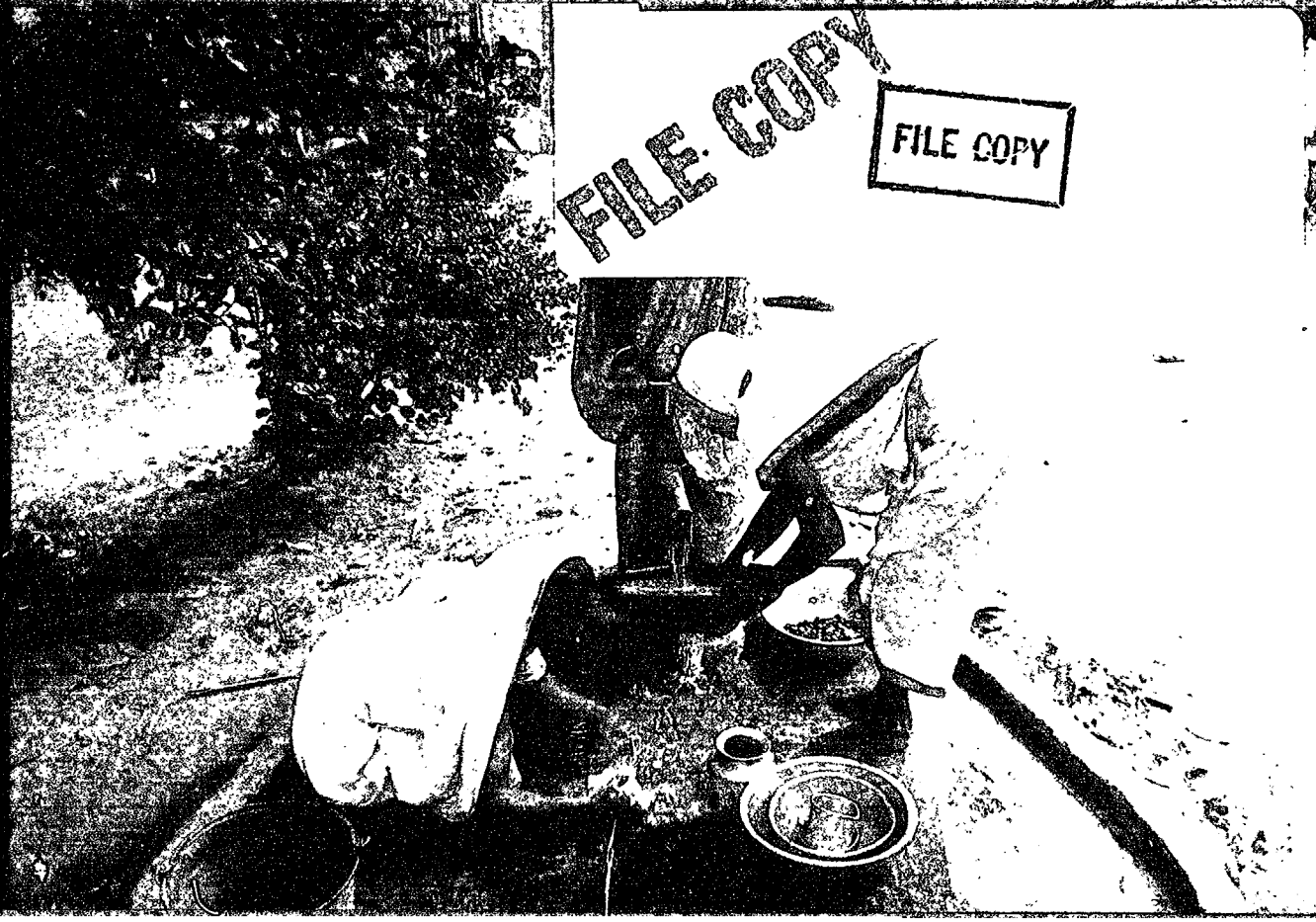M.M. Rahaman, and S. Cairncross

DISCUSSION PAPER.

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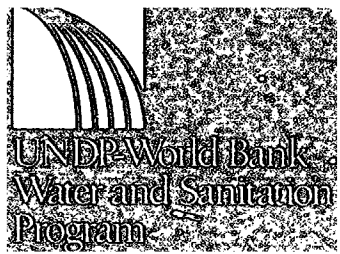
UNDP-World Bank
Water and Sanitation
Program

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Cover photo: Enamul Karim Nirjhar

The UNDP-World Bank Water and Sanitation Program was organized as a joint endeavor of the United Nations Development Programme and the World Bank and has been one of the primary players in worldwide efforts to meet the challenge of providing basic water supply and sanitation services to those most in need in the developing world. Fartners in this venture are the developing countries themselves and the multilateral and bilateral agencies that fund the Program's activities.

The UNDP-World Bank Water and Sanitation Program produces its own publications and also releases works under the auspices of the World Bank. The Program's publications are divided into two series, a **Water and Sanitation Program Report** series and a **Water and Sanitation Discussion Paper** series. The Program Report series presents formal discussions of the Program's operations and research activities as well as examinations of relevant projects and trends within the water and sanitation sector. Program Reports are subject to rigorous external review by independent authorities from appropriate fields. The Discussion Paper series is a less formal means of communicating timely and topical observations, findings, and opinions concerning Program activities and sector issues.

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Preface

In 1978, UNDP and the World Bank began a program to develop the technologies and delivery systems needed to promote the extension of water supply and sanitation services to low-income groups. As part of the United Nations International Drinking Water Supply and Sanitation Decade, the activities of the UNDP-World Bank Water and Sanitation Program have reached more than 40 countries over the past 10 years. From the outset, the program has aimed to alleviate poverty and safeguard health. It has expanded to include a number of related projects financed by UNDP and bilateral donors and executed by the World Bank.

In 1984, a major collaborative study was initiated in Mirzapur, Bangladesh, to evaluate the success of an integrated package of interventions: handpump water supplies, pit latrines, and hygiene education. Prototypes of the Tara pump were installed in 1982, and the design was refined. The Mirzapur project provided the testing needed for the performance, acceptability, and maintainability of the pumps. In addition, a study to assess the health impact of the integrated package was undertaken. The project was executed under the UNDP-World Bank Interregional Handpump Project, with the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B) appointed as consultant for the operation, monitoring, and evaluation. Funding came from the Canadian International Development Agency (CIDA) and UNDP. This report details the results of a study on the health impact of the Mirzapur project.

There are two reasons for studying the impact of water, sanitation, and hygiene education projects on health. First, information on health impact helps to allocate resources between these projects and other measures such as immunization programs designed to improve child health. Health impact data inform the discussion on the *external efficiency* of investments in water supply, sanitation, and hygiene education. Second, knowledge of health impact assists with the design of projects so that they optimize their impact on health at a given cost. Thus, health impact data also contribute to the understanding of *internal efficiency*. For example, data showing water-source-to-household distance to be a particularly important explanatory variable of health impact will encourage the designers of future projects to minimize this distance.

The literature on health impact can be roughly divided into the pre-1985 studies, which were mostly prospective, and the post-1985 studies. These latter studies are of generally superior epidemiological quality, are mainly case-control designs (although two--Mirzapur, reported here, and Imo State, Nigeria--were prospective), and have consistently shown impacts on childhood diarrhea.

We believe that, of the post-1985 studies, the Mirzapur study that forms the subject of this report is outstanding and noteworthy. Why is it outstanding? Because, first, the study design, although conventional, was well conceived and executed by an experienced institution. Second, field work was carried out carefully, with attention to detail and quality control. Third, data cleaning and computerization were meticulous and, again, carefully checked for discrepancies.

Fourth, and most important, analysis and interpretation were sophisticated, critical, and mindful of the inherent dangers in studies of this type.

The Mirzapur study is noteworthy because its findings are consistent, robust, and plausible. In the intervention area, relative to the control area, there was significantly and substantially less diarrhea of all kinds, in each village, in all seasons, in each year of project follow-up, and for all children over six months of age. Significant reductions in *Ascaris* prevalence rates in children were also recorded.

The other substantial prospective study in the post-1985 group of health impact studies is the one conducted in Imo State, Nigeria. Impacts were recorded on guinea worm, nutritional status, and diarrhea. However, the impact on diarrhea was much less dramatic than that found at Mirzapur. The explanation for this difference lies in the striking contrasts between the two interventions. The Mirzapur project brought larger quantities of clean water closer to people, established higher rates of latrine ownership and usage, and had a successful hygiene education component.

The other post-1985 health impact studies have mainly been case-control designs and have been much quicker (less than one year) and less expensive (under $100,000) to conduct than the prospective studies in Bangladesh and Nigeria. However, by their nature, they cannot provide the richness of detail of the Mirzapur study or such convincing proof of impact.

The findings from Mirzapur contained in this report should encourage both governments and agencies to continue to invest in sustainable, low-cost improvements in water supply, sanitation, and hygiene. They should also assist in project design in order to extend coverage of basic needs to low-income groups. The importance of water availability--having plenty of handpumps close to where people live--was clearly demonstrated in this study. Further work in this field could concentrate on questions of internal efficiency and seek to clarify the relative advantages, in health terms, of different project designs.

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Executive Summary

This is the report from a study of the health impact of an integrated project comprising handpumps, improved latrines, and hygiene education in a rural area of Bangladesh. The study was carried out by the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B), supported by the London School of Hygiene and Tropical Medicine, under contract to the UNDP-World Bank Interregional Handpump Project. It was financed by the Canadian International Development Agency. The study was conducted in the Mirzapur area, some 60 km north of Dhaka. It involved longitudinal follow-up over four years of an intervention area and a control area, some 5 km apart, each with a population of about 5,000.

The intervention area served simultaneously as the proving grou: for a new pump, the Tara handpump. The pump had been developed to supply drinking water when the groundwater table was too low for the traditional shallow well handpumps. There were 148 pumps installed, 1 for every 33 inhabitants. Village women were trained to maintain the pumps, and backup support was provided by project staff. The functioning of the pumps was monitored closely so that the pump design and maintenance arrangements could be perfected. The results of the work on the handpumps are presented in a companion report (Minnatullah et al. 1989).

Approximately one year after the handpumps were installed, pour-flush latrines of an experimental double-pit design were also provided, one for each household. All below-ground components were provided and maintained by the project, whereas householders were responsible for the superstructure. Superstructures were completed for 720 latrines, covering 90 percent of the households in the intervention area.

These interventions were accompanied by a hygiene education program using three different approaches:

▶ *Household visits*--each household was visited eight times for half an hour.
▶ *Group discussion*--this was organized at 80 neighborhood meetings, each with an average of 25 participants, mainly women.
▶ *Training sessions*--one woman from each household attended a two-day training course, involving discussion followed by demonstration.

The cost of the three project components, under normal implementation conditions but at the levels of service provided, were estimated as follows:

Project component	Investment cost ($ per inhabitant)
Handpumps	6.89
Latrines	4.67
Hygiene education	3.60
Total	15.16

These figures do not include maintenance costs. They are low by regional standards, but the total, even when converted to the equivalent annualized cost, is significant in comparison to the per capita GNP of Bangladesh, approximately $160 in 1987.

Regular questionnaire surveys, combined with occasional observational studies to confirm the accuracy of responses, were used to investigate the use of the new facilities and compliance with hygiene education messages. The results showed that 90 percent of the households in the intervention area used handpump water for practically all domestic purposes, whereas the corresponding figure in the control area was less than 20 percent. Observation of water collection at the pump showed that per capita water use in households within 50 meters of a handpump was more than 50 percent greater than it was in households whose pump was more than 100 meters away. Wealthier households also used slightly more water than average.

Regular monitoring surveys found that 90 percent of the completed latrines were in regular use. By the end of the project, 98 percent of the adult population in the intervention area said that they used latrines. In the control area, despite an independent hygiene education campaign, nearly 20 percent of the adult population continued to use the fields or bushes. Only among children below three years of age was there no improvement in defecation habits. A remarkable change, attributable to hygiene education, was that the majority of households in the intervention area, who had previously used mud for hand cleansing after defecation, began to use ash instead.

The project had a significant impact on childhood diarrheal disease in the intervention area, where the incidence of diarrhea fell to three quarters of that in the control area. The incidence and proportion of persistent diarrhea episodes, and the incidence of dysentery, also fell in the intervention area compared to the control area. The relative incidence of diarrhea in the intervention area also declined significantly in each age group between six months and five years, and in each of the three seasons of each project year. Each of these results was significant at the 0.1 percent level. Moreover, the incidence of diarrhea in both intervention villages was lower than in any of the three control villages, in each year after the project interventions began.

Perhaps the most dramatic difference between the two areas was in the proportion of days on which the average child suffered from diarrhea. In the last two years

of the project, this number was nearly twice as high in the control area. The Mirzapur project reduced the prevalence of diarrhea in small children by almost half.

Analysis of diarrhea rates in subgroups within the intervention area suggested that they were lower among households within 25 meters of a handpump and among those using handpump water exclusively for all major domestic activities in the wet season. The rates were also lower among those disposing hygienically of the feces of children under three years of age.

In spite of the project's impact on diarrhea, no impact was detected on the nutritional status of small children in the intervention area. This may be because a child's growth catches up after faltering during episodes of diarrhea.

Finally, there is evidence that strongly suggests that the project interventions reduced the prevalence of *Ascaris* infection by more than one third.

1. Historical Antecedents

A century and a half ago, a scourge from Bangladesh first showed the industrializing societies of Europe and North America how important water supply and sanitation could be for human health. The first world pandemic of Asiatic cholera began in Bengal in 1817, and the disease reached Western Europe 14 years later, in 1831. From there it spread with terrifying speed, and it reached North America the following year. The dramatic and fatal impact of the disease inspired and assisted the research of William Farr and John Snow, the founders of epidemiology. They showed how water supplies could serve to spread or to control the disease and gave urgency to the campaigns of Edwin Chadwick to provide water, adequate in quantity and quality, to the populations of the growing cities of the time.

Chadwick first argued the need to integrate water supply improvements with sanitation. He also emphasized the economic benefits that their health impact could bestow, remarking "that the expense of public drainage, of supplies of water laid on in houses, and of means of improved cleansing would be a pecuniary gain, by diminishing the existing charges attendant on sickness and premature mortality" (Chadwick 1842).

Cholera and other diseases of poor sanitation are no longer a threat to Europe and North America, but Chadwick's words still have meaning for those who seek to promote water supplies and sanitation in the developing countries today. Indeed, the provision of adequate water supplies and excreta disposal has been acknowledged for more than a century as an essential public health measure with significant public health benefits.

Governments have rarely needed to stress the health benefits, as the political demand for water supplies and sanitation has usually been strong enough. However, with the increasing involvement of donor agencies in the developing world during the postwar years, concern has grown to measure these benefits, to justify and even to guide the allocation of resources to the sector. Funding bodies, eager to ensure that their projects were adequately evaluated, have often considered that a study of their impact on the health of the beneficiaries was a suitable tool for this purpose. The result has been a burgeoning literature on health impact studies. When Saunders and Warford (1976) surveyed that literature up to 1974, they found 28 studies, many conducted in the United States. Ten years later, Esrey and Habicht (1986) found 73, of which the vast majority were from developing countries.

Some of these studies were extremely expensive, and many produced disappointing results and sometimes failed to detect any health benefit at all. This has given

rise to a certain attitude of skepticism about the benefits of water supplies and about the degree to which such studies are of value. A panel of experts convened by the World Bank in 1975 concluded that "long-term longitudinal studies of large size and expense are probably the only means through which there is a chance of isolating a specific quantitative relationship between water supply and health," and recommended that the Bank not undertake such studies (World Bank 1976). Others have gone so far as to say that the evidence of such studies "suggests that there is a very tenuous link between improvements in health and investments in water supply and sanitation services" (Churchill et al. 1987).

Erratic evidence of a link, however, ·lc   necessarily mean that it is tenuous. It may be firm but complex and ill-understood.   even significant phenomena can be difficult to detect with inadequate instruments. Awareness has grown, on the one hand, of the different ways in which water supply and sanitation may affect health and, on the other, of the difficulties in measuring health impacts and of how these difficulties can be overcome. The two issues are discussed in turn.

Health impacts of water supply and sanitation

The first step toward a better understanding of how water supplies can improve a population's health came with the development of the Bradley classification of water-related diseases (see Box 1.1).

Of the diseases that better water supplies may help to control, the feco-oral infections are of greatest worldwide public health importance. These infections can be transmitted by any means through which fecal material from one person enters the mouth of another. The group includes not only the notorious scourges of cholera and typhoid, but also the diarrheal diseases caused by many less well-known microorganisms. This latter group of diseases is common among poor communities, particularly among young children. It has been estimated (Snyder and Merson 1982) that each year these diseases cause more than 5 million deaths among children under five years of age in the developing world. They also contribute to widespread malnutrition and place a heavy burden on health services. Although adults suffer from them less frequently, diarrheal diseases can remain an important cause of mortality well into adult life (Gordon et al. 1964).

Although it has long been known that feco-oral infections can be transmitted by the waterborne route, particularly in epidemics, they can also be transmitted by contaminated food, utensils, hands (Khan 1982), and even clothes (Stanton and Clemens 1986). In other words, they can be transmitted by a variety of routes that are facilitated under conditions of poor domestic hygiene. Although waterborne transmission can be prevented by improved water quality, these other routes are more likely to be controlled by better access to water in quantity, and are therefore water-washed. It appears that, in

Box 1.1 The Bradley Classification of Water-Related Diseases

Medical workers usually classify infectious diseases by the type of organism which causes them: viruses, bacteria, protozoa, and so on. The insight of Bradley (1974) was to group the many water-related infections in terms of their transmission route. Since the impact of water supply improvements on a disease depends on its transmission route, water supplies can be expected to affect the diseases in a given group in a similar way. The four main water-related transmission routes are described in the table below.

Feachem (1977) pointed out that this is a grouping of transmission routes, not diseases, because the feco-oral infections can be both water-borne and water-washed. He therefore suggested a slight rearrangement, as shown in the right-hand columns of the table, to produce the classification of all the water-related diseases into four groups.

Water-based diseases are not a major health problem in Bangladesh, and although insect vector diseases exist there, they are not likely to be much affected by water supply.

Transmission route	Description	Disease group	Examples
1. Water-borne	Transmission by consumption of contaminated water	Feco-oral (water-borne or water-washed)	Diarrheal diseases Dysentery Typhoid
2. Water-washed	Person-to-person transmission due to lack of water for personal and domestic cleanliness	Skin and eye infections (Purely water-washed)	Trachoma Scabies
3. Water-based	Transmission via an intermediate host (e.g., a snail) which lives in water	Water-based	Schistosomiasis
4. Water-related insect vector	Transmission by insects which breed in water or bite near water	Water-related insect vector	Malaria Filariasis

many settings, most of the endemic transmission of diarrheal disease is not waterborne but water-washed. Indeed, in most of the health impact studies in which a significant reduction in diarrheal disease was detected, there had been improved access to water in quantity (Esrey and Habicht 1986). In many of the studies that failed to detect an impact, only the water quality had improved.

It has also been suggested that the availability of clean water on its own may not be sufficient to bring about health benefits unless it is accompanied by other interventions to improve the way in which it is used, and the environment in which that use takes place (WHO 1981). A more significant health impact might be expected to stem from a program in which water supply is combined with health education to ensure that the available water is fully used for hygienic purposes, and with improved excreta disposal to minimize fecal contamination of the domestic environment. Few health impact studies have dealt with integrated interventions of this kind.

Methodological problems

Many health impact studies have been conducted by engineers and other professionals unschooled in epidemiology who have ventured unprepared into what experts agree is one of the most difficult areas of epidemiological research. It is hardly surprising that they have made frequent mistakes.

The ideal study design to measure the health impact of an intervention is the randomized, controlled trial in which the measure under study is administered to one randomly selected group of people and withheld from another. Preferably, neither the subjects nor those who investigate the effect of the measure on their health know who is in which group. Clearly, such an approach is impossible with water supply and sanitation. A water supply is inevitably made available either to a whole community or not at all, and the presence of a handpump or a latrine is obvious to all. There is a further complication with health education. A message successfully delivered to one community is likely to spill over into neighboring areas as the news spreads by example or by word of mouth.

Another problem arises from the infectious nature of diarrheal disease. It is hardly a coincidence if two children in adjacent households suffer from diarrhea; one is very likely to have caught it from the other. Thus, cases of diarrhea in a single community cannot be treated as independent events for the purpose of statistical analysis. Differing rates of disease incidence in two communities may have nothing to do with any material difference between them, but may simply be due to an epidemic that is sweeping through one community but has not yet reached the other. To take an extreme position, one might argue that a comparison between diarrhea rates in two villages is not between two populations, but a one-to-one comparison of two villages. Statistically, the sample size is unity, and no valid conclusion can be drawn from a difference between them.

A third difficulty arises from the many other variables on which diarrhea rates may depend. The incidence of diarrheal disease varies widely with age, socioeconomic status, season of the year, and other factors such as infant feeding practices. If any of these is associated with access to water supply or sanitation in the population studied, it will confound the study by causing a spurious relationship to appear between the environmental

intervention and the disease rate. For example, if a wealthy family is more likely than a poor one to own a latrine and is also likely to suffer less often from diarrhea, it will appear that latrines offer greater protection from disease than is really the case, unless the study includes control measures to prevent this confounding by wealth.

A shortcoming that is surprisingly common in studies of the health impact of water supplies and sanitation is the failure to record the degree to which the facilities are in use, although the literature abounds with cases in which water supplies have broken down and latrines are left unused, or they are employed for purposes other than defecation. Clearly, no health benefits can be expected in such circumstances. Other problems can arise from the difficulty in defining a case of diarrheal disease and from inaccurate responses by subjects who are asked to recall episodes of disease that may have occurred some time ago.

Avoiding all these pitfalls is far from easy and is certainly not cheap. In practice, logistical and financial constraints demand that some compromises be made. Given the vast number of difficulties in water and sanitation interventions and in their evaluation, it is hardly surprising that Blum and Feachem (1983) in their review of 53 health impact studies found none completely free of methodological shortcomings.

When are health impact studies worthwhile?

The negative conclusions of the World Bank expert panel, mentioned previously, did not rule out all studies of the health benefits of water and sanitation. They believed "that the Bank might undertake a few modest impact studies in which perhaps only one or two specific diseases might be closely followed.... A small number of projects could be selected, with reasonable geographical spread, in which base health data, and other economic, social and environmental data, could be obtained at the beginning of the project and be continuously monitored throughout its construction and operation" (World Bank 1976).

In recent years, improved understanding of the failings of previous studies has offered insight into how these failings can be avoided by appropriate study design. In 1983, the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B), hosted an international workshop on "measuring the health impact of water supply and sanitation programmes." The report from this meeting (Briscoe, Feachem, and Rahaman 1986) provided guidelines on how such studies could be designed in the future.

An important contribution of the workshop report was to analyze the conditions under which it would be worthwhile to carry out a health impact study, that is, when it would be a "useful," "sensible," and "feasible" undertaking. A study is "useful" when the information it yields will provide benefits to justify the costs. The information may contribute to the global store of knowledge upon which scientists and planners can draw,

or it may contribute information specific to the area, to be used directly by local planners in making decisions about investments or project design. A study may be considered "sensible" if it is reasonable to assume that a detectable health impact exists. This will often involve some compromise between the internal validity of the study--its capacity to discern a cause-and-effect relationship--and its external validity, which is the capacity to apply its findings to the community at large. Finally, it is necessary to ensure that a study, however useful and sensible, is also "feasible." For some types of study, and to investigate impacts on certain diseases (which may include diarrhea), it can be necessary to study quite unreasonably large numbers of people in order to demonstrate an impact statistically, even if its magnitude is considerable. The more common the disease, the smaller the number of people that must normally be included in the study sample, and hence the more feasible the study becomes. Another important criterion of feasibility, of course, is that the necessary epidemiological and statistical skills should be available to ensure that the study is designed and carried out so that it avoids the many possible pitfalls of such research.

Rationale of the Mirzapur study

This report describes the results of a study of the health impact of an integrated water supply, sanitation, and health education project implemented in Mirzapur, Bangladesh. The project was carried out by the ICDDR,B under contract to the UNDP-World Bank Interregional Handpump Project. It was financed by the Canadian International Development Agency (CIDA). Before describing the project in detail, it is appropriate to consider why the Bank and other agencies involved decided that the study would be useful, sensible, and feasible.

It was certainly considered to be *useful* because the information it would yield would have both global and local relevance. At the global level, there is still a need to clarify the many doubts that prevail about the health impacts of water supply. We have seen that in most of the studies that successfully detected a health impact, access to water in quantity had improved. However, a significant increase in household water consumption normally occurs only if the original water source was very far from most houses, or if the new supply provided water on the plot of each household. An important question, therefore, is whether health benefits are achievable in countries such as Bangladesh, where most households are within a few minutes' walk of a water source (however polluted), but where individual house connections are simply not affordable. It is also useful to examine the health benefits of a project in which water supply is combined with sanitation and health education.

At the local level, Bangladesh has one of the most ambitious and successful rural water supply programs in the world. More than half a million public tubewells are installed and functioning, and there are plans to increase this figure. By comparison, the rural sanitation program has achieved more limited coverage to date, having supplied latrine

components to some 360,000 households, or about 2.2 percent of the population. However, there is a growing recognition of the need to integrate sanitation with water supply and to promote the actual use of both. The government is currently developing a new approach, whereby the installation of tubewells will be linked with health and sanitation promotion (UNICEF 1987). Because this policy seeks to achieve the maximum health impact, it is worthwhile to investigate what that impact might be.

The Mirzapur study was also *sensible*, in that an impact was certainly expected. The level of handpump and sanitation provision in the study area was greater than that offered by the national program as a whole. So was the intensity of the health education component of the project. Because expected health benefits provide the principal rationale for the very large expenditures in the water and sanitation sector that are made in Bangladesh, failure to detect a health impact in Mirzapur would even put in question the soundness of that investment.

Care was taken to overcome the methodological problems discussed previously, which could limit the study's internal validity. Kirkwood and Morrow (1989) have pointed out that these beset any study of the impact of an intervention applied to a whole community, and they suggested four ways to mitigate them. These are:

- ▶ Study more than one intervention and one control community.
- ▶ Select communities that are initially similar.
- ▶ Analyze changes in outcome values following the intervention, rather than simply comparing postintervention values.
- ▶ Compare different subgroups within the community.

As far as logistically possible, all four methods were used in the Mirzapur study.

Although the study was carefully designed to have good internal validity, this has inevitably had some effect on its external validity. Thus, the finding of a health impact in Mirzapur does not imply that equal health benefits will stem from the lower service levels provided by the national programs in rural Bangladesh. However, some compromise on this issue is inevitable, as Briscoe, Feachem, and Rahaman (1986) pointed out. Moreover, the global implications of the study are not affected by the degree to which the Mirzapur interventions were typical of Bangladesh.

Finally, the fortunate conjuncture of several factors made the study *feasible*. A water supply project was already planned in the area, one that would field test and develop a new generation of handpump known as the Tara pump. There was sufficient time to obtain baseline data, and close monitoring would be an integral part of the project, so that the circumstances already met most of the criteria of feasibility set out by the expert panel of the World Bank (1976). The high incidence of diarrheal disease in Bangladesh and the large number of people to be served by the new handpumps meant that the project

was also epidemiologically feasible. Moreover, the presence of ICDDR,B in the country, one of the world's premier centers for research into diarrheal diseases, together with backstopping support from the London School of Hygiene and Tropical Medicine, meant that the necessary epidemiological and statistical skills were available.

2. The Project and its Setting

Bangladesh: floods, disease, and hunger

Bangladesh, to the east of the south Asian subcontinent, is the eighth most populous country of the world. Its 100 million inhabitants, mainly rural, live at a density of more than 700 persons per km^2 in the fertile delta of the Ganges and Brahmaputra rivers. These great watercourses merge and subdivide into a network of hundreds of branches that crisscross the country. Except for a few hilly areas near the borders, the country is flat and low lying, rarely more than 15 m above sea level. During the monsoon, the great rivers that pass through the country burst their banks. For some two months of each year, a third of the country is flooded to depths ranging from 30 cm to more than 2 m in a typical year, and occasionally to greater depths. In 1987, the floods were the worst in 40 years, and in 1988 they were even worse. One of the most remarkable facts of rural life in Bangladesh is how quickly it returns to normal after these annual inundations.

Economic and physical survival under such difficult conditions is helped because residents build their houses on raised mounds known as *baris*, normally 2.5-3 m above the surrounding fields. A typical *bari* is occupied by about half a dozen households. The village exists as a social unit rather than a spatial cluster of houses. Occupied *baris* are scattered about the cultivable land area of each village. There are usually shallow depressions near each *bari* from which the soil was taken to build it. These remain as pools after the flood waters have receded.

The country has a subtropical climate, with three main seasons. Winter, which begins in November and ends in February, is mild and dry, with temperatures from 7° C to 30° C. From March until mid-June, daytime temperatures can reach the high thirties Celsius, the humidity gradually increases, and rainstorms herald the monsoon. Eighty percent of the annual rainfall occurs during the monsoon, from mid-June until October, and humidity reaches 99 percent during this period. Mean annual rainfall in most of the country, including the Mirzapur area, is greater than 2,000 mm.

Though the land they farm is fertile, most rural people in Bangladesh are very poor. A recent World Bank report (World Bank 1987) defined the poor as those unable to meet their minimum energy needs through an average daily per capita food intake of 2,122 calories and 48 gm of protein. Those who cannot even afford 85 percent of this calorie intake level were classified as "hard-core" poor. It was found that in 1982, the poor made up 72 percent of the population, and the portion of hard-core poor had increased

from 43 percent in 1974 to 50 percent in 1982. The 1981-82 Nutrition Survey of Rural Bangladesh found that intake of calories, protein, and fat (essential for the absorption of vitamins) had decreased by more than 10 percent during the previous two decades, and that women and children received a less adequate diet than did men (University of Dhaka 1983).

Malnutrition is an associated contributing factor in most child deaths in Bangladesh, where the infant mortality rate, at 125 per thousand live births, is among the highest in the world. In children from one month to five years of age, diarrheal disease is among the three most common causes of death, accounting for 29 percent of all deaths of children under age five (Government of Bangladesh 1983). Severely malnourished children in Bangladesh have been found to be four times more likely to die of diarrheal disease than those with an adequate nutritional status (Chen, Chowdhury, and Huffman 1980). However, it is not only children who die of diarrhea in Bangladesh. Diarrheal diseases also account for approximately one in five deaths in all age groups over five years (Shaikh et al. 1984).

Among those who survive, the effects of poor diet and frequent diarrhea are compounded by intestinal parasite infections. A study by ICDDR,B found hookworm in 44 percent and *Ascaris* in 85 percent of patients at a rural diarrhea clinic (Hussain, Glass, and Black 1981). The effects of this burden on child development are serious. Sixty percent of children under age five suffer from moderate to severe malnutrition, in that they weigh less than 75 percent of normal weight for their age. This proportion increases slightly during the monsoon, when the floods have begun but the largest of the three annual crops has not been harvested (UNICEF 1987).

Water supply in Bangladesh

Bangladesh has a very successful rural water supply program based on locally made handpumps. These are installed on tubewells sunk using the ingenious "sludger" method. The great advantage of this method is that no sophisticated equipment or machinery is needed. At Independence in 1971, about 150,000 of these handpumps were installed for public use. By 1988, there were more than 700,000, and an additional 600,000 had been installed by individual households for their private use. Thus, there was one public handpump available for every 125 rural inhabitants. Eighty percent of these pumps were functioning. More than 82 percent of rural villagers say that they use tubewell water for drinking, and two thirds of these villagers draw it from a public pump. However, only 12 percent use it for all their domestic needs, which means that the vast majority still use surface sources--which are fecally contaminated (UNICEF 1987)--for other purposes. These other purposes include washing utensils and clothes, and bathing. Bathing in Bangladesh is usually accompanied by washing out the mouth, so that some of the bathing water is likely to be ingested in the process.

The Mirzapur project

The type of handpump commonly used in Bangladesh is not capable of drawing water from a depth greater than about 8 m. The progressive lowering of the groundwater table, caused by the heavy use of groundwater for irrigation, is making it impossible to use this type of pump in an increasing proportion of the country. Thus, the need arose to design and develop a new pump that could be used to draw water from greater depths, but one that would still be inexpensive, reliable, and easy for local people to maintain without special tools. By 1983, a suitable candidate was under development at the Mirpur Agricultural Workshop and Training School with assistance from UNICEF and the World Bank. It is known as the Tara pump (see Box 2.1). A site with an appropriately deep water table was selected to test its performance and develop its design in the field, located in the Mirzapur area some 60 km to the north of Dhaka (Fig. 2.1). The results of the handpump testing and development work are reported elsewhere (Kjellerup, Journey, and Minnatullah 1989).

It was also hoped to test an experimental design of a pour-flush latrine, and to develop and assess the efficacy of hygiene education methods to improve local practices regarding water use, latrine use, and personal hygiene practices. These practices would be regularly monitored during the project, as would the performance of the handpumps and latrines. For the reasons given in section 1, it was decided that the project should include a study to measure the health impact of the package of interventions. In particular, the study sought to measure the impact on the occurrence of diarrheal diseases and of intestinal worm infections, and on nutritional status in children under five years of age.

A quasi-experimental design was adopted for the health impact study, in which two areas were followed up over a period of four years. Data collection began in 1984, prior to any intervention. It continued throughout project implementation and ended in December 1987, 18 months after all the handpumps and latrines were installed. One area of two villages (the intervention area) received the water supply, sanitation, and hygiene education package, while the three villages in the other area (the control area) received no such intervention. However, the residents in both areas were offered free treatment for diarrhea through the project. The two areas are approximately 5 km apart. Both lie on the main road running north from Dhaka through Mirzapur town to Tangail. About midway between them is the only major hospital in the area, Kumudini Hospital, which is run by a charitable trust. It includes a diarrhea treatment center operated in collaboration with ICDDR,B. A field laboratory was set up at the hospital for the microbiological aspects of the study.

Efforts were made to involve the community as much as possible in planning the operation and maintenance of the handpumps and latrines. Adult men and women

Box 2.1 Brief Description of the Tara Handpump

1. The Tara is a low-lift, direct action handpump, which the Government of Bangladesh has now adopted as the standard handpump for installation in areas of the country where the depth of the water table exceeds the suction limit (about 7.5 m) but is less than 12 m. The design of the pump has been developing since the first prototypes were produced in November 1982. Much of that development has been guided by monitoring the pump's performance in the Mirzapur handpump project.

2. The need for a "deep-set" handpump in Bangladesh became apparent at the beginning of the 1980s. The Department of Public Health Engineering (DPHE) rural water supply program, assisted by UNICEF, was by then gathering momentum, and large numbers of rural people were gaining access to safe drinking water through economic installations of the Bangladesh New No. 6 handpump on tubewells sunk by the indigenous manual technique (the sludger method). However, falling water tables over much of rural Bangladesh meant that suction handpumps such as the New No. 6 were not the right answer for an increasing area of the country. More and more pumps were becoming inactive during the dry season, as the groundwater fell below the suction limit.

3. To help DPHE develop a suitable pump for the deep-set areas, a design team was put together in 1981. Members of the team were drawn from DPHE, the Mirpur Agricultural Workshop Training School (MAWTS), the UNDP-World Bank Handpump Testing Project, and UNICEF. At a later stage, the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B) assisted with the field testing. Recognizing that existing designs of force mode handpumps were expensive and difficult to maintain, the design team set some key objectives for the Tara (Bengali for "star"):

    ► A high discharge capacity up to 15 m lift (recognized to be the maximum practical limit for a direct action handpump).

    ► Good user acceptance, indicated by consistent use, positive feedback, few complaints, and negligible vandalism.

    ► Capital costs of about $2-3 per user and recurrent costs in the range of $0.05-0.10 per user.

    ► Easy serviceability, good maintainability, maximum availability for use, minimum down time: easy repair without tools by minimally trained members of the user group. Maximum user group of 75 persons (the national target for service level in Bangladesh is 65 persons per pump).

    ► Manufactured from locally available materials, using skills and tooling available in Bangladesh, with spare parts that could be made in rural workshops.

    ► Compatibility with the indigenous manual well construction technique

Box 2.1 (*continued*)

4. The direct action design was chosen because of its inherent simplicity, the potential for using lightweight and easily obtainable materials, and the comparative ease of access to wearing parts for maintenance purposes. The design includes both the pumping module and the tubewell module, because the well casing also acts as the pump's rising main.

5. The first prototype Taras were produced in November 1982. Since then, the design has evolved as a result of performance testing and user reactions, including the monitoring of 148 pumps under closely controlled conditions in the Mirzapur Field Study. A complete record of the Tara development, and of the pump's achievement of the objectives set for it, is thus available. In fact, it is fair to say that the Tara has proved a popular pump with the users. It is economic to install and to maintain, it is readily serviceable by minimally trained women caretakers, and the Mirzapur pumps have been out of service an average of no more than a few hours in a full year. All the evidence suggests that the pump will be suitable for pumping lifts up to 15 m, which means that it is appropriate even for the problem areas of Bangladesh where the water table continues to fall.

6. The design team is continuing to investigate potential modifications to improve different aspects of the Tara design. It has now established a standard design, however, which is being adopted throughout the deep-set areas of Bangladesh. A production manual has been published, making the design freely available. UNICEF has also introduced prequalification procedures, by which manufacturers can establish their capacity to compete for orders to supply Tara pumps for a continuing program.

7. The well and pump system consists mainly of locally extruded standard uPVC pipes of 2 inch, 1-1/2 inch, and 1-1/4 inch diameters with a locally made, continuously slotted uPVC screen (known as the RoBo screen and developed by World Bank consultants in 1976). The pump head and handle assemblies are made from standard 2-1/2 inch, 2 inch, and 3/4 inch nominal diameter steel pipes, which are hot dip galvanized after welding. Metal threaded fasteners are used for top and bottom connectors and small manually injection molded plastic components for the piston and footvalve assemblies. Only basic fabrication processes are used, making the pump suitable for manufacture in most developing countries. Frequently replaced parts such as valves and seals are inexpensive and simple to make.

8. At the end of 1987, the cost of the pump module in Bangladesh, including pumprod pipes, cylinder module, and pump head assembly, was T 2,000 ($60). Upper well casing for a 15 m cylinder setting, lower well casing to 50 m, and a $3m^2$ concrete platform make the total capital cost of the installation $200.
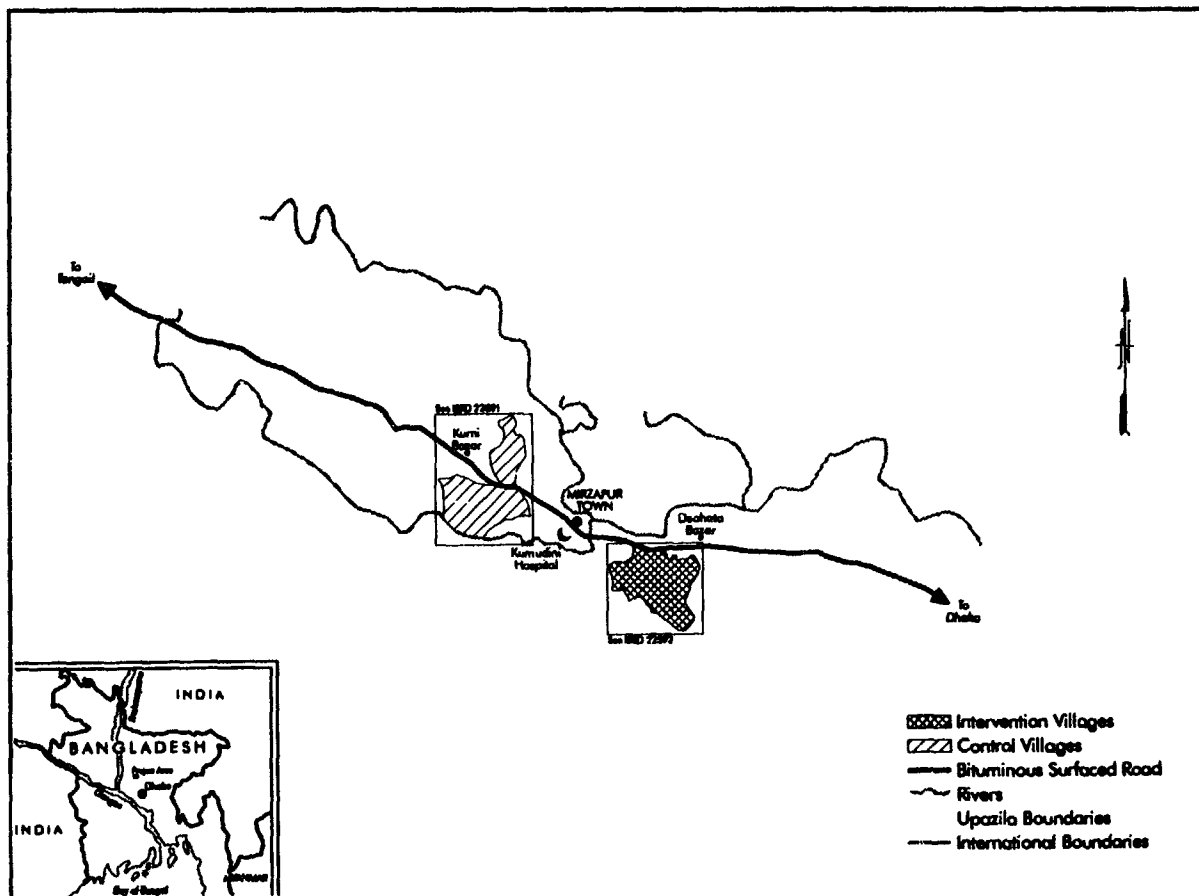
Figure 2.1. Location of study sites

were motivated to participate in various project activities. Both men and women were involved in selecting sites for the handpumps. Women participated in curing the cement of newly constructed handpump platforms, and some of them were trained to maintain the pumps. Women also participated in choosing where latrines were to be built--particularly the construction of the superstructure--as well as in installing them and maintaining them. Women were the chief targets of the hygiene education program, and they agreed to attend the various meetings and training sessions organized for this purpose. Essential to the high level of participation by women in the project was the agreement of the men, who had been informed about the project and were involved in it from the outset.

Baseline data

The main demographic and social characteristics of the intervention and control areas, taken from the baseline census conducted in January 1984, are presented in Table 2.1. The populations of the two areas were broadly similar with respect to age distribution and household size, although there were differences in religion, education, and

Table 2.1
Characteristics of the Study Population, 1984

		Intervention	Control
Number of households		799	713
Number of people		4,856	4,524
Mean household size		6.1	6.3
(standard error of mean)		(0.1)	(0.1)
Percent of household	< 1 year	4	4
	1-4 years	10	10
	5-14 years	28	27
	15-44 years	43	43
	45+ years	16	16
Percent of households with at least 1 child < 5 years		56	60
Percent of households headed by women		6	4
Percent Muslim households		70	84
Percent adults (>15 years) with no education:	males	58	41
	females	83	72
Percent of household heads with occupation:			
Farmer on own land		34	44
Farm worker/sharecropper		10	8
Unskilled laborer		10	15
Business, with capital		12	10
Skilled laborer		8	5
Fisherman		5	0
Service, teachers		3	7
Others		18	10

occupation. There was a larger Hindu minority and a greater number of persons with no land or formal education in the intervention area. Some of these differences are highly significant. However, they do not invalidate the health impact evaluation because the health variables under study were also compared before the intervention was made.

Moreover, the greater proportion of uneducated and landless persons in the intervention area would be expected, a priori, to suffer a higher diarrhea incidence than those in the control area.
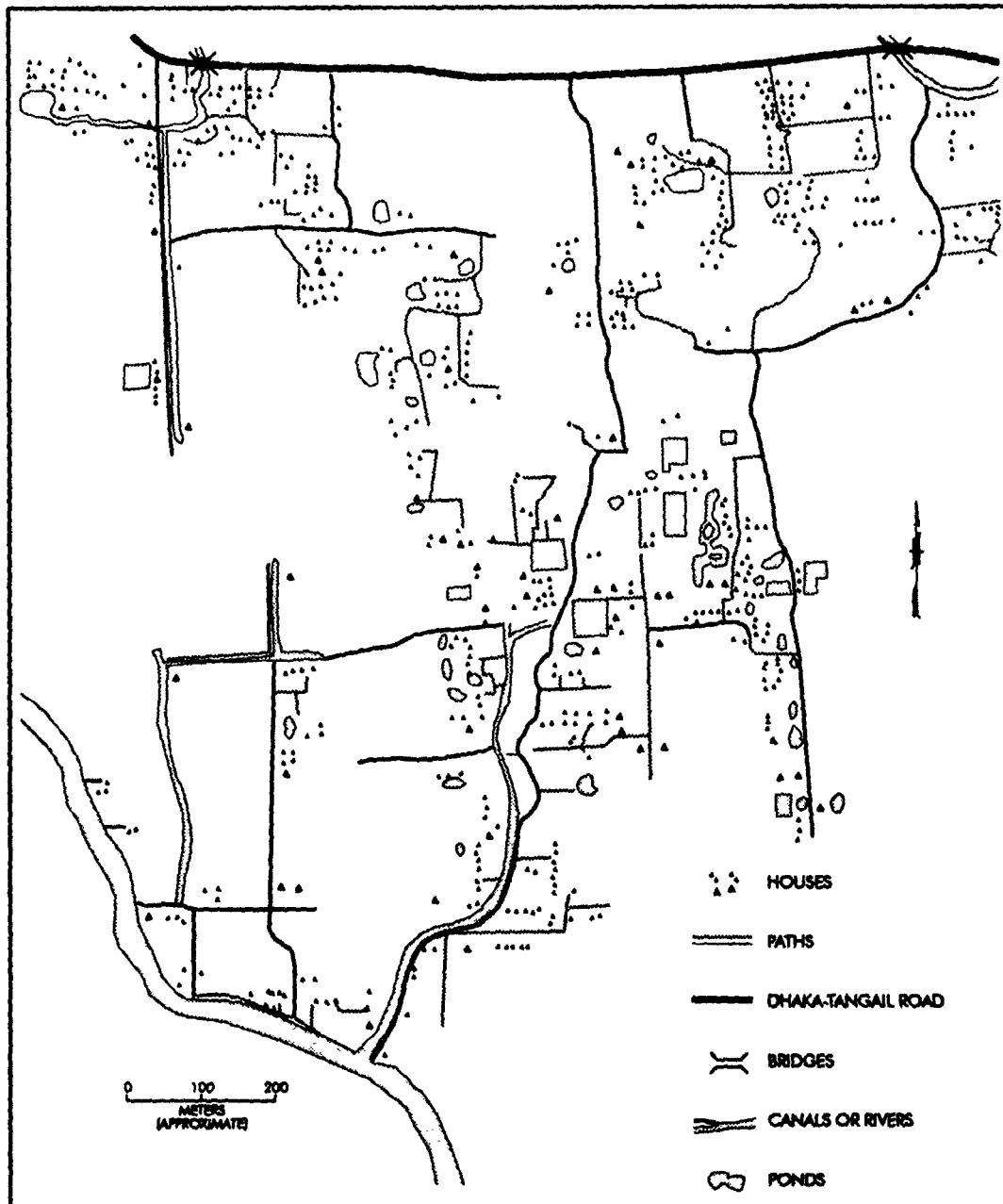
Figure 2.2. Sketch map of intervention area

HOUSES

PATHS

DHAKA-TANGAIL ROAD

CANALS OR RIVERS

PONDS

0   100   200
METERS
(APPROXIMATE)
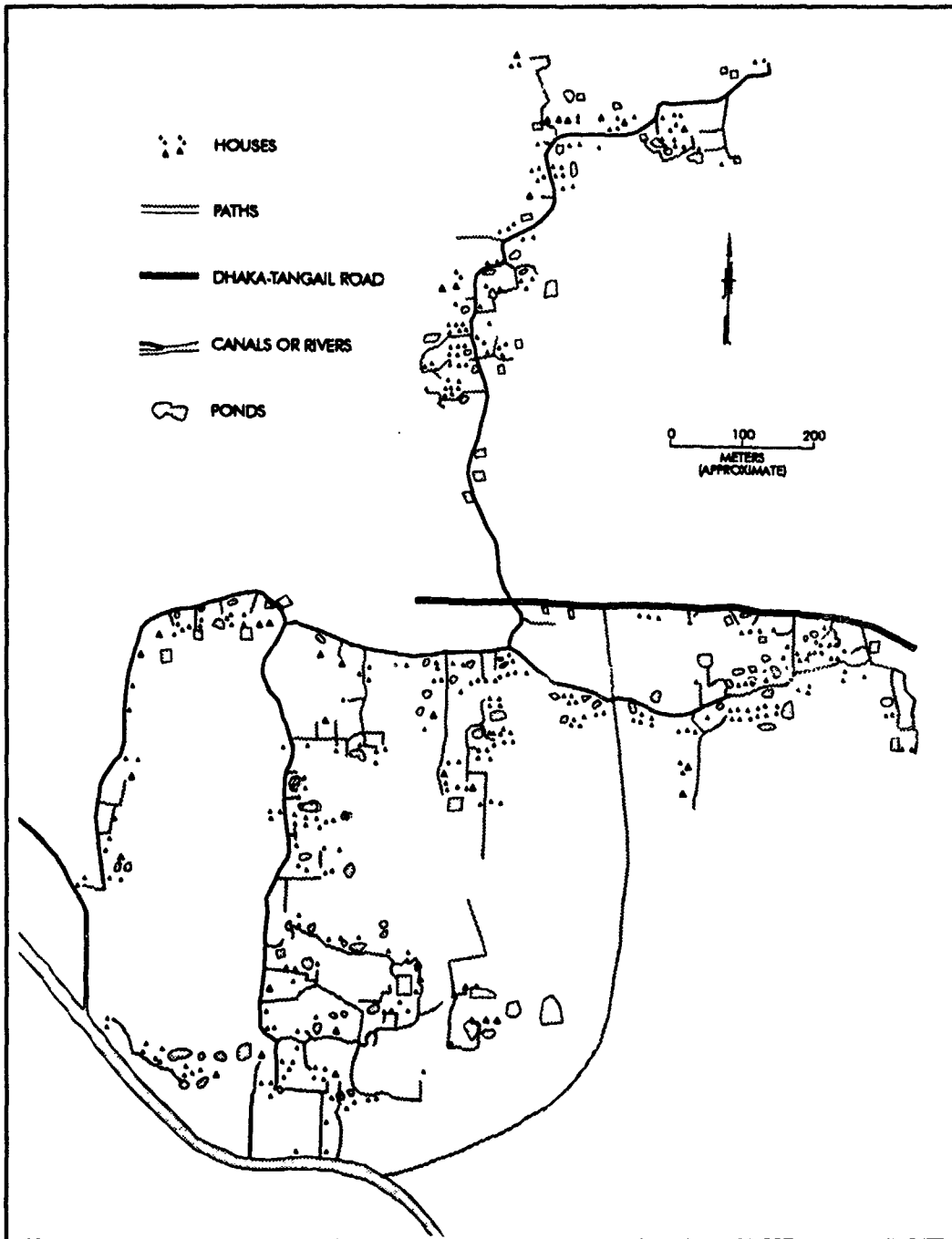
Figure 2.3. Sketch map of control area

Water sources

The maps of the two areas (Figs. 2.2 and 2.3) show that even in the dry season, most households were no more than 100 m from a body of surface water, many of which were used for bathing and other purposes. In the wet season, rainwater was also collected and used from small, temporary bodies of surface water. Some households also had a well in their yard, usually lined with precast concrete rings. Water was drawn from these wells by bucket.

In addition, both areas already had tubewells fitted with handpumps of the Bangladesh No. 6 design. At the time of the baseline survey, there were 34 such pumps scattered throughout the intervention area and 44 in the control area. Some of these had been installed as part of the government's rural water supply program; others had been installed by individual households at their own expense, although this did not necessarily mean that neighbors were prevented from using them. Overall, there was one handpump for every 143 persons in the intervention area, and one for every 103 persons in the control area.

During the dry season, when the groundwater table falls, some of these pumps are unable to draw water for a few weeks. Moreover, monitoring surveys conducted during the project indicated that on average about 20 percent of the pumps in the control area were not working at any given time, a figure that agrees with the results of national surveys conducted by UNICEF. However, the fact that a handpump was not working did not necessarily mean its users frequented a different type of source: there was usually another handpump available nearby.

At the time of the baseline survey, domestic water consumption in the study areas followed a complex pattern in which the various available sources of water (handpumps, wells, rainwater, and surface water) were used for different purposes. Figure 2.4 shows the responses of households in the two areas when asked which source they used for each purpose. The majority of households used tubewell water for drinking, but this source was less popular for other purposes, particularly bathing, where quality is considered less important. The convenience and (for the Hindu minority) the ritual significance of surface water made it the most commonly used source in the dry ﹏ ﹋n. In the wet season, the use of tubewell water for drinking declined slightly because of the greater availability of well water. For other purposes, rainwater became an important source in the wet season and replaced the other types in many households.

A striking difference between the intervention and control areas was the greater use of surface water for washing and bathing in the intervention area. This was observed in both wet and dry seasons and was probably attributable to the larger Hindu minority in the intervention area. However, this does not invalidate the health impact study, because

the project successfully reversed this difference through health education and the provision of more handpumps.

The project interventions sought to promote the use of handpump water for all domestic purposes. However, this was the practice of only a small minority of households at the start, as shown in Table 2.2.
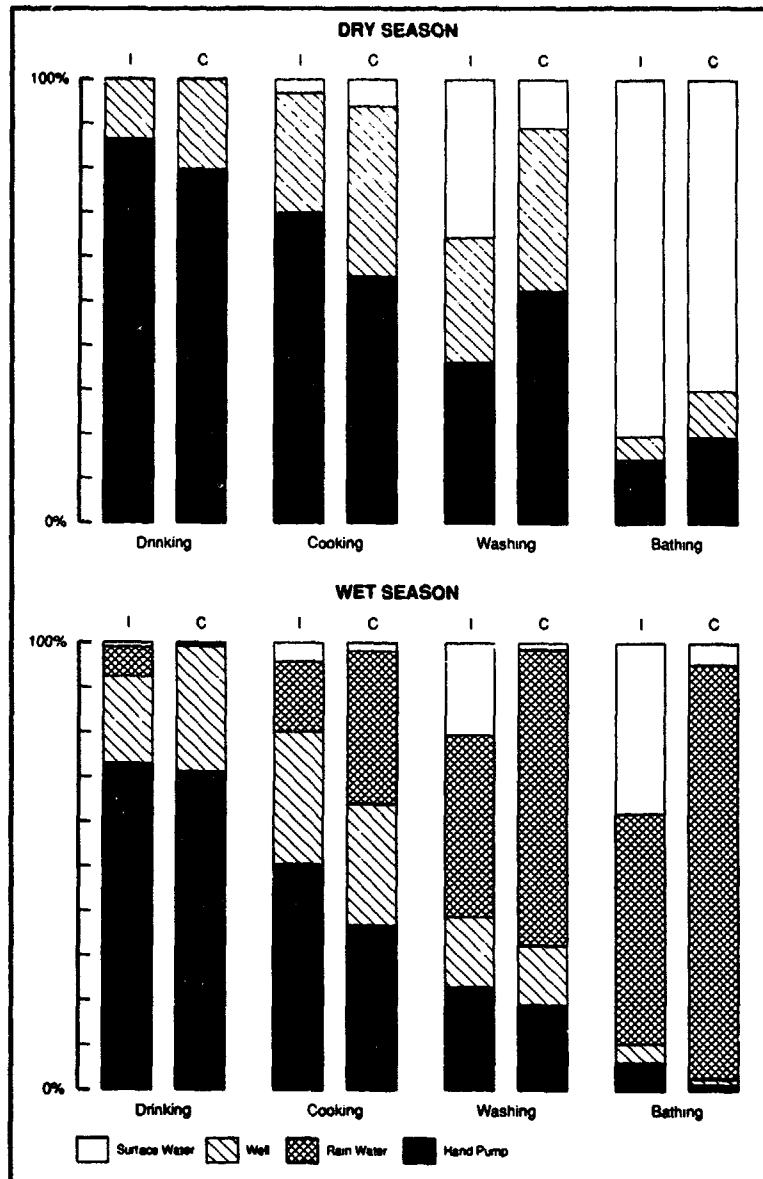
Figure 2.4. Proportions of households in intervention area (I) and control area (C) using various types of water source for different purposes in dry and wet seasons, at time of baseline survey

Table 2.2
Percentage of Households Using Tubewell Water
for All Domestic Purposes
(Baseline Survey, January 1984)

	Intervention area	Control area
Dry season	8	12
Wet season	3	1

Excreta disposal

Most households had access to a rudimentary excreta disposal facility, known as a "kacha latrine" or sometimes as a "fixed place." This consisted, typically, of a raised platform at the edge of the *bari*, surrounded by screening of some kind for privacy. The user squatted on the platform, which often consisted of little more than a few bamboo poles, and excreta fell through the platform onto the ground beneath. The potential for fecal pollution of nearby surface water was, of course, considerable. Only 1 percent of households had a "pucca" latrine, with a covered pit and a floor slab of permanent materials.

Although kacha latrines were widely available, they were not always used, particularly by males, most of whom defecated in fields or bushes (Fig. 2.5). The insubstantial and unsteady nature of most of the kacha latrine platforms, usually poised over a precipitous slope, was probably a deterrent to their use by small children, half of whom defecated around the home. The chief users of kacha latrines were women, who valued them for their privacy and their convenient location close to the home.
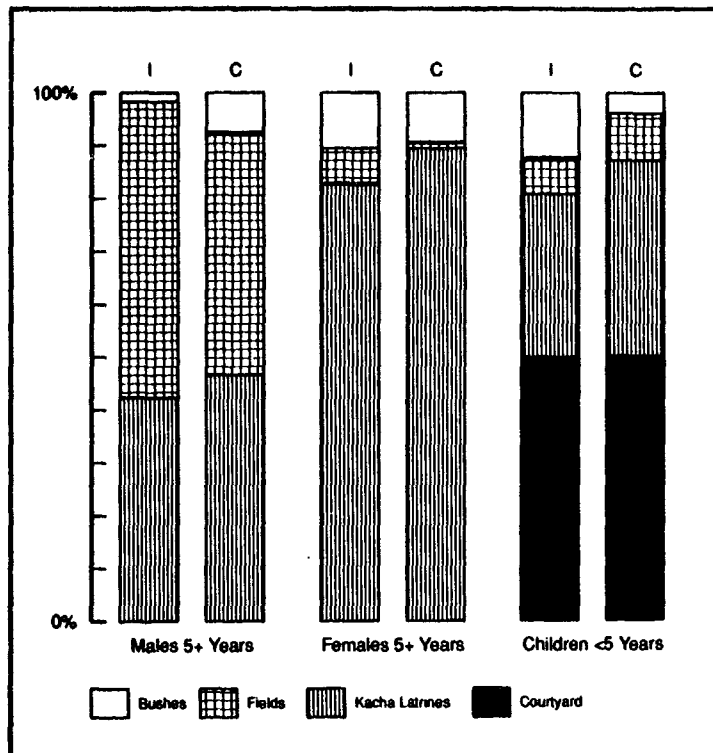
Figure 2.5. Proportion of households in intervention area (I) and control area (C) reporting different defecation sites for men, women and children under 5 years, at baseline (January 1984)

3. The Interventions

The package of sanitary measures implemented in the intervention area consisted of three principal components. First, 148 Tara handpumps were installed. Second, "pucca" latrines were provided for every household, a total of 754 latrines. Third, an intensive program of hygiene education was carried out. These components are described below.

Handpumps

The project team made a preliminary selection of pump locations in approximately March 1984. A sketch map of the intervention area (Fig. 2.2) was divided into 128 groups of households appropriately located to be served by a single pump, bearing in mind the locations of existing No. 6 pumps and the results of the baseline water and sanitation survey. The size of user groups varied widely, depending on the density of housing in each area.

The exact location of the pump within the selected user group was discussed and agreed on by the users. In practice, it was determined by the following parameters:

▶ The spatial arrangement of the households (orientation, availability of space for the platform, elevation above mean flood level, feasibility of adequate drainage, accessibility, privacy)

▶ The presence of a tree beside the pump location (to support the pump rods during retrieval for routine maintenance, and also to provide shade for users)

The tubewells were drilled, concrete platforms constructed, and pumps installed between July and November 1984. Twenty additional pumps were installed in November 1986. The cumulative progress of pump installation is shown in Figure 3.1.

In practice, some households chose to use a pump other than the one originally intended for them, particularly in the larger user groups. Table 3.1 shows the distribution of actual user group sizes. Two thirds of the pumps (65 percent) served only 35 persons (about six households) or fewer. On average, there was one Tara pump for every 33 inhabitants, and 80 percent of the households were within 100 m of a Tara pump. In addition, the existing No. 6 pumps continued to function, and the project made efforts to maintain them.
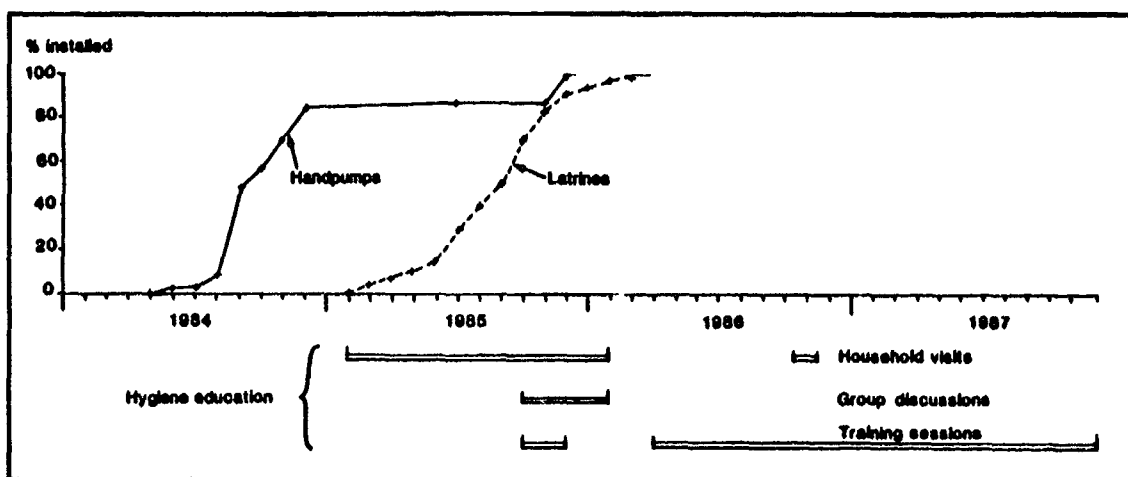
Figure 3.1. Progressive installation of handpumps (n = 148) and latrines (n = 754), and the phasing of the hygiene education interventions

Table 3.1
Sizes of Tara Pump User Groups

Number of Users	Percentage of Pumps (N = 146)
< 20	29
21-35	36
36-50	24
50+	11

However, even with this maintenance, the old pumps cannot have achieved the very high reliability of the Tara pumps. Because one project objective was to study the performance and perfect the design of the new pumps, an intensive monitoring program was carried out, and breakdowns were normally repaired on the same day. Thus, no more than one or two of them are likely to have been inactive at any time (Kjellerup, Journey, and Minnatullah 1989).
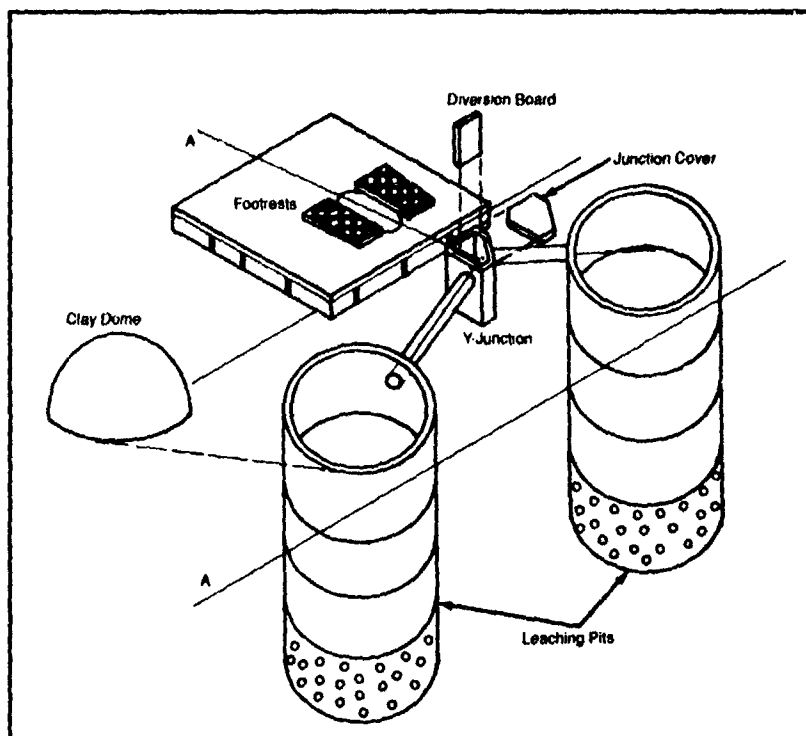
Figure 3.2. Design of double-pit water-seal latrine used in the Mirzapur project: isometric view

Latrines

In addition to serving as a field laboratory for testing and developing the new Tara handpump, the Mirzapur project was also a proving ground for a latrine design that had not then been widely used in Bangladesh. Most of the sanitary latrines in the country are of the pour-flush, water-seal type with a single pit, usually lined with concrete rings. A problem has been the unsanitary manner in which the pit is emptied when it fills up. In the Mirzapur project, however, two pits were installed so that they could be used alternately. The intention was that the second pit would remain in use long enough to permit sludge decomposition and pathogen destruction in the first pit and minimize the health hazard in emptying and disposing of the pit contents.

The latrine design used in Mirzapur is shown in detail in Figures 3.2-3.4. A concrete plate was inserted in the junction box to seal off the pit not in use. The pits were lined with concrete rings of a type readily available from the government sanitation centers, and they were covered with a burnt clay bowl known locally as a *chari*, which is upturned to form a dome. The volume of each pit was approximately 0.64 m³.

The site for installation of each latrine was chosen with the following criteria in view:

- ▶ To be as near as possible to the household dwelling
- ▶ To be as far as possible from any handpump or other potable water source
- ▶ To be above the monsoon flood level
- ▶ To be built on firm soil
- ▶ To be acceptable to the users
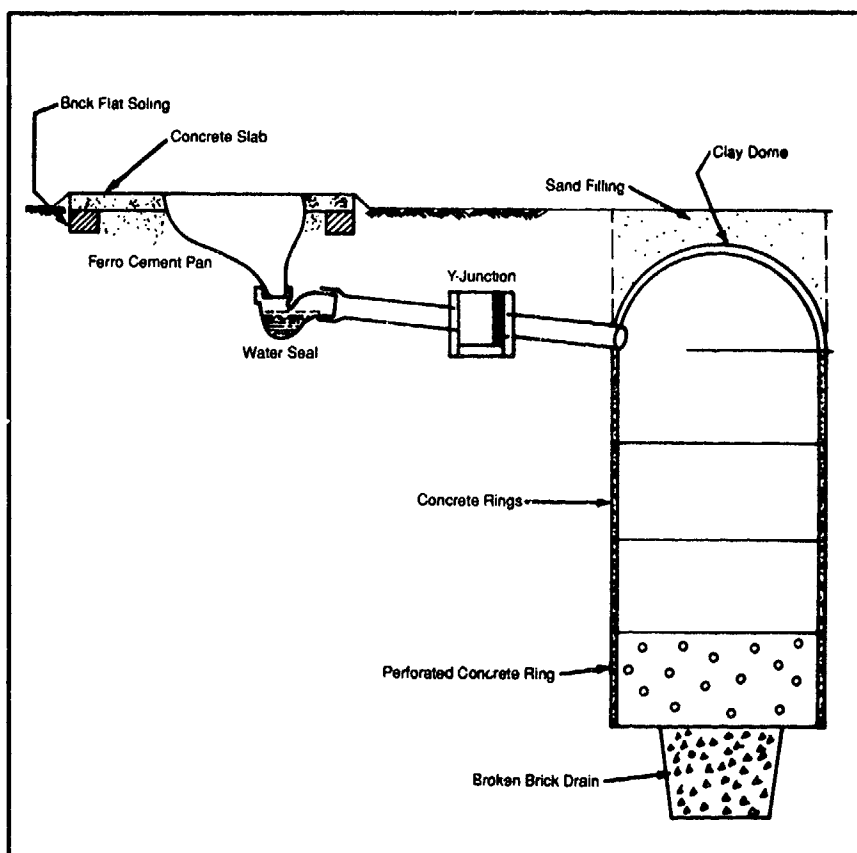
Figure 3.3. Latrine design - Section A - A

Households were consulted about site selection, and the criteria were explained to them. There was initial resistance to the first criterion because the traditional practice was to build a latrine some distance away to minimize the odor problem. In practice, the median distance from the dwelling to the new latrine was 14 m.

Because of space limitations, roughly 10 percent of the latrines were within 10 m of the nearest tubewell. However, bacteriological examination of water samples from 24 of the affected tubewells showed they did not contain significantly more fecal bacteria

than water from other tubewells where there was no possibility of groundwater contamination.

It was originally planned to provide latrines at a subsidized rate, but not free of charge. Households were initially asked to contribute T 300, approximately 30 percent of the cost of a latrine. After some persuasion, a few relatively wealthy families agreed to buy latrines, and these served as demonstration latrines to encourage other households to invest. However, progress in obtaining contributions was slow. There were grounds for concern that too few latrines would be installed for any health impact to be detectable. In mid-1985, therefore, the decision was made to install latrines regardless of the contribution offered, so that reasonably complete coverage could be achieved during the study period. In the end, from the 754 households that received latrines, 409 (54 percent) had contributed some money, although the median contribution was only T 10 per latrine. Only 2.5 percent of the households paid the full amount. Fortunately, those who had contributed expressed no grievance at the fact that noncontributors had also benefitted.

The cumulative progress of latrine construction is shown in Figure 3.1. In all, 754 households had been provided with latrines by March 1986. It can be seen that latrine construction came roughly one year after the installation of most of the handpumps.

The project built only the parts of the latrine shown in Figure 3.2. The households were given the responsibility of building the superstructure themselves. The households built 472 superstructures (on 63 percent of latrines). The remainder of the households took more than about three months to build a superstructure; meanwhile, they were not using their latrine. The project staff then provided free labor to build a superstructure, as long as the household provided materials. Because the laborers engaged for this purpose also belonged to the community, they motivated the household to do this. In this way, 720 latrines were eventually completed, 85 percent of them within 6 months of construction of the floor and the pits. Complete latrines were provided for 90 percent of the 799 households in the intervention area.

Hygiene education

This intervention, similar to the installation of handpumps and sanitary latrines, was undertaken only in the intervention area. It had the following aims:

- ► To promote the exclusive use of handpump water for all personal and domestic purposes
- ► To increase the per capita consumption of handpump water
- ► To encourage hygienic storage and use of handpump water
- ► To ensure the acceptance, use, cleanliness, and maintenance of water-sealed latrines

► To promote the disposal of feces of small children in the water-sealed latrines
► To impart knowledge and awareness about the need for improving personal hygiene
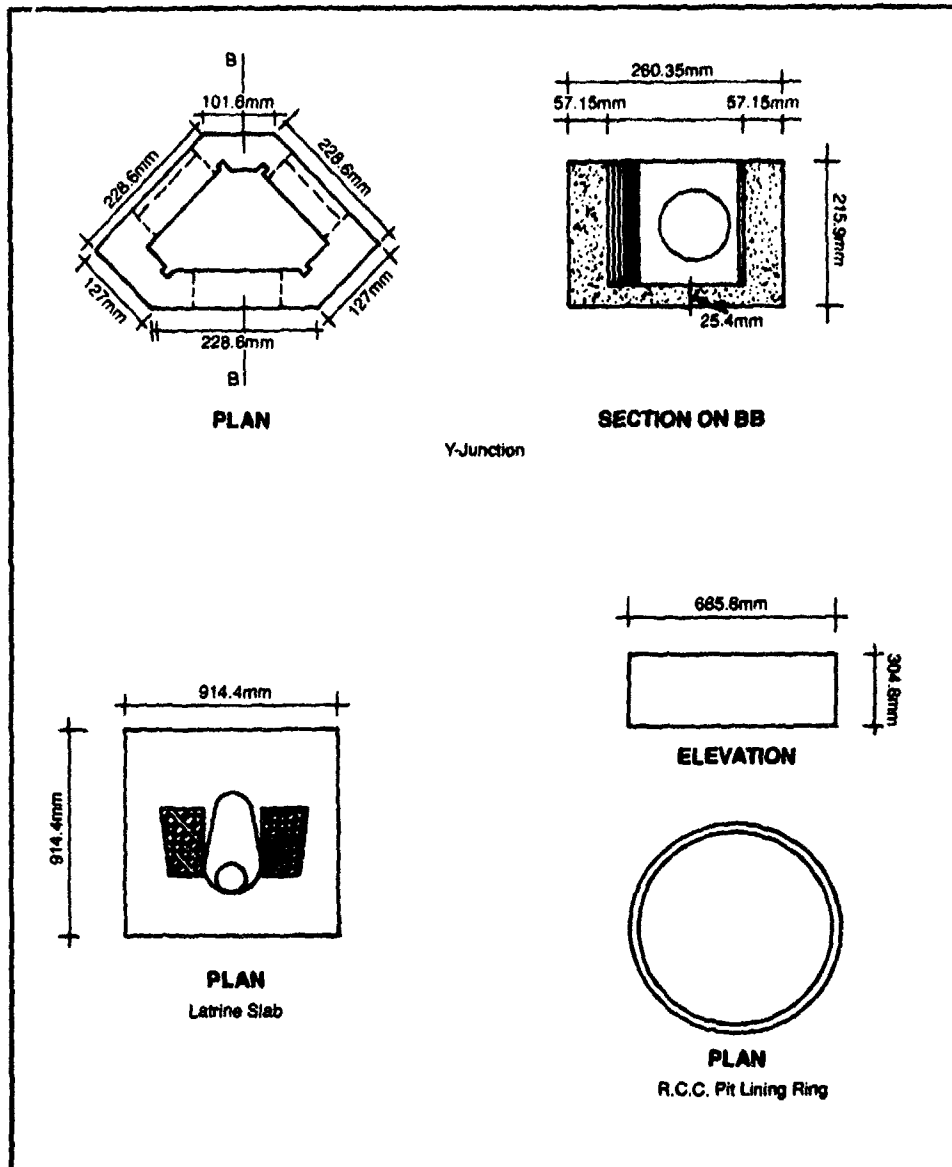
Figure 3.4. Latrine design - details of components

With these aims in view, nine key messages were developed and tested in a place outside the Mirzapur project area. They are listed in Box 3.1. The first five messages relate to the use of handpump water, and the remainder pertain to the use and maintenance of the water-sealed latrines.

Box 3.1 Hygiene Education Messages

Water

1. Use only handpump water for all personal and domestic purposes.

2. Wash vegetables and fruit before cooking or eating them, and bathe directly at the handpump site.

3. After washing pots and pans, plates, glasses, and spoons with adequate amounts of handpump water, store them on a platform.

4. When water is collected, the fetching pitcher and other containers should be washed well at the handpump site. Always keep the collected water covered. Keep the container of drinking water on a platform.

5. Wash hands well with handpump water before eating or serving food to others.

Sanitation

6. The use of sanitary latrines is one of the important ways of preventing the spread of diarrheal diseases and worms.

7. Dispose of the feces of small children in the sanitary latrine.

8. Keep the sanitary latrine clean following use by flushing with one or two pots of water.

9. Following defecation, wash hands well using ash and adequate amounts of handpump water.

Hygiene education was delivered in three overlapping phases:

▶ Household visits: February 1985 to January 1986
▶ Group discussions: October 1985 to January 1986
▶ Training sessions: October 1985 to December 1987

The relationship between the timing of these phases and the installation of handpumps and latrines is shown in Figure 3.1.

1. *Household Visits*

After each handpump was installed, the hygiene education messages related to water use were delivered by a female health worker, who visited each household for about half an hour. Seven follow-up visits were made, making a total of eight rounds. It took

one month to cover all households in the area in each round. During the first three rounds, messages were limited to water use only. But on subsequent rounds, as latrine coverage increased, the messages about sanitation practices were added. During the last two visits, some postcard-size photographs highlighting the key hygiene education messages were shown to the women, and these were found to be useful for maintaining their interest. At the close of the eighth round, most women could state the hygiene education messages given.

A further round of visits was made during the monsoon season in late 1986 to motivate women not to use surface water, omnipresent in the floods at that time, for any personal or domestic purpose.

2. Group Discussion

Group discussion meetings on hygiene education were arranged following the rounds of household visits. Eighty meetings were organized, with 25 participants on average, at the neighborhood level. The neighborhood women were invited, and they were the chief attendees although a few men and children also came. About three rounds of these meetings were held, so that many women attended more than once. The meetings were usually held on a wide veranda or in the shade of trees close to the house of a leading and popular personality, and they lasted for about 45 minutes. Considering the traditional seclusion of women, it was important to hold the meeting in the inner part of the homestead. The meetings were addressed by project staff, usually male, and also by female health workers who had been recruited from within the community. During the meeting, the health education messages were elaborately discussed and key points were demonstrated using water pitchers and utensils. The participants were encouraged to ask questions during the discussion session.

3. Training Sessions

The final and most intense phase of health education consisted of a two-day training course offered to one woman from every household. The training was organized in the project office and in the neighborhood of the women participating in each session. The first session was attended by only 8 women, but groups of 25 to 30 participated in the later sessions. Most of the trainees had children under five years of age, but a few were elderly women whose participation contributed a great deal toward attracting new participants for the next session. In the beginning, the participants were from the comparatively low socioeconomic-level households. Gradually, however, women from all levels took part. Transportation and a small honorarium of just under one dollar were provided during the training period as an incentive to attend. The trainers were senior-level field personnel from the project, but female health workers from the community were also present during the session.

A session lasted six hours on each of two days and included discussion and demonstration.

Discussion

The first day of training started in a classroom at the project office and made special reference to the nine hygiene education messages (Box 3.1) with which the trainees were already familiar from the earlier phases of the hygiene education program. These messages were further discussed in depth, and flip charts illustrating them were shown to the participants. These charts were selected from the WHO published album after pretesting at the community level. Following the presentation of the drawings, a lively discussion took place, in which local terminologies and dialect were used.

Although in an unusual situation, the trainees did not feel uneasy in the classroom, primarily because the community health workers and training staff were already familiar to them.

Demonstration

Demonstration of the nine hygiene education messages was started in the classroom on the first day. Drawings on handwashing were shown and related messages were explained. This was followed by actual handwashing before eating; all the trainees were asked to wash their hands before taking refreshments served in the classroom. The participants' method of handwashing was observed by the trainers. Whenever the method did not fulfill the criteria laid down in the messages, the trainers intervened and provided necessary guidance.

On the second day of training, demonstration of the practices related to hygiene education messages was undertaken around the households. Groups of participants visited one another's homes and discussed what they found. At the handpump site, the participants were asked to demonstrate the best methods of handling water. The use, maintenance, and cleanliness of water-sealed latrines, and the procedure for disposing of children's feces, were explained and demonstrated at a latrine. At the household level, the demonstration centered on the procedure for storing water and utensils. Observations were made in and around the household to identify any irregularities regarding water use and sanitation practices. When any irregularity was observed, it was brought to the attention of the women of the house for correction.

A total of 785 women participated in these sessions, covering 90 percent of households in the intervention area and all of those with children under five years. Eighty-seven women were trained in October and November 1985, and an additional 113 were

trained between April and September 1986. The remaining 585, the majority of the total, attended the sessions held between October 1986 and December 1987.

Costs and replicability

1. Handpump Installation

Because the tubewells and Tara pumps were installed in the context of an experimental program, the actual cost of installing them would not be representative of the cost of a large-scale program. For this purpose, the estimate of T 6,800 based on national experience (UNICEF 1987) is more appropriate. At T 30 to one US dollar, this gives a cost of $226 for a complete tubewell with Tara handpump, concrete apron, and drain. Because 148 pumps were installed for 4,856 persons in the intervention area (one for every 33 inhabitants), this is equivalent to a cost of $6.89 per inhabitant.

However, even this modest price is still far from being a replicable intervention for Bangladesh as a whole. It has taken a Herculean effort to provide one pump for every 143 persons, and most of these have been in areas of shallow groundwater where a tubewell and No. 6 pump can be installed for only $104. Much of the government's efforts in the coming years will have to be devoted to urban water supply and to replacing No. 6 pumps with Tara pumps as groundwater levels fall as a result of increased abstraction for irrigation (Government of Bangladesh 1986).

2. Latrine Construction

Conventional pour-flush latrines with a single pit cost a minimum of T 500, although this figure can increase to twice that amount where components must be transported long distances and a high-quality superstructure is included. In Mirzapur, the latrines were built by contractors, who were paid T 903 for each completed latrine, including the components, which they purchased at cost from the project site office. A few latrines were installed by the project, and the cost was then estimated at T 700. Taking the higher figure as more representative of a larger program where overheads would be included, transport distances would sometimes be greater, and contractors would sometimes be employed, the cost becomes $30 per latrine, or an investment of $4.67 per inhabitant to achieve the 90 percent coverage reached in the intervention area.

Typically, households in the intervention area contributed only $0.30 toward the cost of the latrines, but if a greater cash contribution had been demanded, such a high level of coverage would not have been achieved. It has been estimated that only 25 percent of rural households can afford the latrines currently being offered at a 35 percent subsidy (a 50 percent subsidy of the purchased components) under the existing national sanitation program (Government of Bangladesh 1986). On the other hand, most

households in the study area did provide the labor and materials to erect their own superstructure, once the latrine had been built up to ground level.

3. Hygiene Education

The hygiene education program cost an estimated $17,500, of which 78 percent was project staff salaries. Another 8 percent was accounted for by the wages of the part-time female health workers recruited from the community. The total works out to a cost of $3.60 per inhabitant. This is less than the cost of the handpumps and of the latrines, but it means that a substantial investment would be required for a program that sought to replicate the intervention on a large scale. No estimate has been made of the value of the time voluntarily spent by village women in listening to health education messages and attending the discussion meetings, but it could be argued that this time has a low or negligible opportunity cost.

The total capital cost of the three interventions--water supply, sanitation, and hygiene education--can be estimated at roughly $15 per inhabitant. This is not an extravagant amount in the context of the rural water supply programs of many other countries; the median 1985 construction costs per capita of rural water supply and rural sanitation in Southeast Asian countries have been estimated at $14.50 each, giving a total of $29 for both, by WHO (1987). Nevertheless, the cost of the three Mirzapur interventions, at $15 per person, amounts to more than 10 percent of the per capita GNP of Bangladesh.

4. Data Collection: Intermediate Variables

As the three interventions were implemented, a complex series of monitoring activities was carried out in the intervention area, and some of these activities were also pursued in the control areas. They sought to measure not only the impact of the project on the health of small children--particularly on their diarrheal disease morbidity, intestinal worm infections, and nutritional status--but also a range of intermediate environmental and behavioral variables that the project sought to change and through which it could be expected to have an impact on public health. These intermediate variables included the following:

- ▶ Households' choice of water sources
- ▶ Quantities of handpump water used
- ▶ Microbiological quality of handpump water
- ▶ Use of latrines and defecation practices, especially those of small children
- ▶ Knowledge, attitudes, and practices related to the hygiene education messages, particularly those relating to water storage, hand washing, and defecation practices

Data were also collected on the performance and maintenance of the handpumps and latrines.

The performance and maintenance of the handpumps was monitored to fulfill the project's other principal objective: to develop and field test the handpump design. The methods and results are fully reported on by Kjellerup, Journey, and Minnatullah (1989). The surveys of diarrheal disease, intestinal worm infection, and nutritional status are described in detail in sections 6 and 7. The remaining data collection focused on the intermediate variables and consisted of the components described in this section.

Census and demographic surveillance

A census of both areas was conducted in November-December 1983 with the assistance of local residents with a secondary-level education. One volunteer was recruited from every *para* (an administrative unit of about 300 persons) and given a 2-day training course. The volunteers then collected basic information regarding the age, sex, education, and occupation of all household members. A census team consisting of two experienced

health assistants, one male and one female, then accompanied the volunteer to verify the information collected, taking special care to ascertain the ages of children under five years by referring to important local events and matching them with Bengali and Arabic calendars.

During the second visit, the census takers collected additional information on water sources and defecation practices, in order to establish a baseline for the project. The baseline data are presented in section 2 of this report.

From January 1984 on, all households in both areas were visited once a month to record births, deaths, marriages, divorces, and movements into and out of the area. By means of this demographic surveillance, the census data were kept up to date throughout the study period.

Measurement of water consumption

The quantities of handpump water used by each household in the intervention area were measured at three different times of year during 1987, when the handpumps had been operating long enough for new patterns of water use to become established. Water collection was observed at each working Tara pump after every household using it had been identified. The collection of handpump water was recorded from 5:30 A.M. to 9:30 P.M. over two consecutive days. Women from the user group of a neighboring handpump were engaged to collect these data. Two women were assigned, on a rotating basis, to each pump for the first day, and another two monitored that pump for the second day. Project staff visited the observers three times per day to supervise their performance.

Each observer was provided with family photographs of the handpump's user group, two pots of different colors for each household, and some stone chips. For each stroke pumped by a household member, a stone chip was put into one of that household's two pots. One pot was for strokes pumped by adults and the other for strokes pumped by children (counted as half-strokes). A multiplying factor based on the discharge rate of each pump (available from fortnightly monitoring of all Tara pumps) was used to determine the household consumption of handpump water, in liters, over the two days. This figure was divided by two and by the number of persons in the household to give an average daily per capita consumption rate in liters per capita per day (l.c.d.).

Water quality testing

At the same time as the observation of water collection, samples of water were taken for microbiological examination from handpumps and from household water-storage containers in the intervention area. Pumps were first pumped for at least 10 strokes, and water-storage vessels were shaken, to ensure that the samples were representative. Within

30 minutes of collection, the samples were tested for fecal coliforms using the membrane filtration technique (APHA 1980) filtering 50 or 100 ml of water from the handpumps and 10 or 20 ml of water from the storage vessels.

Monitoring of latrine performance and use

Five quarterly latrine-monitoring surveys were conducted after completion of the construction program, in July 1986 and in February, May, September, and December 1987. Each project latrine was inspected for the condition of its various components, and any odors were noted. The male head of the household or his wife was asked about latrine use by each member of the family, using the list of household members obtained from the census and demographic surveillance. This monitoring applied only to the intervention area, where latrines had been installed by the project.

Knowledge, attitude, and practice (KAP) surveys

These surveys were conducted in both areas every six months beginning in June 1984, with a view to measuring compliance with the hygiene education messages. A fixed random sample of 20 percent of mothers with children under 5 years of age was interviewed by female health workers from the community. The interviewers had at least 10 years of schooling, and they used a pretested interview form that took 45 minutes to administer.

Observation

Answers given in the KAP surveys were verified by observation in three different ways. First, in one of every five households included in the fourth and fifth surveys, a portable conductivity meter was used to measure the conductivity of the water stored in every container in the house, and the conductivity was compared with that of a water sample taken from the handpump the household claimed to use. It was already known that surface water in the area had a different electrical conductivity than the groundwater.

Second, shortly before the fifth KAP survey in the 1987 wet season, all 13 surface water sources used for bathing in the intervention area were observed for two consecutive days from morning to dusk. Two women from the community were assigned to watch each source on a rota basis. They were to note the identity of all women and older girls seen to bathe there and the number of occasions on which it was observed. The performance of these observers was periodically supervised by project staff. The results of their observations were compared with the KAP responses of the corresponding households.

Third, observations of practices related to the defecation of children under three years of age were made in a small sample of households in both areas in 1987. A female community health worker, known to the household, sat unobtrusively in the home for eight hours in the morning of one day and eight hours in the afternoon and evening of the next. She was instructed to record where and how the feces of the child were disposed of, details of handwashing by the mother or caretaker of the child after cleaning the child's anus, and the sources of water used for different purposes. At the end of each day's observations, a member of the project staff reviewed the records to verify the completeness of the work. All of the observation in the control area (18 households) was conducted in the dry season (February-March 1987), but in the intervention area, two thirds of the 66 households were observed in the wet season (August-September 1987).

Water and sanitation survey

A final detailed survey of water and sanitation practices was carried out at the end of the project, in November 1987. All households in both areas were interviewed about water source choice in both wet and dry seasons, and about defecation practices of adults and children, to obtain data comparable to those collected in the baseline survey. Water storage vessels and latrines were also inspected.

Socioeconomic survey

In July-August 1987, a socioeconomic survey of all households in both areas was undertaken to collect data on ownership of land, cattle, and other valuable items, so that it would be possible to analyze their association with water consumption and to control for potential confounding factors in the analysis of the health impact data (sections 6 and 7). A trained team consisting of one male health assistant and one female community health worker interviewed the most reliable adult member of each household.

5. Intermediate Variables: Results

Choice of water source

The KAP survey results show a progressive increase in the proportion of mothers in the intervention area who claimed to use handpump water for each domestic purpose. Their responses were recorded separately for drinking, washing utensils and crockery, washing clothes, bathing (male and female), personal ablution, anal cleansing (male and female), and washing children's clothes soiled with feces. The results for bathing and drinking are shown in Figure 5.1.
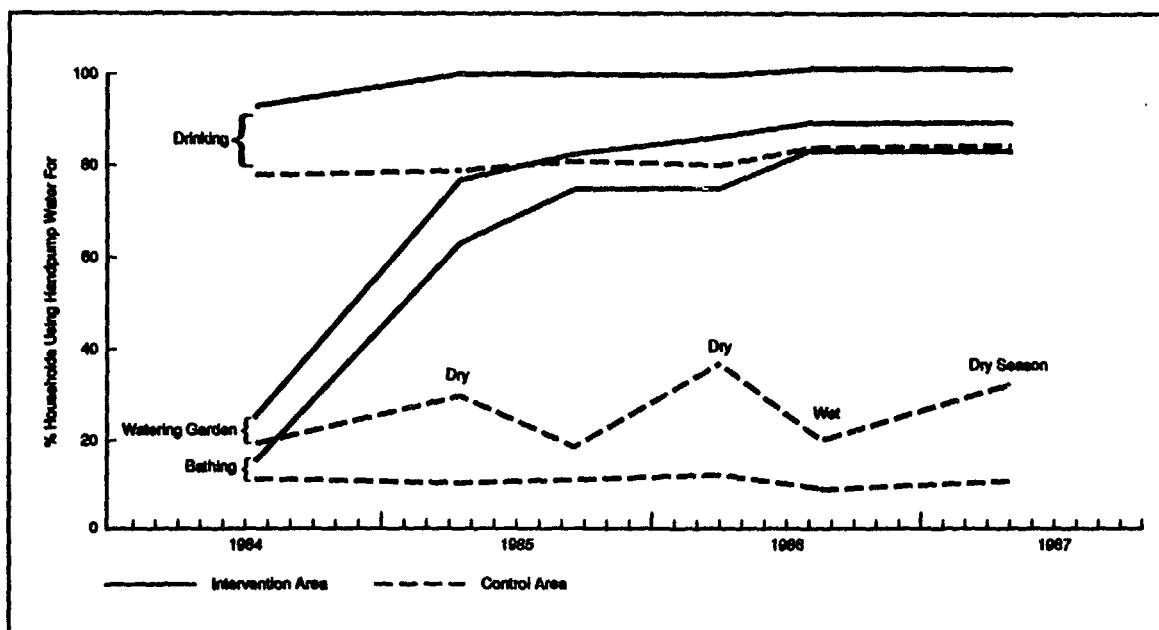
Figure 5.1. Results of KAP surveys, showing changes in water source choice during the project period

By contrast, the responses in the control area remained roughly constant throughout the study period, varying only between wet and dry seasons of the year. This confirms the research team's impression that villagers were not learning the "correct" responses from the form of the questions posed. One result that helps to confirm the honesty of the responses in the intervention area is that the proportion of mothers claiming to use handpump water to wash children's clothes soiled with feces did not increase beyond one third, whereas 90 percent or more said they used it for all the other purposes.

The early increase in the domestic use of handpump water would seem to be the result not of the hygiene education program, but of the increased convenience of the handpumps that had recently been installed. A similar increase was found in the use of handpump water to water kitchen gardens (see Fig. 5.1), which had not been mentioned in any of the hygiene education messages (Box 3.1).

It cannot be said, however, that the hygiene education had little impact on water-source choice. One of its major objectives was to promote the use of handpump water for all domestic purposes, and the proportion of households complying with this message continued to increase long after all the handpumps had been installed (Fig. 5.2).

The results of the final water and sanitation survey are presented in Figure 5.3 in a form comparable to Figure 2.4, and the differences between the two areas, which are highly significant statistically, can be clearly seen.
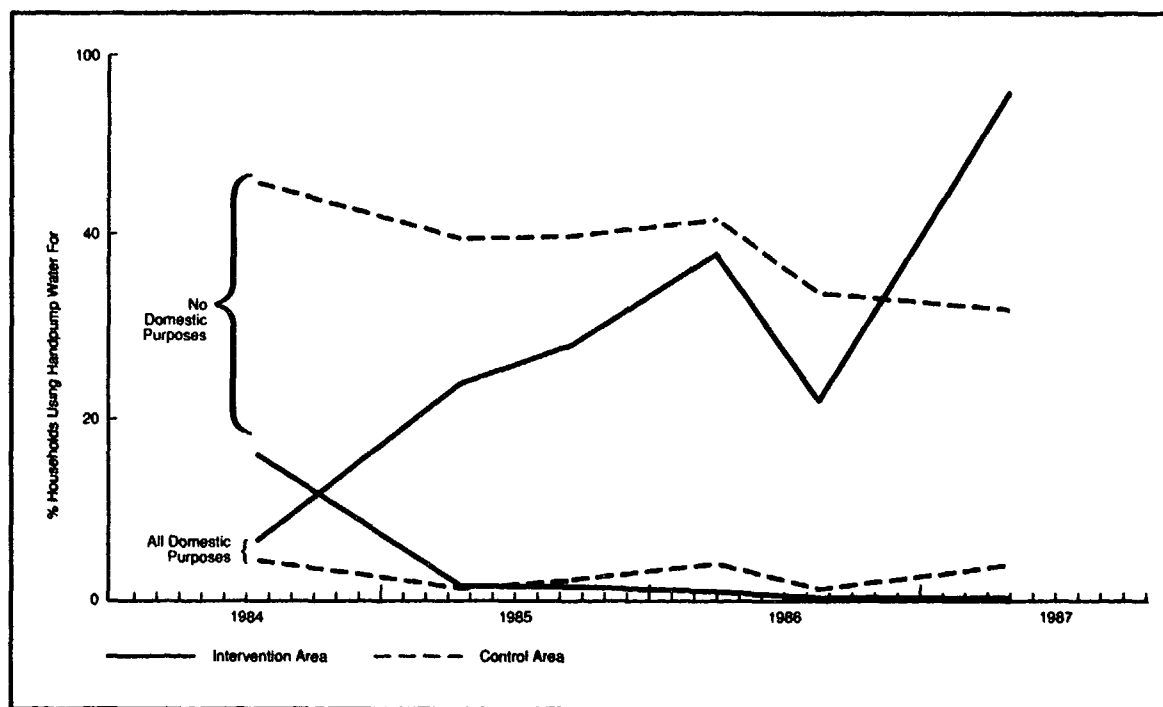
Figure 5.2. Changes in the proportion of households using handpump water as their principal source for all domestic purposes (or none), based on KAP surveys

Box 5.1 Water Source Choices: Comparison of Questionnaire Response with Direct Observations

The accuracy of the KAP responses regarding water that was brought home was borne out by the results of the conductivity measurements on stored water. These confirmed that 94 percent of the responses were correct, whether they referred to water stored for drinking, washing, or bathing.

However, observation of surface water sources showed that a considerable number of people claiming to bathe principally in handpump water continued to bathe at these sites. Of the 176 households interviewed shortly afterward in the fifth KAP survey, female members from 106 households had been observed bathing in surface water. Of those, 80 (nearly half the households interviewed) claimed to use mainly handpump water, and 3 to use well water, for bathing at that season of the year. It seems likely that many people bathed not only at home at the handpump site or at home using stored water, but also in nearby surface sources.

Quantities of handpump water used

About one quarter of the households in the intervention area had to be excluded from the analysis of the water consumption data for various reasons. These reasons included the following:

▶ Some were absent at the time of the survey
▶ Sometimes there was uncertainty about their composition
▶ Some used No. 6 pumps, and these were not observed

The mean quantity of handpump water used measured in the three surveys is shown in Table 5.1.

These figures are on the high side of the range of values found for handpump users in other countries, but they are comparable to the estimate of 10.29 gallons (47 l.c.d.) by Ahmed (1981) for the mean total amount of water collected from all sources by rural households in Bangladesh. The data are thus consistent with the finding that, in the intervention area, most water for domestic purposes came from handpumps. The slightly lower consumption from June to October could reflect increased use of the surface sources that are numerous at that time, although it could also reflect a real falling-off in consumption after the hot weather in March.

Table 5.1

Mean Handpump Water Consumption Measured in Three Surveys

(liters per capita per day, intervention area only)

Time of survey (1987)	Number of households	Mean (and standard error) in l.c.d.
March (dry season)	594	43 (1.1)
June-July (rainy season)	635	38 (1.2)
September-October (end of floods)	640	34 (1.4)

The distribution of household water consumption values from the March survey (Fig. 5.4) shows the wide range and skew pattern typical of such data. Much, and possibly most, of the variation is due to changes in consumption from one day to another rather than to enduring differences between households, even though the figure for each household has been averaged over two days. For example, a household washing clothes at the handpump site on one of the observation days is likely to use far more water than one that only collected water to use in the home.

The impact of various household factors on handpump water consumption is shown in Table 5.2, which presents the data from the March survey. This survey was chosen because it was made when alternative sources of water were least available and least used, so that variations in the quantities collected from handpumps would be most likely to reflect real differences in total consumption rather than differences in the proportion taken from handpumps. Consideration of each factor separately showed that per capita water consumption was significantly higher:

 ▶ for households with fewer people,
 ▶ where no children under five years of age were living,
 ▶ where the household head was engaged in nonagricultural work,
 ▶ where the handpump was located close to the house,
 ▶ where the user group for the pump contained fewer than 20 persons, and
 ▶ where the household owned at least one "luxury" item (radio, bicycle, watch, or ceramics).

DRY SEASON

WET SEASON

Surface Water | Well | Rain Water | Hand Pump
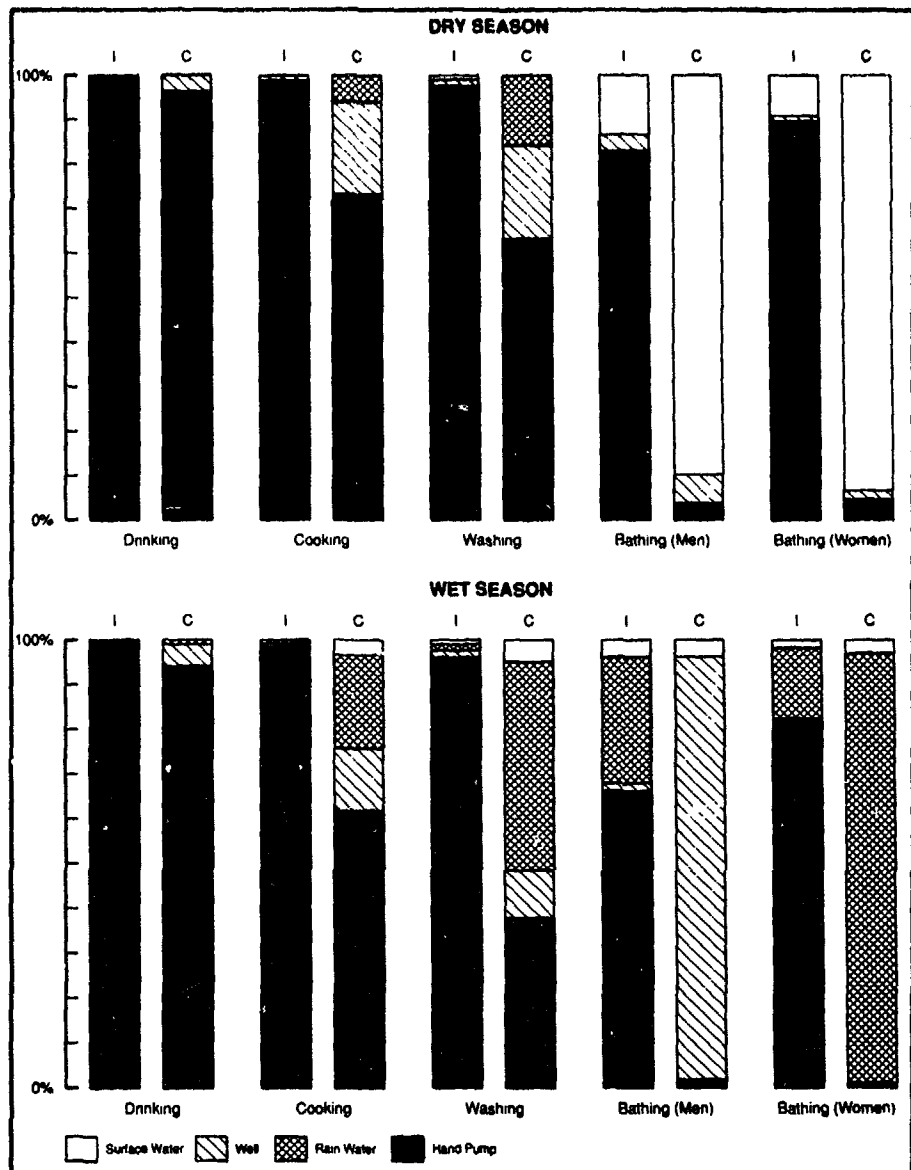
Figure 5.3. Proportions of households in intervention area (I) and control area (C) using various types of water source for different purposes in dry and wet seasons, from final water and sanitation survey (November 1987). Compare with Figure 2.4

Although the differences were not statistically significant, consumption rates were also higher in households where the household head had received more than 10 years of education, and in households of Hindu faith. No relationship was found between water consumption and the spouse's level of education, the highest level of education in the household, the ownership of land or cattle, or the consumption of "luxury" food items.

Table 5.2
Handpump Water Consumption and Household Factors

Factor (no. of households)	Levels	% of Households	Mean Water Consumption in l.c.d. (s.e. of mean)		P-value of Test Statistic[a]
Number of people in household (594)	1-3	15	60	(4.6)	< 0.001
	4-6	44	41	(1.5)	
	7-9	25	41	(1.7)	
	10+	16	34	(1.7)	
No. children < 5 years (594)	0	43	50	(2.1)	< 0.001
	1	34	38	(1.5)	
	> 1	22	36	(1.5)	
Religion (580)	Muslim	67	41	(1.3)	0.06
	Hindu	33	46	(2.0)	
Education of head (years) (594)	0	65	41	(1.4)	0.07
	1-10	31	46	(2.0)	
	> 10	3	51	(6.8)	
Occupation of head (594)	agricultural	45	39	(1.4)	0.004
	other	55	46	(1.7)	
Distance from house to handpump (m) (593)	0-24	9	56	(3.7)	< 0.001
	25-49	28	49	(2.1)	
	50-99	42	42	(1.8)	
	100+	20	31	(1.9)	
User size of pump (594)	< 20	15	49	(3.1)	0.006
	20+	85	42	(1.2)	
Possession of luxury item (575)	none	48	40	(1.5)	0.026
	any	52	45	(1.6)	

[a] Either the z-test or one-way analysis of variance was performed when group variances were similar; otherwise, an approximate test for difference of means (Armitage 1971) or a logarithmic transformation was used. The p-value refers to an overall comparison between subgroup means. Two-tailed significance tests were used.
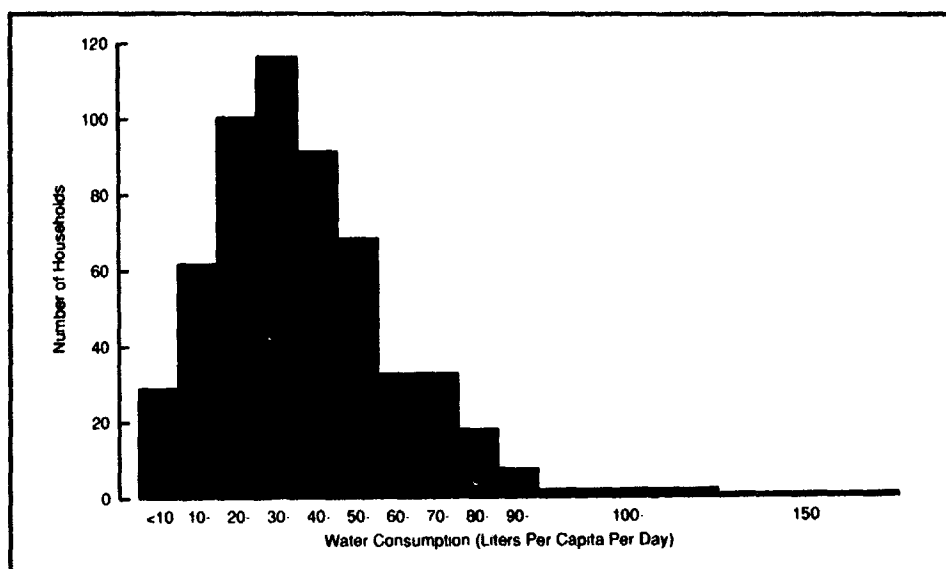
Figure 5.4 Histogram of tubewell water consumption per day (averaged over a 2-day period in 594 households)

In order to determine the combined effects of the factors in Table 5.2, multiple regression analysis was used on the logarithms of the March 1987 water consumption figures(Hoque et al. 1989). It was found that several factors remained significantly associated with handpump water consumption. These were household size, number of children under five years of age, distance to the handpump from the house, and the possession of at least one luxury item. However, their combined predictive value was low, with a multiple correlation coefficient $R^2 = 0.18$. That is to say, these factors explained about 18 percent of the variation in per capita consumption of handpump water.

To some extent, the use of larger quantities of handpump water by some households may correspond to less frequent use of other sources. However, to the extent that the use of more handpump water is associated with higher total water consumption, the finding of higher consumption rates among smaller households agrees with the results of other studies (White, Bradley, and White 1972; Feachem et al. 1978). The lower consumption among families with small children was still significant after controlling for household size. Although it might seem reasonable on the one hand (young children would presumably consume less water used for drinking and cooking), it might have been expected that more water would be used for washing a child and items soiled by that child.

Previous studies have shown that water consumption is greatest when the source of water is located within the homestead or very close to it, stays relatively constant when located up to about 1 km away, and decreases for greater distances (Cairncross 1987). In Mirzapur, households were located close to the pumps (80 percent were less than 100 m away), and there was a decreasing trend in average consumption as the distance to the pump increased. The average pump served 30 persons, and variations in this number had

little influence on water consumption once other factors were taken into account. Households using handpumps serving a small group were more likely to be closer to the pump, and this latter factor appeared to be a more important determinant of handpump water consumption.

Independent of other factors, households of a lower socioeconomic status used less handpump water. It is not clear exactly why this was so, but because these households are at greater risk of diarrheal disease (Islam, Bhuiya, and Yunus 1984), the result emphasizes the importance of giving them special attention during hygiene education. A low rate of handpump water use might be expected to put a household at increased risk of diarrheal disease, either through their greater use of contaminated surface sources or through the poorer domestic hygiene associated with low total water use.

In summary, the project was clearly successful in achieving high rates of handpump water consumption. However, in spite of a high handpump-to-population ratio, consumption did vary widely between households according to several factors. Consideration of these factors is important in planning and siting handpumps in similar water supply projects, and in defining those households that should be the main targets of associated hygiene education.

Water quality

1. *Handpump Water*

No significant differences were found in fecal contamination levels between samples from Tara pumps and those from No. 6 pumps. Therefore, the results are combined for presentation.

In March 1987, the geometric mean level of contamination was 1.6 fecal coliforms per 100 ml; in 38 percent of samples no fecal coliforms were found at all. Contamination appeared to be greater in the monsoon surveys of June and September, although it was still at a relatively low level, with geometric mean counts of 10 and 12 per 100 ml, respectively. Most of the contaminated samples had fewer than 50 fecal coliforms per 100 ml, and only a very few had counts above 100 per 100 ml.

2. *Surface Sources*

No samples from surface sources were taken for examination, but it is clear that the microbiological quality of the handpump water was vastly superior. Unpublished data collected by M. S. Islam have shown gross levels of fecal contamination in ponds and rivers elsewhere in Bangladesh, with fecal coliform concentrations of approximately 10^5 per 100 ml in most cases. There is reason to believe that because of the country's high population

density (and contrary to experience in many other countries), most of the fecal contamination is human in origin. For example, Dr. Islam found fewer than 100 fecal coliforms per 100 ml in the water of the pond in the Mirpur Botanical Garden, where people are prevented from defecating in the open.

3. *Water Stored at Home*

Although handpump water was of relatively good quality, water stored in the home had suffered a certain degree of contamination. In more than 30 percent of the samples, the plate was too crowded to count the colonies accurately, implying a concentration of more than 1,000 fecal coliforms per 100 ml. Including those samples that could not be read, more than half had over 100 fecal coliforms per 100 ml, and only 10 percent had fewer than 50. Similar degrees of water contamination during collection and storage have been found elsewhere (Feachem et al. 1978), but it is unclear exactly how it occurs or how important it is in the transmission of disease.

No consistent relationship was found between the level of contamination at a particular handpump and in the water stored by households using that pump.

Water storage

With a view to controlling the fecal contamination of water during storage, one of the hygiene education messages concerned the need for water to be stored hygienically. In particular, households were urged to keep their water storage containers covered and to place them on a platform 15-30 cm above the ground. Inspection of water storage containers in the water and sanitation survey at the end of the study period showed that these practices had become significantly more common in the intervention area (Table 5.3).

Performance and maintenance of latrines

For about a year after the construction of most of the latrines, the project made no major repairs such as replacing pit rings, pipes, slabs, or pans. In July 1986, however, the first of five quarterly monitoring surveys was conducted. Many latrines were found to have damaged y-junctions, y-junction covers, or problems with erosion of the earth around and beneath the slab. During this survey, the principle of double pit latrines was explained to the residents, as was the importance of having a y-junction gate and cover in place.

From then on, the project took responsibility for the maintenance of all latrine components except the superstructure. Residents were asked not to attempt to maintain or repair those components, but to ask the project staff for help if needed. The subsequent monitoring surveys showed a marked improvement in the number of latrines in good order.

Table 5.3

Prevalence of Hygienic Water Storage Arrangements, November 1987
(% of households where observed)

	Intervention	Control
Drinking water		
Containers covered	96	80[a]
Containers on platform	90	86
Other water		
Containers covered	85	51[a]
Containers on platform	70	55[a]

[a] Chi-squared test for comparison of proportions in the two areas,
$p < 0.001$.

Figure 5.5 shows the proportion of each component that was found to be in satisfactory condition in each of the five monitoring surveys of the 720 completed project latrines.

After the first survey, the only serious drop in the proportion of latrines in good condition was occasioned by the floods of 1987, which came between surveys three and four and were the worst in 40 years. Most of the damage was to superstructures ("fence" in the figure), which usually consisted of a fence of reeds, jute sacking, or other relatively insubstantial material. After the flood damage, repair and maintenance activities were improved and accelerated.

Minor repairs and maintenance were undertaken as and when required during these surveys. These repairs included activities such as earth filling, replacement of y-gates and pit covers, and minor plastering work on cracked slabs. The problems encountered with the slabs were cracking and breakage resulting mainly from construction on unstable earth. Earth filling was often needed because of erosion by rain, as many latrines were built at the edge of the *bari*, adjacent to the steep slope down to the surrounding low-lying ground. Pit covers were often found to be exposed, and they were then easily broken. Minor components such as the y-junction gate and cover were sometimes misplaced by the users and thus needed replacement. In total, interventions were required 1,150 times on the slab earth and 1,050 times on the y-junctions. Water seals required the fewest number of repairs, with only 165 needing replacement during the survey period.
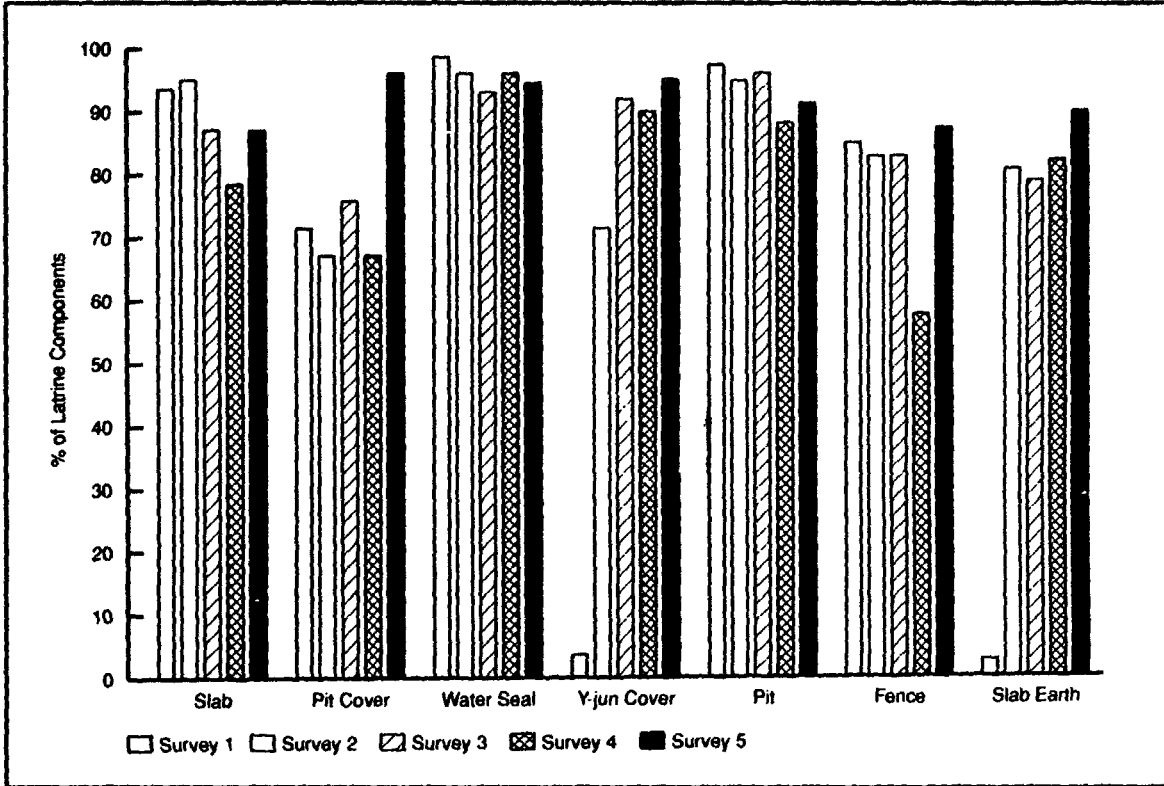
Figure 5.5. Functioning of latrine components by survey

In general, the component that suffered the most damage was the superstructure, but it could be repaired easily. The project did not repair superstructuresuntil after the floods, but the staff tried to motivate the users to repair or reconstruct them. However, this did not always work satisfactorily.

Maintenance costs varied from latrine to latrine, and community members were often involved at no cost to the project. However, the cost of replacing pit covers and y-junction parts amounted to an average of about $0.40 per latrine per year.

An additional maintenance task is essential with any on-site sanitation system such as the latrines used in Mirzapur: emptying or replacing the pit when it is full. The double-pit system introduced here was expressly designed to facilitate the safe performance of that task without machinery by making it possible to ensure that the pit contents are old enough to be innocuous by the time the pit is emptied. Before the cost of pit emptying can be included in the annual maintenance cost of a latrine, it is necessary to estimate the frequency with which the average latrine requires emptying. Information on filling rates was collected from the 276 latrines desludged under project auspices. These were the most rapidly filling latrines, but more than 90 percent of them had been used for

more than a year before the first pit filled up. On average, filling required 23 months from the first use of the latrine.More than half of the latrines filled at a rate of less than 0.045 m³/person/year, which has been suggested as a design figure by the Planning, Research and Action Institute, Lucknow (UNDP Global Project GLO/78/006). As might be expected, the filling rates per person tended to be slightly lower for families with small children. However, some 10 percent of the total filled at more than twice this rate, possibly because of the entry of earth into the pits during floods.
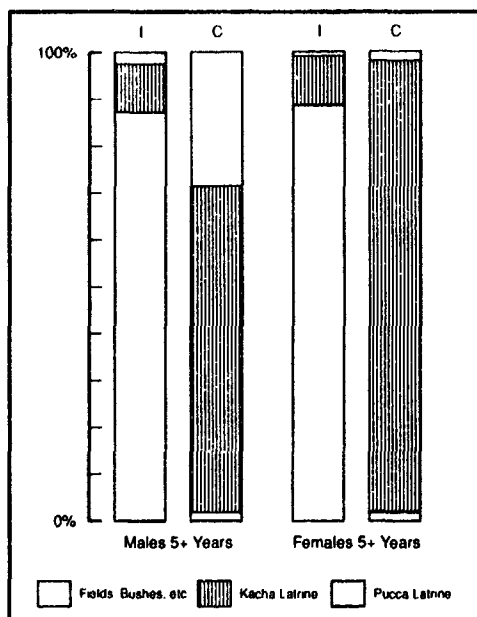
Figure 5.6. Proportion of households in intervention area (I) and control area (C) claiming to use different defecation sties in final water and sanitation survey (November 1987). Compare with Figure 2.5.

Silting-up of pits during floods is a possible explanation for the more rapid filling of the second pit in many of the latrines whose first pit was emptied in 1988. They had been selected because the second pit was more than half full, but in 42 percent of them, less than 6 months had elapsed since the first pit was closed and the drain switched to the second. In only 16 percent had the first pit been closed for the recommended time of a year or more. The second pits would take less time to full if, as is likely, many of them were partially filled with silt during the severe floods of mid-1987. This may have been

made more frequent by the tendency of many households to break the pit covers in the hope that the flood would carry away the contents. Another likely possibility is that the second pit had already begun to fill with sludge before the first pit was closed, as a result of missing or incorrectly placed y-junction gates. This would mean that the filling rates previously given for the first pits were sometimes underestimated.

A conservative estimate is that the average pit needs to be emptied roughly once a year. Combining the costs of replacement parts and of pit emptying, then, gives a total maintenance cost of $4.40 per latrine per year, or about $0.70 per person per year.

Use of latrines

With two exceptions, the latrine monitoring surveys found that about 90 percent of the 720 completed latrines were in regular use. One exception was the first survey when, as has been mentioned, most of the latrines had been functioning for a year or more without attention, and many were in serious need of repair. Nevertheless, 85 percent of the latrines were still in use at that time. The other exception was the fourth survey, when many of the superstructures had been damaged by the 1987 floods. Usage then fell to 81 percent of the latrines.

Of the 343 latrines that were in full working order in the preflood survey, 206 had suffered damage to at least one component. As a result, 32 of them had fallen into disuse. The chief factor leading to nonuse of a damaged latrine appeared to be damage to the superstructure. A latrine with damaged fencing was more than five times more likely to be unused than one with its superstructure intact, as can be seen from Table 5.4.

Table 5.4
Effect of Damage to the Superstructure by the 1987 Floods on Latrine Use

		Used Latrines (n = 311)	Unused Latrines (n = 32)	Percentage Unused
Superstructure	Undamaged	214	8	3.6
	Damaged	97	24	19.8
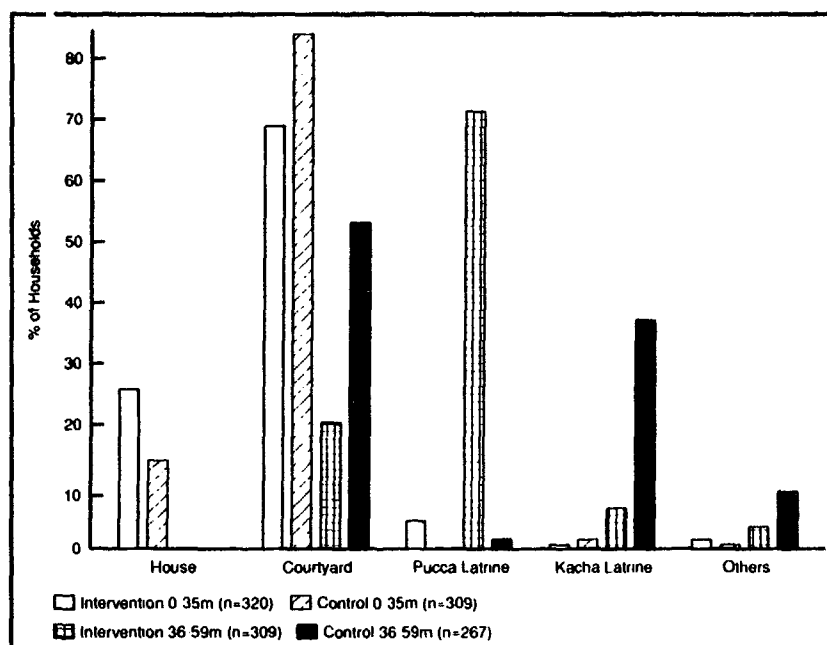
Figure 5.7. Defecation sites of children ages 0-35 months and 36-59 months, by area

Defecation Hygiene

Another hygiene education message was that ash should be used as a cleansing agent when washing the hands after defecation. Ash was recommended in place of soap, which was considered beyond the financial means of many households. At baseline, mud was the material usually used for this purpose in both areas, with a few respondents claiming to use only water. Figure 5.8 shows the progressive intervention area as ash replaced mud in the vast majority of households. Of course, these data refer only to reported handwashing practices, but they are borne out by observational data from two sources.

First, all latrines (including kacha latrines) were inspected during the final water and sanitation survey, and ash was available for use in 62 percent of the latrines in the intervention area but in only 1 percent in the control area (Table 5.5). Latrines in the intervention area were also many times more likely to be kept clean and to have a pitcher of water available.
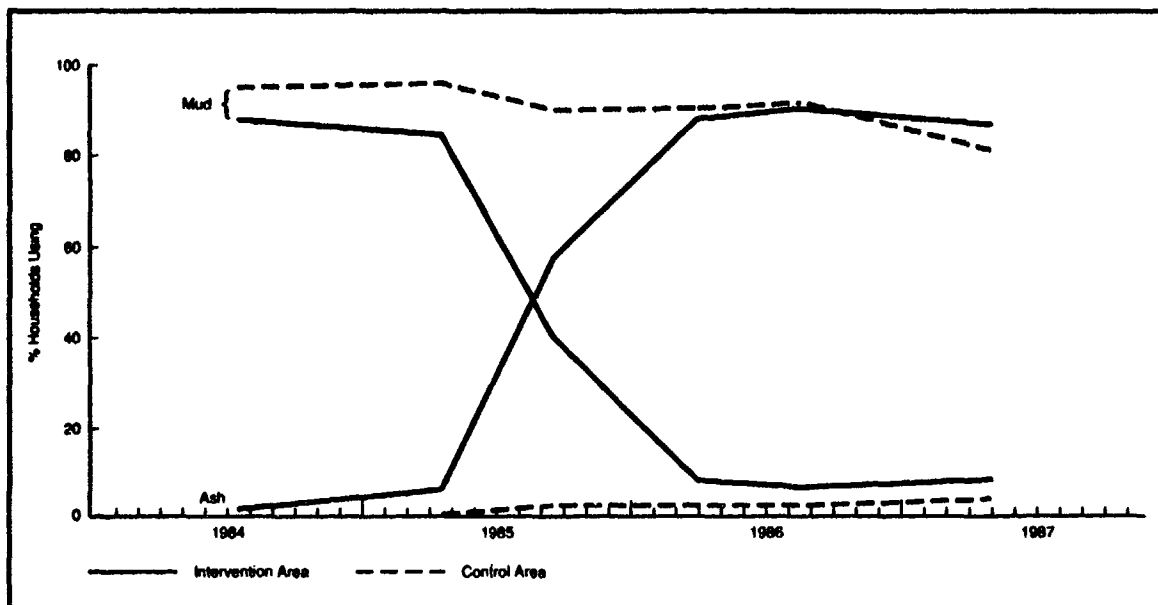
Figure 5.8. Changes during the project in the materials used for hand cleaning after defecation

Table 5.5
Proportion of Latrines in Which Hygienic Practice Was Observed, November 1987 (%)

	Intervention (pucca latrines) n = 770	Control (kacha latrines) n = 705
Ash available	62	1
Water pitcher	69	5
Latrine kept clean	73	2

Second, observation of mothers' behavior relating to the defecation of their children showed that a higher proportion in the intervention area used ash or soap to wash their hands after cleaning the child's anus. The result was not quite statistically significant, but this may be due to the small sample of households observed. This observation did

Box 5.2   How the Pits Were Emptied

After completion of the main project, 276 pits were emptied by hand over a 3-month period beginning in March 1988. These pits were judged to need emptying because the second pit was nearly full. Of these, 98 were emptied by project staff, but the remaining 178 were emptied by local women who were trained in this work and issued special tools. When the contents of the pit were still unpleasantly smelly, ash was added and the contents were left for one week before emptying them. Sludge removed from the pit was buried in a hole dug nearby.

A total of 12 local women were trained in pit emptying, and they worked in groups of 3. The project paid them T 40 (about $1.30) each per pit, which compares with the local unskilled wage rate of T 60 per day. Each group could empty two pits in a day, taking three to four hours on each pit. Thus, each could earn T 80 per day. The cost of emptying each pit therefore worked out to T 120 ($4.00), far less than the price of T 1,000 quoted by professional sweepers from Kumudini hospital. The lower sum is clearly affordable to many local households, because the women have since received requests from other local residents to empty their pits on a private basis. The involvement of local women in this work is a major achievement of the Mirzapur project, because scavenging human excreta is not generally regarded in Bangladesh as a respectable job.

The widespread use of the pucca latrines installed by the project can also be seen in the results of the final water and sanitation survey, which for males and females over five years of age are presented in Figure 5.6 in a form comparable to Figure 2.5. The use of the existing kacha latrines had also increased slightly in the control area since the baseline survey, but in the intervention area the proportion of households in which the adults admitted that they did not use latrines had fallen to only 3 percent for males and less than 1 percent for females.

If the use of latrines by adults and older children became almost universal in the intervention area, this was harder to achieve for children under five years of age. Figure 5.7 shows the distribution of defecation sites used by children in both areas; the results, drawn from the final water and sanitation survey, are given separately for children aged 0-2 years and those aged 3-4. By comparison with the control area, 33 percent more toddlers over age three in the intervention area defecated in a latrine, rather than in the courtyard or other unsuitable place, bringing the total using a latrine of some kind to nearly 80 percent.

Most children under 3 years of age in both areas defecated in the house or courtyard, but 12 percent more children in the intervention area defecated in the house. The reason for this difference, which is significant at the 0.1 percent level, is unclear. In households where children defecated in the home or yard, feces were usually swept or shovelled up and disposed of in the bushes or fields. Responses to the KAP questionnaires indicated that the feces were thrown into the latrine in only 20 percent of such households, even in the intervention area. Observation of mothers' practice in 55 households in the intervention area showed that the latrine was used for this purpose in only 3 families, although one of the hygiene education messages had recommended latrine disposal.

Table 5.6
Hygiene Practices Including Those Relating to Defecation of Children under Three Years (percent of households where practice was observed)

Practice observed	Intervention n = 66	Control n = 18
Water use		
Exclusive use of handpump water for all purposes	15	0
Handpump water used, except for washing child's anus	18	6
Surface water used for any other purpose	36	72[a]
Observations inconclusive	31	22
Handwashing after cleaning child		
Use of handpump water and ash or soap	59	39
Use of handpump water only	24	17
Use of surface water	17	44[a]

[a] Chi-squared or Fisher's exact test for difference in proportions, p < 0.05.

produce two statistically significant results (see Table 5.6), confirming the finding that surface water was only rarely used in the intervention area.

The public health significance of the use of ash for handwashing is unclear, but it does indicate the success of the hygiene education program in changing behavior in the intervention area. The impact of the three Mirzapur project components (water supply, sanitation, and hygiene education) on the health of the community is discussed in the following sections.

6. Impact on Diarrheal Disease

Methods

The impact of the project on diarrheal disease was studied in children under five years of age, using two different approaches. The first compared diarrheal morbidity between the intervention and control areas. The second compared subgroups of the intervention area according to different levels of use of the improved facilities.

Detailed data on diarrhea were collected in weekly interviews conducted by female community health workers. Diarrhea was defined as three or more loose motions in a 24-hour period, and an episode was said to be complete when two diarrhea-free days had elapsed. The information recorded for each episode included the type of diarrhea, the duration of the illness, and any associated symptoms. Until December 1985, all children residing in the study areas each month (known from the demographic surveillance program) were considered at risk of suffering a diarrheal attack. Beginning in January 1986, temporary absences of children from their homes were also recorded, providing more accurate follow-up of children and allowing the population at risk to be adjusted accordingly.

The different measures of diarrheal morbidity are used in the following analyses represent both the incidence and the prevalence of disease. Incidence rates, expressed as episodes per child per year, are presented for overall diarrhea, for persistent diarrhea (defined as those episodes lasting more than 14 days), and for dysentery (defined as those episodes where blood was present in the child's stools).

Rectal swabs were taken from children with diarrhea on the day of the interview, and they were examined for infection with *Shigella* spp. bacteria. However, the proportion of children found to be infected cannot be used to estimate the incidence of shigellosis, because episodes of shigellosis tended to last longer than other episodes of diarrhea. Episodes of greater duration are more likely to be found on the day of the interview than are shorter episodes. Instead, it is appropriate to use a prevalence measure, the proportion of days spent with diarrhea, and hence to estimate the prevalence of shigellosis.

In the following discussion, comparisons of two proportions are made using the chi-squared test with a continuity correction. Incidence rates are compared by calculating the incidence density ratio (IDR), which is the incidence rate experienced in one group (such as the intervention area), divided by the incidence rate in another group (the control area, for example). Also presented are 95-percent test-based confidence intervals for the

Table 6.1

Diarrheal Morbidity by Study Area and Year

	1984	1985	1986	1987
Child-months of observation				
Intervention	6,922	8,301	8,450	8,527
Control	6,603	8,210	8,111	8,165
Overall incidence				
Intervention	3.85	2.71	2.18	2.34
Control	3.75	3.59	2.98	3.12
IDR[a]	1.02	0.75**	0.73*	0.75*
95% confidence interval	.96,1.09	.70,.80	.68,.78	.70,.80
Incidence of persistent diarrhea				
Intervention	0.60	0.62	0.56	0.63
Control	0.58	0.91	0.94	1.10
IDR	1.02	0.68**	0.59**	0.58**
95% confidence interval	.87,1.2	.60,.77	.52,.67	.52,.65
Proportion of episodes > 14 days duration				
Intervention	0.15	0.23	0.26	0.27
Control	0.16	0.25	0.32**	0.35**
Incidence of dysentery				
Intervention	0.62	0.34	0.24	0.27
Control	0.54	0.37	0.34	0.36
IDR	1.16	0.92	0.70**	0.73**
95% confidence interval	1.0,1.34	.77,1.09	.57,.84	.61,.88
% of days with diarrhea				
Intervention	8.8	9.7	9.1	9.5
Control	8.9	14.1**	16.8**	17.5**
% of rectal swabs positive for *Shigella* spp.				
Intervention	7.3 (1,398)[b]	9.9 (933)	17.0 (865)	17.5 (961)
Control	8.0 (14,637)	11.2 (1,323)	17.2 (1,206)	17.2 (1,351)
% of days with shigellosis[c]				
Intervention	0.64	0.96	1.55	1.66
Control	0.71	1.58	2.89	3.01

Note: Chi-squared test for significance of difference between areas: * p < 0.01; ** p < 0.001.

[a] Incidence density ratio.
[b] Number of rectal swabs taken.
[c] Calculated by multiplying the percentage of rectal swabs positive for *Shigella* spp. by the percentage of days with diarrhea.

IDR (Kleinbaum, Kupper, and Morgenstern 1982). These confidence limits should be interpreted with some caution because repeated episodes of diarrhea in a child are not always independent events. However, no satisfactory alternative method of analysis exists for comparing incidence rates.

For the analysis within the intervention area, incidence rates of overall diarrhea, dysentery, and persistent diarrhea were compared between subgroups of the under-five population, according to a variety of socioeconomic, demographic, and environmental risk factors. These risk factors were collected from various sources: demographic surveillance, socioeconomic survey, baseline census, water and sanitation survey, and the water consumption surveys (see section 4). This analysis was conducted for morbidity in 1986 and 1987, when the interventions were established, with the aim of studying the effects of different levels of use of the improved facilities.

To study the combined effects of multiple risk factors, logistic regression analysis was used. Diarrhea incidence rates per se cannot be used for logistic regression because repeated (nonindependent) episodes can occur in a child. Thus, the observed number of episodes that a child experienced in a year was compared to the expected number of episodes for a child of the same age group and followed up over the same time period in the year (this eliminated age and seasonal effects in the calculations). Those children who had more than twice the expected number of episodes were classified as a "frequent diarrhea" group. The proportion of children classified as "frequent diarrhea" was compared for different levels of the various risk factors. This classification was made for overall diarrhea, and also for dysentery and for persistent diarrhea.

Comparison of intervention and control areas

During the baseline year (1984), the diarrheal morbidity experienced in the intervention and control areas was similar (Table 6.1). Respectively, the overall incidence rates were 3.85 and 3.75 episodes per child per year, and those of persistent diarrhea were 0.60 and 0.58 episodes per child per year, representing 15 percent and 16 percent of all episodes. The incidence rates of dysentery were 0.62 and 0.54 episodes per child per year, representing 16 percent and 14 percent of all episodes. The mean percentage of days that children spent with diarrhea was 9 percent in each area, and the results of rectal swab analysis indicated that 7.3 percent and 8.0 percent of these were due to shigellosis.

Table 6.1 shows that several changes occurred in the measures of diarrheal morbidity during the study period. The overall incidence rates declined in both the intervention and control areas, but significantly more so in the intervention area (1987 rates were 61 percent and 83 percent of the 1984 values, respectively). The IDR was about 0.75 in each year from 1985 to 1987; that is to say, children in the intervention area experienced 25 percent fewer episodes of diarrhea than those in the control area. The incidence of

persistent diarrhea remained at the baseline level in the intervention area but increased in the control area, so that rates in the intervention area were 40 percent lower than those in the control area. These results combine to show that persistent diarrhea assumed a greater proportion of all episodes in both areas, but more so in the control area. The incidence of dysentery declined over time in both areas, but children in the intervention area experienced about 30 percent fewer episodes than those in the control area. The strongest impact of the project interventions was apparent in the percentage of days with diarrhea, which remained constant in the intervention area but nearly doubled in the control area. The estimated prevalence of shigellosis appeared to rise in both areas. This last result must be interpreted with caution, however, because it is only an estimate and not a direct measurement.

The comparison between the two areas can be analyzed further, breaking the data down by season of the year, individual village of residence, and age. The results are given in the next three headings of this section.

Seasonality

The overall incidence rates for each month and area are shown in Figure 6.1. The steady decline in the annual rate is evident, as is a yearly cyclical pattern. Rates are generally highest in March and decline thereafter, but they show a second, smaller peak around July. The rates then remain relatively low until December; after that, they increase to reach the peak in March. The incidence of persistent diarrhea showed a similar seasonal pattern, except that the peak in July was similar or greater in magnitude than that reached in March. The incidence of dysentery showed a less clear seasonal pattern--rates were lower in February each year and generally highest in March to June.

The overall incidence rates were computed for the three main seasons: March to May (hot and dry), June to October (warm and wet), and November to February (cool and dry); they are shown in Table 6.2. In general, for each year the incidence is greatest in the March-to-May period. Rates were very similar in the intervention and control areas for each of the three seasons in the period March 1984 to February 1985. Thereafter, the incidence was lower in the intervention area than in the control area. From the IDR, the impact of the project is particularly evident in the June-to-October season. Similar results were found for persistent diarrhea.

Table 6.2

Diarrhea Incidence Rates by Season, Year, and Area

	March-May	June-October	November-February
1984-1985			
Intervention	4.42	3.69	3.30
Control	4.24	3.55	3.47
IDR	1.04	1.04	0.95
95% confidence interval	.96,1.13	.96,1.12	.87,1.03
1985-1986			
Intervention	3.46	2.41	2.13
Control	5.01	3.27	2.51
IDR	0.69**	0.74**	0.85**
95% confidence interval	.64,.75	.68,.80	.76,.95
1986-1987			
Intervention	2.88	1.72	2.16
Control	3.58	3.11	2.50
IDR	0.80**	0.55**	0.86*
95% confidence interval	.73,.89	.50,.61	.78,.96
1987			
Intervention	2.87	2.14	
Control	3.67	3.25	
IDR	0.78**	0.66**	
95% confidence interval	.71,.86	.60,.72	

Note: Chi-squared test for intervention vs control comparison: * $p < 0.01$; ** $p < 0.001$.

Box 6.1 Duration of Diarrhea Episodes

The percentage of days with diarrhea is not a very representative measure of overall diarrhea morbidity. It is based on the average duration of diarrhea episodes, which can be strongly affected by relatively few cases of persistent diarrhea. However, the median duration of episodes behaved in much the same way as the mean. By either measure, the duration in both areas was similar in 1984. In the subsequent years, the duration of episodes increased in the control area so that in 1986 and 1987, it was some 40 percent greater there than in the intervention area, by either measure.

Mean and Median Duration of Diarrhea Episodes by Study Area and Year

	1984	1985	1986	1987
Mean duration (days)				
Intervention	8.4	13.1	15.2	14.8
Control	8.7	14.3	20.6	20.5
Median duration (days)				
Intervention	5	5	5	5
Control	5	6	7	8

Thus, the strong impact of the interventions on the number of days with diarrhea is not simply a reflection of their impact on the most persistent episodes of disease, but corresponds to an impact on the pattern of diarrhea as a whole.

Individual villages

Diarrheal morbidity was also investigated separately for each village to see whether the impact of the project was consistent across villages. At baseline, the overall incidence rate in intervention village 1 (the larger of the two intervention villages) was higher than that observed in intervention village 2 (Table 6.3). Rates were similar thereafter, decreasing in each village. Differences in incidence rates were also observed between the three control villages in each year except 1987. However, the incidence of diarrhea in both intervention villages was consistently lower than that in all three control villages, from 1985 on.
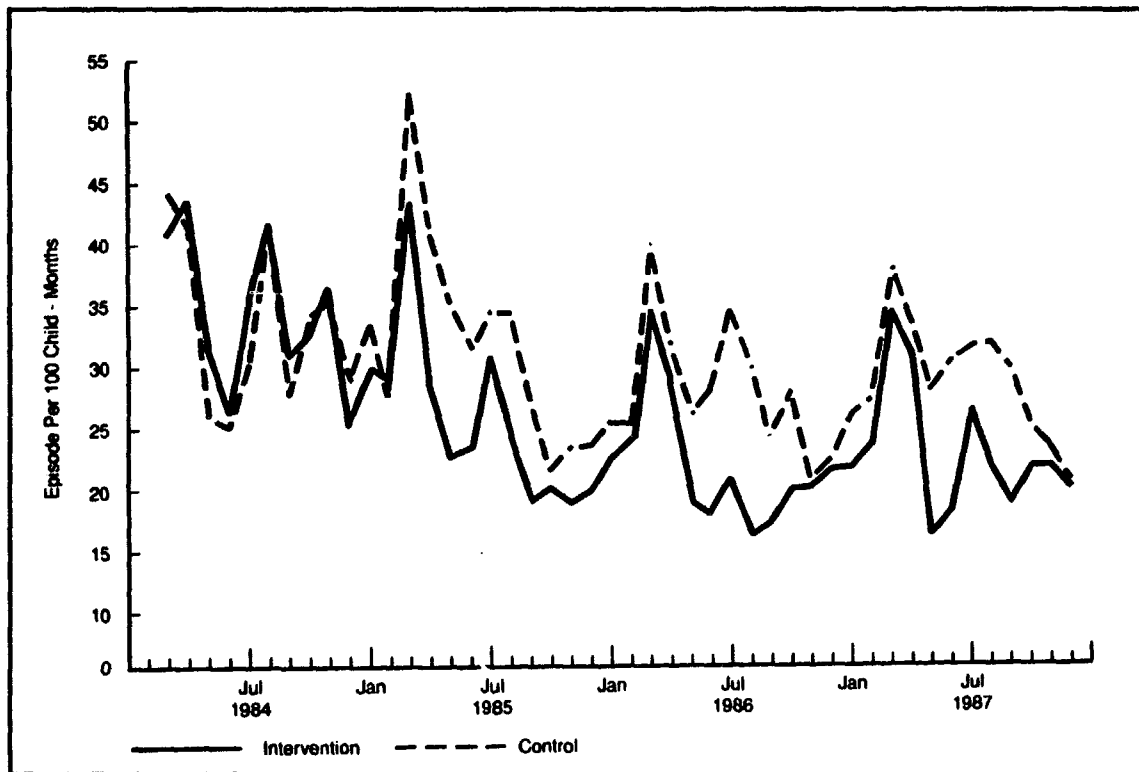
Figure 6.1. Incidence of diarrhea by month and area

Age-specific impact

Age-specific diarrheal morbidity measures were calculated, and the overall incidence rates are shown in Table 6.3. In general, incidence was higher in the second six months of infancy than in the first six months, stayed at a similar level in the second year of life, and decreased thereafter. Rates were similar for the intervention and control areas within each age group at baseline, except for those aged 36 to 59 months, where the rate was significantly higher in the intervention area.

An impact on the incidence of diarrhea was seen in each age group except for those aged zero to five months, where rates remained fairly constant throughout the four years. In all other age groups, the incidence rates declined, especially in the intervention area. The IDR showed that the impact of the project appeared to increase slightly, but not significantly, with age. Similar effects were seen for the incidence of persistent diarrhea, except that this doubled in incidence in the zero-to-five-month age group in both areas. For dysentery, an impact was apparent for 1986 and 1987 in all age groups except those aged zero to five months, although the lower rates make statistical demonstration of an impact more difficult in subgroups.

Table 6.3
Incidence Rates of Diarrhea by Village and Age Group, 1984-87

		1984	1985	1986	1987
Village					
	Intervention 1	4.03	2.71	2.14	2.35
	Intervention 2	3.16	2.70	2.34	2.32
	Control 1	4.39	3.90	2.78	3.12
	Control 2	3.44	3.58	3.16	3.13
	Control 3	3.98	3.37	2.76	3.11
Age 0-5 months					
	Intervention	2.46	2.28	1.89	2.43
	Control	2.27	2.73	2.46	2.26
	IDR	1.09	0.84	0.77*	1.08
	95% confidence interval	.87,1.36	.69,1.01	.62,.95	.87,1.32
Age 6-11 months					
	Intervention	4.11	3.89	3.22	3.33
	Control	4.63	4.62	4.10	4.25
	IDR	0.89	0.84**	0.79***	0.78***
	95% confidence interval	.78,1.01	.74,.96	.68,.91	.68,.90
Age 12-23 months					
	Intervention	4.79	3.63	2.93	3.13
	Control	5.17	4.64	3.94	4.12
	IDR	0.93	0.78***	0.74***	0.76***
	95% confidence interval	.85,1.01	.71,.86	.67,.83	.68,.84
Age 24-35 months					
	Intervention	4.44	2.72	2.32	2.36
	Control	4.15	4.11	3.04	3.34
	IDR	1.07	0.66***	0.76***	0.70***
	95% confidence interval	.96,1.19	.59,.74	.67,.86	.62,.80
Age 36-59 months					
	Intervention	3.32	2.03	1.49	1.66
	Control	2.73	2.64	2.29	2.46
	IDR	1.22**	0.77***	0.65***	0.68***
	95% confidence interval	1.10,1.34	.69,.85	.58,.73	.60,.75

Note: Chi-squared test for intervention vs. control comparison * p < 0.05; ** p < 0.01; *** p < 0.001.

Effect of recording absence of children

For 1986 and 1987, incidence rates of diarrhea were computed in two ways. The tables show the data calculated in the same way as the rates for 1984 and 1985. Alternatively, taking account of children's absence affected both the number of children at risk and the number of diarrhea episodes, because some episodes partially coincided with periods of absence and were thus discarded. The results showed that the overall incidence of diarrhea was little affected by taking account of absence, but that the incidence of persistent diarrhea was significantly reduced (Huttly et al. 1989a). The effects of considering absence were similar in the two areas, however, so that the conclusions about the project's impact were unaffected.

Factors within the intervention area

Within the intervention area, the association between diarrhea incidence and several demographic, socioeconomic, and environmental risk factors was also investigated. The following risk factors were studied:

- ▶ Family size and number of children under five years of age
- ▶ Parental age, occupation, and education
- ▶ Religion
- ▶ Ownership of land and of cattle
- ▶ Possession of luxury items
- ▶ Distance to the handpump
- ▶ Number of people sharing a household's handpump
- ▶ Exclusive use of handpump water in the wet or dry season, for drinking, or for all major domestic activities
- Quantity of handpump water consumed
- The defecation site of children aged 0 to 35 months and 36 to 59 months
- The disposal site of children's feces collected around the home: Whether or not ash was used in the household's latrine

For the purpose of evaluating the project's impact, the risk factors of prime interest are those related to use of the improved facilities. Of these, the most consistent in their association with diarrhea incidence were distance to the handpump, exclusive use of handpump water in the wet season for all major domestic activities, and the use of a latrine by a child under age five and/or the disposal of the child's feces in the latrine. The results are shown in Table 6.4. Several demographic and socioeconomic factors also showed some association with diarrhea, although not always consistently. The important factors that were found, and those kept as potential confounding variables in the logistic regression analysis (see below), were family size, mother's age, father's occupation, religion,

and ownership of land or cattle. Hindu families and landless families tended to have less diarrhea than average.

It can be seen that in both 1986 and 1987, all three measures of diarrhea incidence increase as distance from the household to the handpump increases. A lower diarrhea incidence is associated with the use of a pit latrine, either directly by the child or when the child's feces are disposed of in a latrine. The association with exclusive use of handpump water is less clear, but results from 1987 (and those of 1985 when the handpumps, but not the latrines, were installed) showed less diarrhea among children from households claiming to use only handpump water. The associations are stronger for overall diarrhea than for persistent diarrhea or dysentery.

Table 6.4 Incidence of Overall Diarrhea, Persistent Diarrhea, and Dysentery (Episodes per Child per Year) for Environmental Risk Factors: 1986 and 1987, Intervention Area Only

| Risk factor | 1986 | | | | 1987 | | | |
	Per-cent[a]	Overall diarrhea	Persistent diarrhea	Dysen-tery	Per-cent[a]	Overall diarrhea	Persistent diarrhea	Dysen-tery
Distance to handpump								
less than 25 m	8	1.42	0.35	0.12	9	1.77	0.47	0.15
25-49 m	25	2.12***	0.53	0.24	26	2.18*	0.58	0.29
more than 50 m	67	2.34***	0.61*	0.26*	65	2.49***	0.66	0.28
Exclusive use of handpump water for all major domestic activities in wet season								
Yes	31	2.23	0.56	0.28	31	2.13	0.54	0.28
No	69	2.19	0.56	0.23	69	2.43**	0.66*	0.26
Defecation of children 0-59 months or disposal of feces in latrine								
Yes	61	2.10	0.52	0.24	60	2.12	0.57	0.27
No	39	2.40**	0.67*	0.27	40	6.61***	0.66	0.28

Note: Significance of difference from incidence at lowest factor level: * p < 0.05; ** p < 0.01;
     *** p < 0.001.

[a] Percentage of children exposed to risk factor.

Table 6.5

Odds Ratios (95% confidence interval) of "Frequent Diarrhea" for Environmental Risk Factors: 1986 and 1987

Risk factor	1986 (n = 666)			1987 (n = 693)		
	Overall diarrhea	Persistent diarrhea	Dysen-tery	Overall diarrhea	Persistent diarrhea	Dysen-tery
Percentage of children with "frequent diar-rhea"	14	17	22	12	18	20
Distance to hand-pump						
25-49 m vs <25 m	1.9 (0.6,5.9)	1.2 (0.5,2.6)	1.9 (0.7,4.9)	1.7 (0.6,4.9)	1.3 (0.6,3.0)	1.7 (0.7,4.1)
>50 m vs <25 m	2.9 (1.0,8.4)	1.1 (0.5,2.3)	1.7 (0.7,4.2)	1.7 (0.6,4.6)	1.5 (0.7,3.3)	1.4 (0.3.3.3)
Exclusive use of hand-pump water for all major domestic activi-ties in the wet season						
No vs yes	1.0 (0.6,1.7)	1.3 (0.8,2.0)	0.8 (0.5,1.3)	1.8 (1.0,3.1)	1.2 (0.8,1.8)	1.1 (0.7,1.7)
Defecation of children 0-59 months or dispos-al of feces in latrine						
No vs yes	1.3 (0.8,2.0)	1.5 (1.0,2.1)	1.3 (0.8,1.9)	1.7 (1.0,2.8)	1.2 (0.8,1.8)	1.0 (0.6,1.5)

Note: Variables controlled for in analysis were age, sex, father's occupation, mother's age, religion, family size, land owned, cattle owned.

Box 6.2 Intestinal Worm Infections

A small survey was conducted to assess the impact of the project on intestinal worm infections, because there is evidence that these can be controlled by hygiene improvements, particularly sanitation (Feachem et al. 1983). Stool specimens were collected from a 20 percent random sample of children under five years of age in both study areas in March 1985, 1986, and 1987. In November 1987 an additional survey was conducted, only in the intervention area, but covering all children under five years of age. The stools were examined in the laboratory at Kumudini by a qualified parasitology technician, using the MIF method (Dunn 1968).

The prevalence of infection with *Trichuris* and hookworm was too low to draw firm conclusions. This is not altogether surprising: it usually takes several years for the average child, uninfected at birth, to acquire the level of infection in the population at large. However, in children age 1-4 years, the prevalence of *Trichuris* was 7 times greater, and that of hookworm 10 times smaller, than that found by Nawalinski, Schad, and Chowdhury (1978) in children of comparable age from rural West Bengal.

Only *Ascaris* infection was common enough for analysis. No discernible trend in *Ascaris* prevalence over time was observed in the three annual surveys. The prevalence remained about 40 percent in the intervention area and 54 percent in the control area. However, by November 1987 a sharp drop in prevalence was found in the intervention area, which was significant at the 0.1 percent level (see the following table). It is to be expected that the impact of the project should take some time to appear, because *Ascaris* worms can live for one to three years in a human host. It is possible that a greater impact would have been observed with longer follow-up. Nevertheless, the lack of comparable data from the control area means that this result, although strongly suggestive of an impact from the project, remains inconclusive.

Prevalence of *Ascaris* Infection in Children in the Intervention Area

Age (months)	----- March 1985 ----- Sample size	Prevalence (percent)	-- November 1987 -- Sample size	Prevalence (percent)
0-11	19	15.8	83	4.8
12-35	50	52.0	280	22.9
36-59	51	39.2	266	36.8
Total	120	40.8	629	26.4

Note: Mantel-Haenszel test for significance: $p < 0.001$.

Finally, logistic regression analysis was used to study the combined effects of these risk factors The outcome variables used were "frequent diarrhea" (more than twice the expected number of episodes) for overall diarrhea, dysentery, and persistent diarrhea. All analyses were controlled for the potential confounding effects of age, sex, and the six demographic and socioeconomic variables listed previously. Complete data for analysis were available for 666 children in 1986 and 693 in 1987. Table 6.5 shows the results in the form of adjusted odds ratios. The odds ratio is roughly equivalent to the ratio of risks to children in two groups of having "frequent diarrhea," other things being equal. An odds ratio greater than one implies that the association with the risk factor is in the expected direction.

After controlling for confounding variables, the associations between diarrhea and these three environmental variables remain, although statistical significance was demonstrated only with the variable representing overall diarrhea. No significant interactions between risk factors were found.

7. Impact on Nutritional Status

Methods

The impact of the project on nutritional status was assessed by 14 quarterly surveys of the height and weight of all children aged 0 to 35 months. The surveys were conducted in both the intervention and control areas beginning in October 1984. Although seven biannual surveys were also made of all children aged 36 to 59 months, the analysis was restricted to children aged 12 to 35 months because it was believed that anthropometric indicators would be most sensitive to the effects of the project in these children. Nutritional status was represented by three indicators: weight-for-age (w/a), height-for-age (h/a), and weight-for-height (w/h), using the NCHS growth standards as reference values (WHO 1983). Children's ages were computed from the date of birth recorded by the demographic surveillance system. Z-scores, representing the number of standard deviations from the NCHS median value, were computed for each indicator. Comparisons of mean z-scores were made between the intervention and control areas, and between subgroups within the intervention area. The proportion of children with severe malnutrition were also computed for various subgroups within the intervention area, exposed to different risk factors.

Comparison of intervention and control areas

Because some children reached the age of 12 months, and others 36 months, during the study, the study population changed from one survey to the next. On average, complete data were available on 213 and 192 children in each survey in the intervention and control area, respectively, with a mean age of 23 months.

The nutritional status of children in this study, as elsewhere in Bangladesh, was found to be poor when compared to the NCHS standards. At all ages, the children were shorter and lighter, so that their weight-for-age (w/a) and height-for-age (h/a) z-scores were very low. Because they were both short and light, their weight and height (w/h) z-scores were not as depressed.

Figures 7.1 through 7.3 show how the mean h/a, w/a, and w/h z-scores in each area varied during the study.
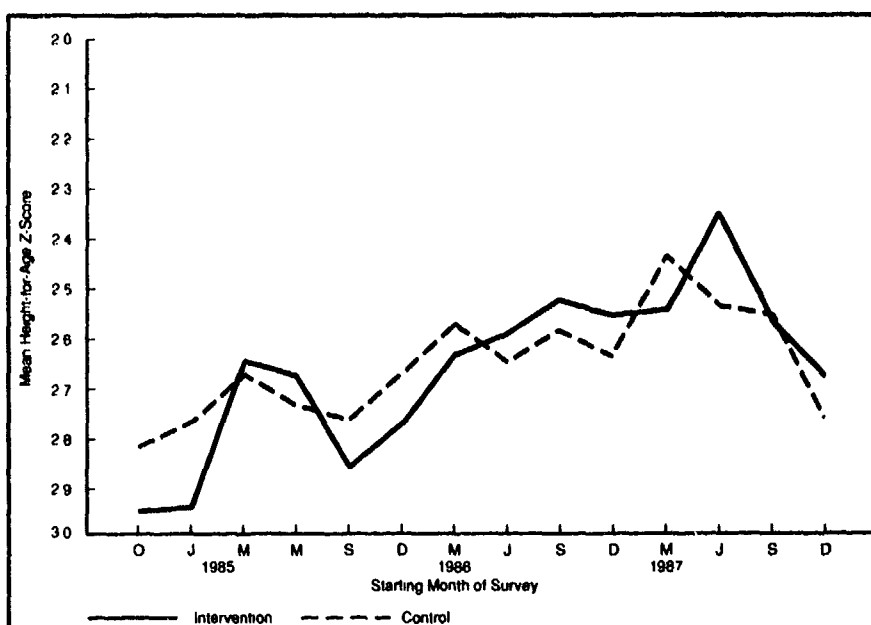
Figure 7.1. Mean height-for-age z-score, by area and survey

1. Height-for-Age

In both areas, the mean height-for-age z-scores were between -2.3 and -3.0. That is, the children's height-for-age was between 2 and 3 standard deviations below the NCHS median, showing a high degree of stunting in this population. Figure 7.1 shows that in the first two surveys, children in the intervention area had a lower mean h/a z-score than those in the control area, but these differences were not statistically significant. Thereafter, the mean z-scores were similar in the two areas and showed a steady increase over time until the last two surveys. There was no clear seasonal pattern.

2. Weight-for-Age

The mean weight-for-age z-scores were also low, ranging between -2.4 and -3.0. Throughout the study period, the z-scores were similar in the two areas. There was also a clear seasonal pattern, indicating that nutritional status was best around December/January, after the harvest, and worst in September, immediately after the monsoon. There was a slight upward trend in the mean w/a z-scores over time in both areas.

3. Weight-for-Height

Mean weight-for-height z-scores ranged between -1.1 and -1.6 and followed a pattern similar to those of weight-for-age. Again, the z-scores were very similar in the two areas and were greatest in December/January and least in September. No upward trend over time was found.
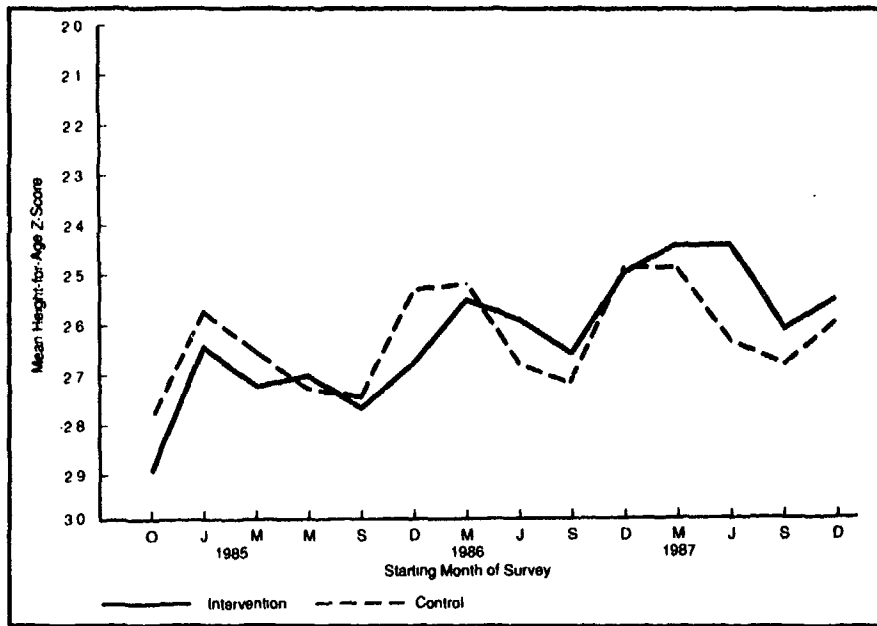
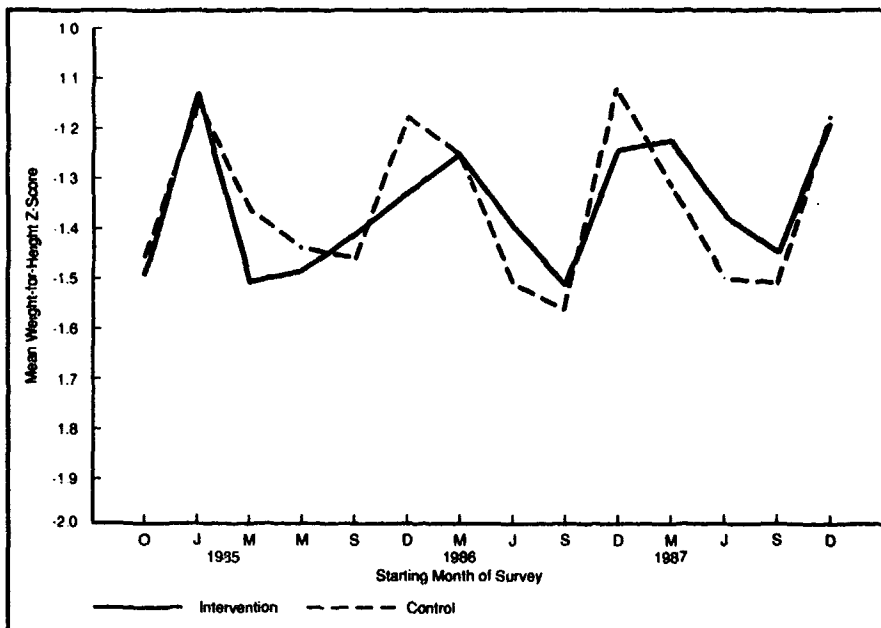**Figure 7.2.   Mean weight-for-age z-score, by area and survey**

Figure 7.3.   Mean weight-for-height z-score, by area and survey

Subgroups within the intervention area

To study the effect of differentials within the intervention area on nutritional status, the same socioeconomic, demographic, and environmental risk factors were used as those studied for diarrheal morbidity. Mean h/a, w/a, and w/h z-scores were compared for different levels of exposure to each risk factor. In addition, the risk of a child's becoming severely malnourished was studied. Children were classified as "low h/a," "low w/a," and "low w/h" if their h/a, w/a, and w/h z-score fell below the 10th percentile of the respective frequency distributions, that is, if the child in question were among the 10 percent whose growth, measured by the respective indicators, was most retarded. The proportions of children with low h/a, low w/a, and low w/h were compared for different levels of each risk factor.

The results showed little association between nutritional status, using any of the three indicators, and the risk factors studied. The environmental factors that showed a relationship to diarrhea also showed some relationship to nutritional status (Table 7.1), but no other environmental risk factors did so. No socioeconomic or demographic variables showed any significant or consistent association.

The distance to a handpump did not show a statistically significant relationship to any of the nutritional indicators. Insofar as any trend was discernible, it was the reverse of what might be expected. The exclusive use of handpump water was consistently associated with nutritional status, but this also ran contrary to expectation. Children in households claiming to use only handpump water had lower mean z-scores for all three indicators, although these differences were statistically significant only in 1986.

On the other hand, all these indicators showed some relationship to sanitation facilities. Those children from households where the children used a latrine, or the feces were disposed of there, had higher mean z-scores. The differences were only statistically significant in 1987 for w/a and w/h, although the same trend was seen in 1986 and for h/a.

No significant interactions were found between the risk factors when an analysis of variance was used. The risk factor analysis with "low h/a," "low w/a," and "low w/h" yielded no further information on relationships with nutritional status. Therefore, the results are not presented.

Table 7.1

Mean h/a, w/a, and w/h z-Scores for Environmental Risk Factors: 1986 and 1987

Risk factor	1986 h/a	1986 w/a	1986 w/h	1987 h/a	1987 w/a	1987 w/h
Handpump distance						
< 25 m	-2.59	-2.62	-1.39	-2.54	-2.58	-1.35
25-49 m	-2.57	-2.56	-1.34	-2.59	-2.63	-1.42
50+ m	-2.57	-2.57	-1.33	-2.52	-2.47	-1.23
P value[a]	>0.9	0.9	0.9	0.8	0.3	0.1
Exclusive use of handpump water for all major domestic activities in the wet season						
Yes	-2.77	-2.76	-1.48	-2.62	-2.62	-1.36
No	-2.50	-2.51	-1.29	-2.51	-2.48	-1.27
P value	0.02	0.01	0.03	0.3	0.2	0.3
Defecation of children or disposal of feces in latrine						
Yes	-2.52	-2.54	-1.34	-2.50	-2.43	-1.21
No	-2.60	-2.58	-1.35	-2.57	-2.62	-1.40
P value	0.5	0.7	0.9	0.6	0.05	0.01

[a] One-way analysis of variance or t-test were used to compare group means.

8. Discussion and Conclusions

Impact on diarrheal disease

There can be no question that the Mirzapur project had a significant effect cn behavior. Its impact went beyond the changes in the choice of water source and defecation site that would be expected to result from providing handpumps and latrines: the hygiene education program also played a significant role.

The impact of the project on diarrheal disease morbidity is similarly indisputable. The incidence of diarrhea in the intervention area fell to three quarters of that in the control area. The incidence and proportion of persistent diarrhea episodes and the incidence of dysentery also fell in the intervention area compared with the control area. Each of these results was significant at the 0.1 percent level (Table 6.1).

The relative incidence of diarrhea in the intervention area also declined significantly in each age group between six months and five years, and in each of the three seasons of each year. These results were also significant at the 0.1 percent level (Table 6.2). Moreover, the impact of the project was still noticeable when each village was considered separately. In each year after 1985, the incidence of diarrhea in both intervention villages was lower than in any of the three control villages.

Perhaps the most dramatic difference between the two areas, seen after 1984 when the interventions began and in all three subsequent years, was in the proportion of days on which the average child suffered from diarrhea. In the last two years of the project this figure was nearly twice as high in the control area. The Mirzapur project, it seems, reduced the relative prevalence of diarrhea in small children by almost 50 percent.

Readers new to the treacherous waters of diarrheal disease epidemiology might be misled by the finding that diarrheal disease incidence also declined in the control area. This is a common finding in longitudinal studies of diarrhea (Dworkin and Dworkin 1980; Huttly et al. 1989b), although case-control studies are unable to detect such trends. It was precisely to prevent the drawing of spurious conclusions from tendencies of this type that a control area was included in the study. It should be noted that although the overall incidence of diarrhea fell in botu areas, the incidence of persistent diarrhea and the proportion of days on which children suffered from diarrhea both increased in the control area.

It is also possible that some local people discovered the aims of the study, and this may have affected their answers to the KAP questionnaires in particular. A number of measures were adopted to verify KAP responses, but it is inconceivable that falsified responses could also explain the differential impact on diarrheal disease. This would require families in the intervention area, over a period of several years, to give persistently slightly lower values than those in the control area for incidence of diarrhea, persistent diarrhea, and dysentery, in each age group and season of the year.

There are two possible explanations for the decline in diarrheal disease incidence in the control area during the four years of the Mirzapur study. One is that hygienic conditions and practices were improving there, too, as part of the overall process of national development in Bangladesh. For example, whereas there were 44 No. 6 handpumps in the control area at the time of the baseline survey in January 1984, the number had increased to 58 by April 1987 as increasing numbers of households opted to install one for their private use. Meanwhile, a health education program, funded by CARE but not as intensive as the one organized by the project, was implemented in the control area. Besides promoting handwashing with ash, soap, or waste from a nearby soap factory, this program introduced a rudimentary pour-flush latrine that could be constructed with bricks and a polyethylene sheet. These may not have been the only developments to occur in the control area, quite independently of the Mirzapur project, and which could contribute to a decline in the incidence of diarrheal disease.

A still more likely explanation for the decline in the incidence of diarrheal disease in the control area is that it reflects only the secular variations in diarrheal incidence rates that are known to occur from one year to another because of variations in the weather, changes in the pathogens, and other reasons. Community-based observations of diarrheal disease morbidity have never been made for more than a few years, which is not long enough to show the long-term stability that may underlie the variations. However, some idea of this underlying stability can be seen from the remarkable set of data collected by ICDDR,B through the demographic surveillance system that it has operated for more than 20 years in Matlab, a rural area in Bangladesh similar to the Mirzapur study area. The annual death rate from diarrheal disease in Matlab from 1966 to 1983 is shown in Figure 8.1. The annual incidence of diarrheal disease can be expected to have behaved similarly. It is not difficult to see from the graph that, if Matlab had served as the control area for a health impact study conducted from, say, 1978 to 1981, a decline in the diarrheal death rate would have been observed, although the long-term tendency was for the rate to remain roughly constant.

It is difficult to say with certainty which parts of the complex of interventions made in Mirzapur produced the significant reduction in diarrheal disease. However, there are two reasons for believing that the installation of handpumps played the major role. First, the impact was clearly seen in 1985, although most of the latrines were only brought into use toward the end of that year and the hygiene education work was still in its early
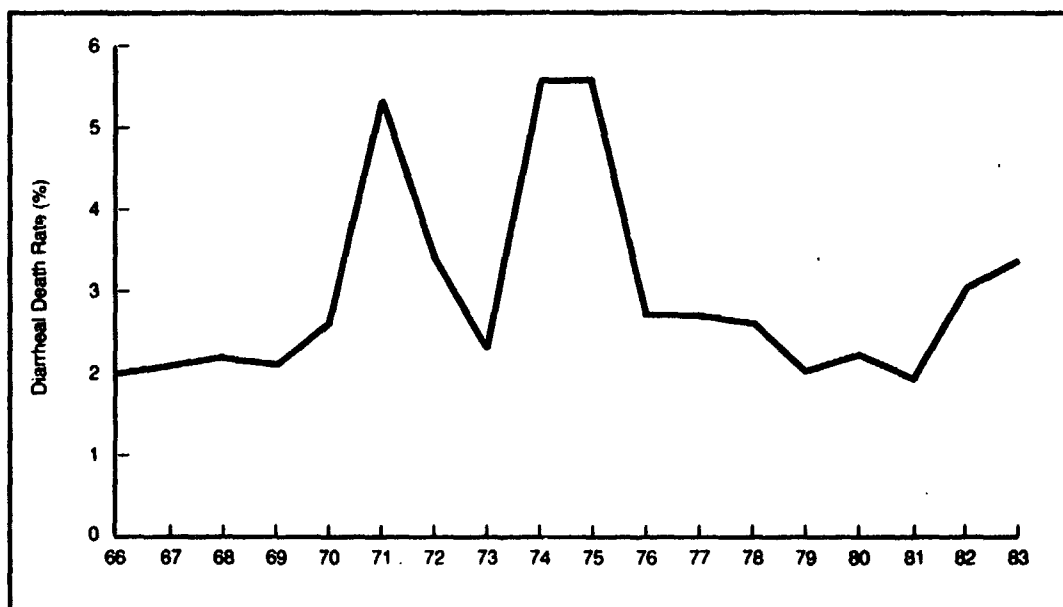
Figure 8.1. Deaths due to diarrheal disease in Matlab, Bangladesh, over a period of 18 years (per 1,000 population)
Source: Shaikh *et al.*

stages. The differences between the two areas did not become much larger in the two subsequent years.

Second, the most consistent environmental risk factor for diarrhea within the intervention area was the distance of the household from the handpump, which can be taken as an indicator or proxy variable for the amount of handpump water used in the household (Table 5.2). It is not surprising that this distance should be a better predictor of a household's diarrhea incidence than its measured water consumption. The water consumption measurements for individual households were made over a short period of only two days and probably reflect transient factors such as whether clothes were washed in that period, rather than each household's overall hygiene pattern.

Certainly it was found that households closer to a pump tended to use more handpump water, and this could protect them from diarrhea in two ways. Increased use of handpump water could lead either to a reduction in the use of highly contaminated surface sources or to an increase in total water consumption and hence to improved domestic hygiene. Most households in the intervention area used handpumps as their principal or only source of water for all domestic purposes; most of them were closer to a handpump than to a surface source, at least in the dry season. It therefore seems that the second of the two mechanisms was most important here. This conclusion--that the protective effect of handpumps results from increased water use rather than the quality of the water they provide--is supported by the fact that, in the multivariate analysis, distance to the handpump

was a more consistent risk factor for frequent diarrhea (Table 6.5) than failure to use handpump water exclusively for all major purposes.

However, the evidence is not strong enough to attribute the project's impact to a single component. The water supply intervention had the advantage of being the first, and the most easily implemented and accepted. It is conceivable that the initial reduction in diarrhea incidence would have been achieved by any one of the three components had it been the first to be implemented. Moreover, the continuous presence of a large number of project staff in the area may have been an "intervention" in itself. The intervention in Mirzapur was intended as an integrated package of water supply, sanitation, and hygiene education; all that can be said with certainty is that this package had a significant impact on diarrhea.

Intestinal worms

The results of the Mirzapur study suggest that the interventions significantly affected the prevalence of ascariasis. It has been known for 50 years that improvements in excreta disposal, particularly with regard to children's excreta, are a powerful measure to control the transmission of this infection (Feachem et al. 1983). Such evidence as exists from other studies suggests that the hygiene improvements stemming from better water supply, particularly handwashing, do not exert such an impact on *Ascaris* transmission. For example, a program to promote handwashing in a low-income area of Rangoon, Burma, was successful in reducing the incidence of bacterial dysentery (Han and Hlaing 1989), but it had no effect on the prevalence or intensity of infection with *Ascaris* (Han, Hlaing, and Kyin 1988).

The project's impact on intestinal worms may have been substantially greater than the results suggest, for four main reasons. First, the decline in the prevalence of ascariasis was only noticeable in the final stool survey in November 1987 and may have continued after that date as adult worms died off and a new cohort of uninfected children was born. Second, if the project had an impact on the transmission of *Ascaris*, it is probable that it had a similar impact on the other species of intestinal worms, particularly *Trichuris* and the hookworms, whose transmission routes are facilitated by promiscuous defecation habits. Third, the prevalence of infection with intestinal worms is normally greater in adults than it is among small children; the number of adults protected from infection by a given proportional reduction in prevalence is therefore far greater than the number of children observed to avoid it. Finally, if the prevalence of infection (the proportion of people infected) was reduced, experience suggests that the mean intensity of infection (the average number of worms per infected person) was reduced still more, with a consequently amplified impact on the proportion of people with heavy worm burdens. These individuals are the minority who are most at risk of serious disease complications as

a result of their infection, as well as being the major source of contamination of the community's environment with worm eggs and larvae.

The apparent impact of the project on intestinal worms is a finding of considerable interest, and it deserves further study. Because infection with *Trichuris*, at least, is an important cause of chronic colitis in small children (Bundy 1986), the subject is not outside the brief of ICDDR,B.

A first step would be to conduct a further parasitological survey to confirm the findings concerning ascariasis. Stool samples from children and adults in both the intervention and control areas should be collected and examined for the prevalence and intensity of infection. This should be followed by mass antihelminthic treatment of both populations, not only for ethical reasons but also because the intensity of infection can be found more accurately by worm expulsion than by stool examination.

Nutritional status

Nutritional status is probably the single most informative indicator of the overall health of a population, and it has been argued on theoretical grounds that it is as important and appropriate a measure of the impact of water supply and sanitation projects as diarrheal disease (Chen 1980; Esrey and Habicht 1983; Magnani, Tourkin, and Hartz 1984). However, the conceptual model underlying these arguments is one in which repeated episodes of diarrhea in a child have a cumulative effect on the child's growth. It is not clear how much this model corresponds to reality. There is evidence that, at least in Bangladesh, children catch up after an episode of diarrhea so that the impact of each episode on growth lasts only a few weeks (Briend et al. 1989). If this is true, an intervention that controls diarrhea is not necessarily likely to cause a durable improvement in children's nutritional status.

Moreover, an impact on nutritional status has not always been detected in practice. Several studies have found an association between the use of water supply and sanitation and the nutritional status of the users, but most of these have been cross-sectional studies of whole communities, in which multivariate analysis of the data on individual households was used to detect the association. It is possible that what they have detected is an association between nutritional status and some other characteristic of a family that predisposes it to make better use of the facilities. This characteristic could be a higher-than-average level of health awareness in the mother or an aspect of higher socioeconomic status that their indicators have been unable to measure accurately. Magnani, Tourkin, and Hartz (1984) found, for example, that "childhood nutrition levels are more sensitive to variations in standard of living indicators than to variations in any of the water variables."

It has been more difficult to detect an impact on nutritional status in a community in which a water and sanitation intervention has been made, possibly because individual household factors are less likely to confound a study of this type. For example, Esrey et al. (1988) found an association with nutritional status when they performed a multivariate analysis of individual households in villages with a water supply, but they also discovered that, even in households that used the supplies exclusively, children did not grow as well as children from villages with no supplies at all. In Bangladesh, Rahaman et al. (1983) found that a water supply intervention did "not appear to produce any positive impact on the level of undernutrition (measured by weight-for-age) and stunting (measured by height-for-age)," even though households using traditional water sources had an average incidence of diarrhea that was 19 percent higher.

There are two noteworthy exceptions. Studies in St. Lucia and Nigeria by Henry (1981) and Huttly et al. (1989b), respectively, found significant nutritional impacts. In part, this can be attributed to the reduced rates of infection with intestinal parasites and with guinea worm, respectively, which are known to have an impact on nutritional status (Crompton 1986). Another factor may have been the saving in women's time spent collecting water, enabling them to prepare more nutritious meals for their children (Popkin and Solon 1976). Neither of these factors would apply to the Mirzapur project, where the impact on worm infections was only detectable at the end of the study period, and where water was never far enough from a household for water collection to take up very much of a woman's day.

Mortality

It may be, however, that there are nutritional effects that are not detectable by the conventional anthropometric indicators of weight and height. It is also possible that these may affect a child's risk of death. There is an interesting parallel with recent findings on the impact of breast feeding. Dr. Briend and colleagues at ICDDR,B recently found that in the Chandpur area in rural Bangladesh, weaned children under three years of age had a slightly higher weight-for-age, but they were more than three times more likely to die than breast-fed children of comparable age.

In the same area of Bangladesh where Rahaman et al. (1983) had failed to detect an impact of water supply on nutritional status, Rahman et al. (1985) found a lower level of infant mortality in households that exclusively used handpump water for domestic purposes. And in Mirzapur, as we have seen, there was a significant reduction in the incidence of dysentery, which causes 33 percent of deaths among children aged one to four years, and 18 percent of deaths in the population at large (Shaikh et al. 1984).

The sample size was too small and the study period too short for a study of the impact of the Mirzapur project on mortality. But its significant impact on at least one

major cause of that mortality is reason enough to suppose that the project interventions may prevent a substantial number of deaths.

Policy implications

A principal objective of water supply and sanitation programs is to improve the health of the community. This not only reduces human suffering, but also enables economic gains to be made. However, demonstrating and quantifying health impact have been elusive goals. The Mirzapur study is important because it substantiates a fundamental assumption on which much water and sanitation policy is based: that improvements in water supply and sanitation have a positive impact on community health.

It is particularly significant that the impact was demonstrated in rural Bangladesh, in spite of the fact that most households are within a few minutes' walk of an alternative water source, however polluted, but that individual connections are not an affordable level of water supply service. Very significant health benefits were achieved by an integrated package of handpumps, latrines, and hygiene education. However, it is not clear to what extent these benefits could have been achieved by those three components individually, or at lower levels of provision.

The study makes important contributions to diarrheal disease epidemiology and to our understanding of the relationship between diarrhea and nutrition. For example, it suggests that nutritional status may not be such an efficient indicator of impact on diarrheal disease as had previously been thought. These epidemiological findings are important and worthy of publication (Hoque et al. 1989; Huttly et al. 1989a; Briend et al. 1989), but they are not directly relevant to water and sanitation policy. In addition to the fundamental result that a health impact is feasible, the policy implications that can be inferred from this study derive largely from the experience of implementing the combined package and from its impact on intervening variables.

Certainly the project demonstrated the feasibility, indeed the operational advantages, of the integrated approach in which water supply, sanitation, and hygiene education are combined. The hygiene education component helped to ensure the use of the handpumps and acceptance of the latrines, and at the same time its messages could not have been put into practice without them. It is hoped that integration of the three components will lead to greater health benefits, but the operational advantage of easier project implementation is more likely to commend it to the skeptical project manager.

With regard to the water component, the Mirzapur project has demonstrated the advantages of involving women, not merely as passive recipients of improved facilities, but as active participants in maintaining them. The approach to women by many water supply agencies has been largely rhetorical until now; the Mirzapur project has shown that

it can be much more concrete. Indeed, if women had been *more* involved--as trainers and not just as trainees, for instance--their contribution to the project would no doubt have been still more valuable.

The health impact of the handpumps seems likely to be related to the number of pumps provided, because the distance to the nearest pump, though small in the intervention area, was shown to be a risk factor for diarrhea. The Government of Bangladesh cannot afford to offer the very high level of service provided in Mirzapur, least of all with the more expensive Tara pump. However, the need for the Tara pump, as opposed to the more inexpensive shallow well pumps already in widespread use in Bangladesh, arises principally from the large-scale abstraction of groundwater for irrigation. Therefore, the additional cost of Tara pumps should not be considered a cost of water supply, but should properly be attributed to the irrigation that renders them necessary. Donors funding irrigation projects in Bangladesh should consider the additional cost of Tara pumps for domestic water supply as a legitimate component of a project budget.

The principal implications from the sanitation component is that it is possible to achieve 90-percent coverage with latrines in rural Bangladesh. Though a substantial subsidy was required to achieve this degree of coverage, it gives an idea of the *potential* market for sanitation--far greater than the 2.2 percent of the country's rural population that has so far elected to buy latrines. Not only did the vast majority in Mirzapur accept the improved latrines, they also used them; they used them more, in fact, than their old kacha latrines. There is a need for closer study of this market and how it may best be stimulated so that sanitation can be effectively promoted, and also to determine its sensitivity to different financing and cost recovery policies.

Important technical questions are raised by the project's experience with double pit latrines. To what extent is the use of pits alternated correctly? What are the most appropriate arrangements for removal and possible use of composted wastes? What sludge accumulation rates are suitable for the design of latrines in areas with a high water table? These questions have relevance beyond Bangladesh, and further research is needed to answer them.

The experience of hygiene education in Mirzapur also has lessons to offer. In the first place, the evidence in section 5 indicates that it is feasible, through a reasonably replicable program of hygiene education, to bring about significant changes in the behavior of a rural population. This study is thus one of the very few existing reports "that quantify the impact of a given hygiene education programme on a specific set of personal or domestic hygiene behaviours" (Feachem 1984).

However, this finding also raises important questions that can only be answered by further research. For example, which of the three approaches used in Mirzapur (household visits, group discussions, and training sessions) was the most effective? As

hygiene education is increasingly accepted throughout the developing world as a component of water and sanitation programs, there is an urgent need to evaluate the effectiveness of these and other methods in changing behavior. Only from this evaluation can a sufficient body of knowledge be built up for hygiene education programs to be designed and implemented rationally and professionally.

The need for tools to evaluate such changes in behavior is more fundamental still. Some of the results from Mirzapur suggest that some data from questionnaires can be more accurate than many would expect. What information can be collected reliably by this means, and what methods are needed when it cannot? There are particular problems when a stigma is attached to certain responses, and when the questions asked relate to taboo behavior (such as defecation) or occasional behavior (such as forgetting to wash one's hands).

Methods to measure hygiene behavior are needed as tools for research into hygiene education. The Mirzapur study took more than five years to complete and cost hundreds of thousands of dollars. Health impact studies of this scale are hardly a ready method for the operational evaluation of water and sanitation projects. However, there is reason to believe that the most significant health impacts of such projects stem from the behavioral changes that constitute hygiene improvements and those that can follow from better water supply and excreta disposal facilities. A study of such behavioral factors can be carried out more quickly, and much more inexpensively, than a health impact study, and its results would offer far greater power to diagnose problems in an existing project. Efforts to develop sharper tools for studies of that type would be amply rewarded by better project evaluations and hence, in the long run, by more successful water and sanitation projects.
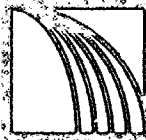
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