THE ROLE OF WATER SUPPLY IN IMPROVING HEALTH IN POOR COUNTRIES

John Briscoe

INTERNATIONAL CENTRE FOR
DIARRHOEAL DISEASE RESEARCH, BANGLADESH
Dacca, Bangladesh

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THE ROLE OF WATER SUPPLY IN IMPROVING HEALTH IN POOR COUNTRIES

(With Special Reference to Bangladesh)

by

John Briscoe, Sanitary Engineer
Epidemiology Division

CHOLERA RESEARCH LABORATORY
G.P.O. Box 128, Dacca - 2
Bangladesh

PREFACE

The Cholera Research Laboratory (CRL) operates under a bilateral project agreement between the government of Bangladesh and the United States of America. Research activities of CRL center on the inter-relationships between diarrheal disease, nutrition, fertility and their environmental determinants. CRL issues two types of papers: scientific reports and working papers which demonstrate the type of research activity currently in progress at CRL. The views expressed in these papers are those of authors and do not necessarily represent views of Cholera Research Laboratory. They should not be quoted without the permission of the authors.

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ABSTRACT

The consumption of insufficient quantities of water of poor bacteriological quality is widely believed to be a major factor contributing to the high incidence of gastro-intestinal diseases in poor countries. Governments of these countries have undertaken water improvement programs in the belief that such programs will result in substantial improvements in the health of the populations served.

In a rural area in the flooding plain of the Meghna River in Bangladesh four recent studies have examined the effect of the provision of domestic water through hand-pumped tubewells on the incidence of cholera and other diarrheal diseases. These studies have uniformly concluded that drinking tubewell water was not associated with a reduction in the diseases studied. Each of the studies has suggested reasons for this surprising finding. In this paper we examine these explanations closely and offer an alternative hypothesis which may account for these results. A subsequent study, which is reported in the addendum to this paper, suggests that this alternative hypothesis, too, does not explain the results of the field studies.

The implications of these findings for the formulation of water supply policy in the study area and in rural Bangladesh as a whole are examined. The problems which arise from the use of cholera as a paradigm for all water-related diseases are emphasised as is the necessity for taking into account different ecological conditions in the formulation of water improvement programs. The paper concludes with a discussion of the necessity for understanding the factors which affect the behaviour of individuals who face a variety of sources of domestic water and the importance of including the proposed users in the design of these programs.

INTRODUCTION

The purpose of this paper is to review the state of knowledge concerning the potential of improved water supplies for easing the burden of infection in poor countries and to identify some short-comings in both the available research and formulation of water improvement programs.

The literature on water supply and health is strikingly heterogeneous in design, in method and in conclusions (Bradley 1974) and "offers little in explaining water's health impact beyond confirming the existence of a general association between improved quality and increased quantity of domestic water and a reduced incidence of enteric disease" (Wall and Keeve 1974). We will briefly examine some of the important features of and problems with these studies without trying to replicate several excellent recent reviews of this literature. (See White el al 1972, White and Seviour 1974, Wall and Keeve 1974, Bradley 1974, Saunders and Warford 1976.) Since water-health relationships are so markedly affected by the cultural, socio-economic and ecological characteristics of an area, universal conclusions are necessarily very general and of limited practical value. The approach taken in this paper is to examine in detail a limited set of studies which have been conducted in the same environment, a rural area of Bangladesh. The analysis will be illustrative rather than comprehensive. Through examination of these studies some of the more general methodological problems will become apparent, the difficulties in drawing a consensus from a set of studies of essentially the same population will become clear, and the ways in which imperfect information may be useful in formulating policy will be illustrated.

PART I: RESEARCH ON WATER SUPPLY AND HEALTH

1. Some methodological issues in studies of the effect of water supply on health

Both inferential and deductive reasoning have been used in analyzing the relationships between water supply and health.

1) Deductive Analyses:

A large number of diseases are believed to be contracted through the ingestion of pathogenic organisms which are present in the water, and it is thus assumed that the provision of a "pure" water supply will drastically reduce the incidence of these diseases. There are several difficulties with this approach.

Diarrheas, accounting for about 30% of the mortality in the Indian subcontinent, are usually assumed to be the most important of these diseases, yet sophisticated laboratories such as the Cholera Research Laboratory in Bangladesh are unable to isolate pathogenic agents for more than 60% of patients having diarrhea. Understanding of this most important syndrome is rudimentary:

> Aside from the traditional water-related diseases caused by the bacteria, shigella, salmonella and cholera, which typically produce diarrhea, the syndrome remains inscrutable.... The disease acts as though it was due to some contagious agent, possibly viral as well as bacterial.... The intestinal pathology seen with diarrhea is not specific for any disease of known etiology.... On the other hand, non-diarrheic children may carry high levels of enteropathogenic organisms in their intestines.... Infections quite remote from the gastrointestinal tract, in the middle ear or lungs, for example, or measles often produce serious diarrhea in Children. (Wall and Keeve, 1974).

While interesting epidemiological models of typhoid and cholera have been developed by Cvjetanovic and his colleagues at WHO (Cvjetanovic et al 1971, Uemera et al 1971) it is questionable whether adequate primary epidemiological data exist for the construction of realistic models for even these much-studied diseases.

In general, the epidemiological understanding of enteric diseases is so poor that realistic *a priori* models cannot be constructed. Investigators therefore usually use statistical inferential methods to analyze the relationships between water supply and disease.

2) Inferential Analyses:

The large literature on the empirical relationships between water supply and health consists of both cross-sectional and longitudinal studies. The cross-sectional studies, such as those of the WHO Diarrheal Diseases Advisory Team (see van Zijl 1966), have been plagued by the existence of high multi-collinearity in "independent" variables (for instance income and nutritional status are usually highly correlated with quality of water supply) and by the existence of simultaneity (a correlation between water supply quality and health may imply that the communities or individuals with better health status are more healthy because of the quality of their water supply or that a more healthy community has taken steps to improve the quality of its water supply). It is somewhat surprising and unfortunate, given the frequency with which the multicollinerity question has arisen, that no analysis of cross sectional data using multi-variate techniques has been attempted. The longitudinal studies are generally prospective studies in which water supply improvements are made in an "experimental" community, while the health of this and a "similar" control community are monitored. The assumption that the two communities are similar in all important respects has proved to be a major problem. Frequently adequate pre-intervention monitoring has not taken place and often there have been differential changes in the "experiment" and "control" communities which have had unmeasurable effects on health in the two communites. Particularly serious is the fact that the communities have often been exposed to quite different probabilities of infection due to the occurrence of an epidemic in one of the communities only. One of the most carefully conducted longitudinal studies, the INCAP study in the 1960's (see Scrimshaw 1970), failed to yield any definitive conclusions since the interventions failed, for a variety of reasons, to substantially alter either water use or defecation patterns.

2. Studies of water supply and cholera (and other diarrheal diseases) in rural Bangladesh

Under the auspices of the Cholera Research Laboratory (CRL) four studies have been conducted on the effect of the provision of hand-pump tubewells on the incidence of cholera and other diarrheal diseases in Matlab Thana, a rural area in the deep water flooding plain of the Meghna River. Both the practical and research implications of these studies are of major importance.

In one of the studies the long held belief that "... there can be no doubt that the large-scale installation of adequate tubewells would be of cardinal importance for the prevention of cholera in rural areas in which it is not possible to provide for piped water supplies" (Pollitzer, 1959) is supported in the case of Classical cholera but not for El Tor cholera, while the other three studies show that, for both cholera bio-types, there is no difference in attack rates between tubewell users and non-users. All four of the investigators suggest that the Government of Bangladesh hand-pump tubewell program is not meeting its stated objective in reducing the incidence of cholera.

The studies raise another important policy issue in examining the hypothesis that those who use tanks to meet their needs for water have lower cholera attack rates than those who draw their water from other surface sources. The findings of the two studies which address this issue are apparently contradictory.

Beyond the field of water per se, the studies have implications for the understanding of disease transmission in general. The counterintuitive results have suggested to some that the widely accepted model of cholera as primarily a water-borne disease may be incorrect, at least in the tropical countries.

The analysis presented in this section is undertaken in the belief that, until satisfactory answers are given for both the counterintuitive findings and the apparently contradictory results, these studies confuse those who are attempting to devise appropriate water improvement programs in rural Bangladesh.

a) Water use in the study area:

Surface water sources - ditches, tanks, canals and rivers - are easily accessible to most Matlab families and are used by all families for all purposes other than drinking. Despite the fact that these sources are frequently contaminated with fecal organisms, the water quality -- colour, turbidity, temperature, smell and taste -- is generally perceived as satisfactory. The only protected water sources available are hand-pumped shallow tubewells, about 20% of which are privately owned. While about 30% of the families report tubewell water as their source of drinking water, tubewells are virtually never used for any other purposes. Tubewell water is not attractive, for a variety of reasons. Tubewells are usually less accessible than surface water sources, pumping of water requires considerable effort, and the quality of ground water is generally poor in this area: "Tubewell water looks clear when fresh but turns turbid and forms brown scum and precipitates on overnight storage. It causes discoloration of teeth, rice, curry, clothes and tea and tastes of iron" (Khan et al 1975).

b) The studies and their findings:

1) Sommer and Woodward (1972) wished to examine the effect of a protected drinking water source (a handpump tubewell) on cholera attack rates. Since they considered the answers given by villagers to questionnaire on water use to be unreliable, they compared cholera attack rates between those families who lived within fifty feet of a functioning tubewell and those who lived further than fifty feet from such a tubewell during two successive years in Meheran, a Hindu fishing village of about 1800 inhabitants.

> During the first epidemic (1968-9) caused by the Classical/Inaba strain, participants in the immediate vicinity of tubewells had a lower rate of infection (1 out of 27 or 3.7%) than those living farther away (19 out of 75 or 25.3%). During an epidemic the following year (1969-70), caused by the El Tor/Ogawa strain, there was no difference in the rates of infection of these two groups (16 out of 53, or 26.9%, and 37 out of 149, or 26.4%, respectively) (ibid).

The authors suggest that the difference

> might reflect the inherently different patterns of transmission of the Classical and El Tor biotypes. Infection with the El Tor strain results in both a longer period of vibrio shedding and a lower incidence of clinically apparent disease than infection with the Classical variety. In addition, the El Tor vibrio is hardier than the Classical and remains viable in water much longer (ibid).

2) Khan et al (1975) examined the relationship of reported water use patterns to cholera attack rates for a random sample of over 2000 families in Matlab Thana over the period 1966/70. Ninety five percent of the cholera was of the Classical/Inaba type.

Table 1, compiled on the basis of Khan's data, suggests that those who use tank water (tanks which connect with canals and receive tidal flow during the cholera season were omitted) for drinking, washing or bathing have attack rates from cholera which are lower than those for families using other sources. In particular there is no significant difference between attack rates of families drinking canal, river or tubewell water, while the attack rate for tank water drinkers is significantly lower than that for users of any other source. Extending the period of analysis to 10 years and thus including both Classical and El Tor cholera, Khan found similar differential attack rates.

Table 1: The Effect of Water Source on Cholera Attack Rates in Matlab Thana, Bangladesh (Khan et al 1975)

DRINKING:	% of families with cholera 1965 - 70:	Significant difference at 5% level? Canal	River	Tank	T.well
Canal	6.9% (27/389)	--	No	Yes	No
River	5.6% (19/342)	No	--	Yes	No
Tank	1.9% (18/962)	Yes	Yes	--	Yes
Tubewell	5.2% (27/515)	No	No	Yes	--

WASHING:	% of families with cholera 1965 - 70:	Significant difference at 5% level? Canal	River	Tank
Canal	8.9% (35/395)	--	No	Yes
River	4.1% (6/145)	No	--	No
Tank	3.0% (50/1663)	Yes	No	--

BATHING:	% of families with cholera 1965 - 70:	Significant difference at 5% level? Canal	River	Tank
Canal	7.0% (32/459)	--	No	Yes
River	5.4% (17/317)	No	--	Yes
Tank	2.9% (42/1430)	Yes	Yes	--

3) Levine et al (1976) observed the water collection practices of 88 families in two cholera prone villages in 1975. "For four days individuals using each source were identified and questioned about intended water use, if water was taken away" (ibid). Hospitalization rates for cholera and diarrheal diseases from 1963

to 1969 were computed for all families. The attack rates for those families who carried tubewell water five times more often than water from any other source for the stated purpose of drinking were compared with the attack rates for other families.

The data (presented on Table 2) were interpreted as showing that "tubewell users had as much or more cholera and other diarrheal diseases than non-users" (ibid). The authors also reported that "in affected baris annual rates for canal and tank users were almost equal (cholera = 11.9, 10.4 and hospitalized non-cholera diarrhea = 4.0, 3.8 per 1000 annual respectively)" (ibid). Tubewell water was found to be free of coliforms while canal water had coliform counts of over 1800 per ml. Since "connections exist between tanks and canal, particularly during the monsoon" (ibid) tank water was also, presumably, highly contaminated.

Table 2: Tubewell Use and Diarrhoeal Disease (Levine et al 1976)

	Cases	Person-years	Annual rate/ 1000	Rate ratio	Rate ratio 90% C.L.	p(2-tailed exact)
Cholera:						
Tubewell users	53	3725	14.2			
Tubewell non-users	13	1545	8.4	1.7	1.0;2.8	0.08
Non-cholera diarrhea:						
Tubewell users	28	3725	7.5			
Tubewell non-users	5	1545	3.2	2.3	1.0;5.2	0.07

C.L. = Confidence limits

4) Curlin et al (1976) have reported the preliminary results of the first year of a two year project, commissioned by UNICEF and undertaken by the CRL, to study the impact of the hand-pump tubewell on cholera, shigellosis and overall diarrheal illness rates

in 12 villages of Matlab Thana. Families were visited weekly and diarrheal episodes recorded. Each month families were questioned on the sources of water for drinking, bathing, cooking, washing utensils and use after defecation. From their data, summarized on Table 3, the authors "failed to detect a consistent pattern relating drinking tubewell water and diarrhea rates" (ibid).

Table 3: One Year Disease Rates (per 1000 per year): Curlin's Matlab Study

Drinking Water Source	Reported Diarrhea Rates (in field)	Confirmed Cholera Rates (at hospital)	Confirmed Shigellosis Rates (at hospital)
Tubewell	789	4.32	0.93
Other sources	757*	1.04*	1.50**

* Rates are significantly different at 1% probability level.
** Rates are not significantly different at 1% probability level.

c) Why the surprising and contradictory findings?

While these studies were executed in the belief that the findings would provide policy-makers with guidelines for future water improvement programs, taken as a whole they serve to confuse rather than to illuminate. In this section we will subject the methods and the findings of these studies to closer scrutiny through the examination of a series of hypotheses. The epidemiological and practical implications of the studies are critically dependent on which set of hypotheses appears most plausible. Some of these hypotheses have been suggested and supported or rejected by the investigators themselves, others have appeared in the literature as possible explanations of the findings, while a few have not been presented previously but appear to resolve some of the confusions arising from this set of studies.

Hypothesis 1: The use of tubewell water for drinking does not protect individuals against cholera.

Hypotheses concerning the effect of protected drinking water supplies on attack rates from cholera arise from the knowledge that the vibrios must be ingested and the belief that the bulk of this ingestion comes through the swallowing of polluted water. To test the hypothesis that those who drink bacteriologically pure water will have lower cholera attack rates than those who drink polluted water, the variable which needs to be measured is actual water ingestion by the individual in terms of source, quality and quantity. Since these data are extremely difficult to collect and demand considerable resources when they can be collected, a variety of surrogates have been used in these studies.

Thus, despite the fact that each of the Matlab studies has been interpreted as rejecting the hypothesis that the use of tubewell water for drinking protects individuals against cholera, the hypothesis cannot be tested on the basis of the available data, since none of these studies have collected data on actual water consumption by individuals. Sommer and Woodward stated that villager's responses were unreliable and assumed that distance to a protected source was a proxy for the use of drinking water from that source; Khan used questionnaire response data directly; Levine observed water collection patterns at the village tubewells; Curlin checked questionnaire responses by testing drinking water containers in the home for iron (since the iron content of Matlab tubewell water is high). As will become evident, this failure to measure actual consumption of water by individuals may be a serious deficiency in these studies.

This limitation is clearest in the study of Sommer and Woodward. They assumed that villagers who lived within fifty feet of a tubewell would be much higher users of tubewell water than those who lived more than fifty feet from a tubewell. Levine's data, however, show that families close to tubewells did not take water from this source any more frequently than those further from the tubewell, while Curlin's data show that there is a relationship between proximity and use by the family, but that this relationship is much less pronounced than that assumed by Sommer and Woodward. An examination of 1974 reported water use data in Meharan, the study village, reveals the following:

Table 4:

% of families using tubewells for drinking water	Families living within 50 feet of tubewell	Families not living within 50 feet of tubewell
Sommer and Woodward's assumption	very high use	very low use
1974 Census data	100%	89.7%

Since Curlin's data (which included the village of Meheran) show that there is virtually no mis-reporting of tubewell water use (in that every family which claimed to drink tubewell water had a container of tubewell water in their house). Sommer and Woodward's analysis appears to be completely invalidated by their choice of an inappropriate water consumption surrogate.

The other three studies do not obviously suffer from the same deficiency in the surrogate measure. Taken as a whole they provide convincing evidence that those families who say that they use tubewell water for drinking, who carry tubewell water to their homes, and who have tubewell water in a container in their homes do not have significantly lower attack rates than those families who do not use tubewell water. These studies do not, however, refute the hypothesis that those individuals who drink primarily tubewell water have lower cholera attack rates than those who drink primarily from surface sources. The difference is subtle but, as will become apparent, possibly extremely important. Hypothesis 2: Cholera in rural Bangladesh is not primarily a water-borne disease.

The Matlab studies have stimulated a provocative response from Feachem, who has stated that "cholera is more likely to be spread by indirect faecal-oral contacts, for example with contaminated food, than by water" (Feachem 1975) and has "read the paper by Levine et al as another piece of evidence to support the concept that much faecal-oral disease transmission in the rural tropics is non-water-borne" (Feachem 1976).

For cholera in Bangladesh, however, a large body of epidemiological evidence corroborates the classical findings of John Snow, leaving little doubt that water is the primary vehicle of transmission while person to person contact is of secondary importance. We review some of this evidence below.

Martin and his colleagues examined an epidemic of Classical cholera in Dacca. They found that cholera clustered in geographically compact communites each of which was affected for a relatively short time and that while "family outbreaks were seen in only 6.9% of families where adult males were the first cases, ... multiple cases occurred in 21.3% of families in which women and children were the first cases" (Martin et al 1969). The postulate that this descrepancy in secondary case development is due to the closer contact of women and children with food and water supplies is not supported by the timing of these secondary cases. The authors suggest that this differential is due to the fact that the more mobile male is exposed to sources of infection which are not shared by other family members.

The relative unimportance of person-to-person spread in Bangladesh is suggested by other data, too. "Repeated bacteriological examinations of hospital attendants of cholera patients and of neighbourhood contacts not sharing a common water supply have rarely revealed infection, suggesting that person-to-person contact is very rare" (Mosley 1970).

Extensive monitoring of the presence of V. cholerae in the environment of index cases in the 1976/77 cholera season in Matlab Thana by W. Spira and his colleagues supported previous findings that vibrio are seldom detected in food (Barua, 1970) and formites (Gangarosa and Mosley 1974) under natural conditions. Spira was, further, seldom able to isolate V. cholerae on the hands of those who lived in the community of the index case, but consistently detected vibrios in the majority of tanks and canals in the vicinity.

Exceptionally high attack rates in groups whose occupations bring them into close association with surface water sources, too, indicate the primary role of water in cholera transmission in Bengal. Boatmen and people who reside on boats have been especially afflicted (Pollitzer, 1959) while boatmen and fishermen have frequently been the source of infection for others using surface waters. (See Khan and Mosley, 1967 and McCormack et al 1969.)

Thus, while contaminated foods, in addition to contaminated water, have been implicated in explosive cholera epidemics, in the typical protracted cholera epidemics of Bangladesh "this pattern has been related primarily to transmission by water" (Gangarosa and Mosley 1974). "Usually a large body of water, such as a river, tank or canal, exposes a community to a relatively low dose, which only occasionally reaches a susceptible person to produce a frank case" (Gangarosa and Mosley 1974).

The apparent inconsistency of Levine's (and other's) data with the theory that cholera in Matlab is water borne, the apparent inconsistency which led Feachem to suggest that cholera was not water-borne, will be examined later. Anticipating that discussion, we suggest that there is an alternative explanation for the lack of an effect of "tubewell drinking" on the incidence of cholera which appears to fit with the other epidemiological evidence which has been compiled on the epidemiology of cholera in Bangladesh.

Hypothesis 3: The small amount of protection afforded by drinking bacteriologically safe water is overwhelmed by the exposure to polluted surface water through bathing, food preparation and utensil washing.

In rural Bengal, in general, "during bathing and washing a handful of water is repeatedly taken into (the mouth)" (Kochar 1975) and "the nose and mouth are irrigated and rinsed, a procedure accompanied by vigorous hawking and spitting" (Bang et al 1975); in addition in Matlab the high-iron in the tubewell water ensures that this water is virtually never used for cooking or utensil washing. The investigators of each of the tubewell studies in Matlab have suggested that these non-drinking water use habits explain their findings, namely that families who used tubewell water did not have lower cholera attack rates than those families who did not use tubewells.

> Sommer and Woodward (1972): "... the El Tor biotype ... might be capable of transmission through more casual contact with, and less ingestion of, alternative sources of contaminated water. The potential for such contact abounds, especially with the ubiquitous practice of washing and bathing in the local rivers and tanks."

> Khan et al (1975): "It can be inferred that the water used for washing and bathing is either equally or more important than the water used for drinking alone in the occurrence of cholera."

Levine et al (1976): "The unexpected finding that tubewell users do not have lower cholera infection-rates suggests that their regular use of contaminated surface-water sources maintain-infection-rates equal to those of tubewell non-users. Even tubewell-water drinkers preferred surface water for bathing, washing and preparing food."

Curlin et al (1976): "In the Bangladesh context surface water is an integral part of the rural culture and the small amount of protection afforded by drinking bacteriologically safe water may be overwhelmed by the exposure to polluted surface water through bathing, food preparation and utensil washing."

This explanation does not appear to be entirely satisfactory. The water use habits of rural Bengalis are such that all members of a community would be exposed to cholera if the surface sources contained cholera vibrios. The issue, however, is not whether it is possible for those who drink tubewell water to contract cholera from surface water sources -- it certainly is -- but whether cholera attack rates among tubewell drinkers are substantially lower than attack rates among populations who do not drink tubewell water.

To examine this issue further, consider the following simple model:

$$\text{Probability of acquiring cholera} = \sum_{\text{all } i} \left(\text{probability of ingesting } i \text{ vibrio} \times \text{probability of contracting cholera given to the ingestion of } i \text{ vibrio} \right)$$

While we know little about the behaviour of vibrios in water, it seems unlikely that there would be systematically different vibrio counts, per unit of volume, in the water used for bathing and in the water which is drawn from the same surface source for drinking. While, again, there are no data on this factor, it seems reasonable to assume that the quantities of water which people consciously drink are likely to be substantially larger than those which are ingested during other interactions with water. We would thus expect people who drink tubewell water to ingest a given number of vibrios, say i vibrios, far less frequently than people who drink surface water.

Something is known (Hornick et al, 1971) of the second factor in the above equation for a small group of U.S. prison volunteers, but nothing is known about the susceptibility of any population, including rural Bangladeshis, under field conditions, to various doses of cholera vibrios. What is important, however, is not the absolute level of this dose, but the relative levels of this dose in the tubewell-using and surface-water-drinking populations. There is unlikely to be any systematic difference. This simple model — and it is, of course, no more than a simple model — would suggest that the apparent finding, namely that people who drink primarily tubewell water do not have substantially lower cholera attack rates than those who drink surface water, is not plausible.

That this model is not radically different from the implicit models of cholera epidemiologists was evident from the results of informal interviews with a small sample of foreign cholera experts in Dacca. The results indicated that these people all drank boiled water but that they generally brushed their teeth and bathed in unboiled water and that their dishes were generally washed in unboiled water. Upon being questioned on the effects of their water use habits on their susceptibility to cholera, if there were cholera vibrios in the water supply, the experts suggested that it would be possible for them to contract cholera but that the probability of contracting cholera would be substantially reduced as a result of their drinking of boiled water.

Hypothesis 4: In families who are tubewell users there may be individuals who do not drink tubewell water and these individuals may be those who are most susceptible to cholera.

The hypothesis that the tubewell program in Matlab would affect cholera rates in the population was founded on two assumptions: i) that cholera is primarily a water-borne disease in this environment; and ii) that those who drink bacteriologically pure water are much less likely to contract cholera than those who drink contaminated water. These assumptions have been examined above and seem to hold in the Matlab environment. Why, then, do tubewell-using families not have lower attack rates from cholera?

McCormack et al (1969) have published data on the age specific attack rates from classical cholera in Matlab in 1963/4, 1964/5 and 1965/6. ....The age structure for Bangladesh as a whole in 1961, as presented by Mosley and Hossain (1973), is assumed to hold for Matlab in these years. Yen (1964) has documented an outbreak of cholera in Taiwan which occurred 16 years after the previous outbreak, and found that the carrier to case ratio in children was much higher than in adults. In Bangladesh, an endemic cholera area, the opposite is found — the carrier to case ratio is higher for adults than it is for children in both urban (see Mosley et al (1968)) and rural (see McCormack et al (1969) and Benenson et al (1968)) settings. Pooling the available Bangladesh data we find:

carrier to case rate for children under 10 = 1.22, and
carrier to case rate for people over 10 = 2.07.

From these data Table 5 is derived.

Table 5:

Age group	Average attack rate (3 seasons data): Cases/ 1000/year	% of Total Population	% of Total Cholera Cases	% of Total Cholera Carriers
0-4	10.0	19.5	48.2	40.9
5-9	6.2	17.2	26.3	22.4
10-14	2.9	10.1	7.2	10.4
15-29	2.9	21.4	15.3	22.1
30-49	0.6	19.7	2.9	4.2
Over 50	0.0	12.1	0.0	0.0

Cholera in Matlab, then, is strikingly a pediatric infection and disease.

The age distributional characteristics of cholera make the drinking habits of those over the age of ten essentially irrelevant in the Matlab investigations. If the drinking habits of children under the age of 10 years are such that they consume most of their water from non-tubewell sources, even when there is tubewell water in the house and this water is used for drinking by other family members, then we would not expect the presence of this tubewell water to have a discernible effect on the incidence of cholera disease and infection in this community.

Experienced field workers suggest that children in tubewell-using families may well drink primarily surface water. Several factors seem important:

1. Since no families use tubewell water for cooking, there is always at least one container of surface water in the house.

2. In middle class Matlab families, "children below the age of about one year are said never to be given plain cold water to drink as its temperature is considered too chilling for them... (and) ... some people say that (tubewell water) temperature is too cold and causes them to catch cold and lose their voices" (Lindenbaum, 1965).

3. Children are unlikely to be instructed or supervised concerning the choice of a container from which to extract drinking water.

4. Children may prefer the non-tubewell water for drinking, since "the surface water is warm .... (and) of much better quality in both a chemical and aesthetic sense" (Curlin, 1976).

5. Children may drink water from outside of the home.

There are two ways of investigating the issue further.

1. If it is true that children, say under the age of ten, do not drink tubewell water even when it is in the house but that people over the age of ten do drink this water, then we would expect no differential attack rates for those under the age of ten but would expect to find differential attack rates for those over 10 years old.

   From the results presented earlier it is clear that only Khan's data give large enough numbers of cholera cases to even consider this analysis. Unfortunately Khan's family data — the village data collected since 1970 would be of no use for this purpose — were misplaced in the turmoil surrounding the Liberation of Bangladesh in 1971. While these data, or a similar set, could be recovered from the CRL records, this is not a trivial task. If these data <u>were</u> retrieved, what could we expect to learn?

   Khan's family attack data are summarized on Table 1. We assume the average family size to be 5.8, and, from the data presented earlier, assume that 63.3% of the population is over 10 years old and that this group accounts for 25.5% of the cholera cases. Using a one-tailed Student's t criterion, we find that we require:

$$\frac{\text{cholera attack rate among tubewell users}}{\text{cholera attack rate among non-tubewell users}} \leq 23\%$$

before we could show a difference in attack rates at the 5% significance level.

If we look, instead, at the age group over 10 years which has the highest attack rates, namely the 15-29 age group, we find that we require:

$$\frac{\text{cholera attack rate among tubewell users}}{\text{cholera attack rate among non-tubewell users}} \leq 5\%$$

before we could demonstrate a significant difference in attack rates at the 5% level.

From these calculations it is clear that a larger sample (Khan's population was about 13,000) is needed before meaningful conclusions can be drawn from such an analysis. This would certainly be a useful exercise, but the work involved would be considerable.

2. The other approach would be to study, at the household level, the water consumption practices of different age groups in both tubewell using and non-tubewell using families. This would appear to be a highly worthwhile study which would give a good idea of whether or not the hypothesis advanced in this section provides an explanation for the counter-intuitive results of the Matlab studies.

Hypothesis 5: Those who use water from "disconnected" tanks for their surface water requirements are likely to have lower cholera attack rates than those who use canal or river water for drinking, cooking, bathing and utensil washing.

There is an apparent contradiction in the findings of Khan and Levine on the difference in attack rates between tank users and canal users. Khan's results, based on data for the whole of

Matlab Thana, indicate that those who use tanks which are disconnected from canals and rivers during the cholera season have much lower cholera attack rates than those who use canal water, while Levine found no such differential when he examined cholera rates among users of all tanks (from Levine's description these appear to be mostly "connected" tanks) and canal users in two villages which have unusually high attack rates. Since these findings have potentially important policy implications we will examine this "contradiction" further.

Extensive monitoring of water sources in villages which had cases of cholera during the 1976/7 season by Spira and his colleagues (personal communication) showed that there is little, if any, difference in the mean vibrio counts in tanks and in rivers and canals in these villages. These data support those of Levine, and it seems reasonable to conclude that once cholera is introduced into a community there is unlikely to be any difference in attack rates between tank users and canal users.

The spread of cholera has been widely associated with communication and transportation routes. (Pollitzer, 1959). In Bangladesh the association between rivers and canals has been documented many times and unusually high cholera attack rates in boatmen and fishermen recorded (Gangarosa and Mosley, 1974). We thus expect communities which are located on busy canals to have higher attack rates than those which are more isolated. There appear to be two factors which may account for Khan's finding that disconnected tank users have lower cholera attack rates.

1. Communities which are not located on canals and rivers may be expected to have a higher proportion of "disconnected" tanks. Since these communities are likely to have lower cholera rates for the same reason, namely their distance from canals, the apparent relationship between the use of disconnected tanks and low attack rates may be, in part, a spurious relationship.

2. The probability of introduction of cholera into a community which is located on a canal may be proportional to the percentage of the population who use the canal and/or connected tanks to meet their water requirements.

The findings of Khan and Levine, then, are not necessarily contradictory. It seems reasonable to conclude:

1. Given its location relative to a canal, if the proportion of the community using disconnected tanks increases, the likelihood of that community having cases of cholera will decrease;

2. Once cholera has entered a community, those who use "disconnected" tanks are likely to have the same attack rates as those who use canal, river and "connected" tank water.

PART II: ISSUES IN DOMESTIC WATER SUPPLY POLICY

1. The implications of the CRL studies on water and cholera for policy in rural Bangladesh

The CRL investigators have suggested that the present program for increasing the number of tubewells in rural Bangladesh (a $40 million program) may not be justified for the stated purpose of controlling cholera and other water-borne diseases. On the basis of the cholera data only -- the limitations of cholera as a model for water-related diseases will be addressed in the next section -- the implications of the analysis presented above are quite different.

The unusually high population density (2322 persons per square mile in Matlab Thana compared to 1286 persons per square mile in Bangladesh as a whole (Government of Bangladesh 1975a)) implies an unusually high density of housing, while the deep flooding to which the area is subjected (World Bank data show that but 15% of the population of Bangladesh live in comparably flooded areas) necessitates abnormally large flood-protection mounds for these houses. Since tanks are excavated to obtain earth for both the mounds and the houses themselves, the areal density of tanks in Matlab is almost certainly extraordinarily high. These demographic and hydrologic factors further lead to an exceptionally dense network of rivers and canals. The average Matlab villager, then, is an atypical Bangladeshi villager in terms of access to surface water sources.

While the government has experience difficulties in its tubewell program in other areas (approximately 14% of the thanas require deep tubewells, 2% of the thanas have chloride problems and 1% of the thanas are unsuitable for either deep or shallow tubewells in at least some areas), the tubewell situation, too, is atypical in Matlab since in only 6% of the thanas have similar problems been experienced with the high iron content of the groundwater (Government of Bangladesh 1975b).

The combination of these factors means that in Matlab tubewell water is less attractive than it is in most other parts of Bangladesh, while there is an uncharacteristically high availability of water from tanks, canals and rivers.

If the hypothesis that young Matlab children are drinking a large amount of surface water which is in the house for cooking purposes is correct, then we would expect quite different results from a similar study of water use and cholera in an area where the ground water quality is good and where this water is used for drinking and cooking.

While data on water use habits in other parts of Bangladesh are few, informal interviews with Bangladeshis from different parts of the country suggest that in most areas groundwater sources are used for both cooking and drinking water. Data from the Teknaf Dysentery Project in the extreme southeastern tip of the country show that, despite the availability of surface water in a few tanks, drinking water is obtained exclusively from groundwater sources (85% from ringwells) and that in virtually all families cooking water and drinking water are drawn from the same source (Mujibur Rahaman, personal communication). In this area we would expect groundwater users to have substantially lower attack rates than those who use surface water sources for drinking and cooking. If the hypothesis behind these speculations is correct, in areas where tubewell-(or other ground-) water is used for drinking but not for cooking, health education programs should stress the importance of encouraging young children to drink from the drinking water and not the cooking water pot.

The interpretation of the data on differential attack rates among "disconnected" tank users and other surface water users has interesting policy implications. It would appear that the probability of introducing cholera into a village would be substantially reduced if a higher proportion of villagers used "disconnected" tanks for most of their water requirements. This could be achieved by a construction program which would make "connected" tanks into "disconnected" tanks. It could also be achieved by educating people to use disconnected tanks and by enhancing the attractiveness of these tanks through further excavation and by improving the quality of the ghats. While land is scarce, the possibility of constructing new disconnected tanks should also be considered. Tank development programs should explicitly take into account the integral relationship between health and poverty and, particularly, health and nutrition. The use of ponds for other important purposes, such as irrigation, fish, fertilizer and fuel production (see Smith 1973 and National Academy of Sciences 1976), may be competitive with their use for domestic water supply. Pond fertilization, for instance, may increase fish productivity but adversely affect water quality, while the maximum demands on the ponds for both irrigation and domestic water supply are likely to occur during the dry season. Problems arising from unequal distribution and divided and disputed ownership of tanks must also be explicitly addressed if these resources are to be efficiently and equitably utilized.

2. <u>The use of classic water-borne diseases, such as cholera, as models for water-related diseases.</u>

The approach taken by John Snow in his investigations of the Broad Street Pump cholera epidemic of 1854, an approach which has been modified and elaborated in many subsequent studies of common-source epidemic outbreaks, has enormous appeal. The scientific method, in which a model of disease communication is postulated and the validity of the model tested by the acquisition of field data, is elegant, while the results have clear and immediate policy implications. For most endemic diarrheal diseases, however, understanding is relatively poor. Pathologists are unable to isolate causative organisms for most diarrheas and epidemiologists have yet to satisfactorily describe the relationships of most diarrheal diseases to environmental conditions. The clarity of the cholera-type model has made this the dominant form for conceptualization of the relationships between the environment and water-related diseases. "Water-borne" is widely considered to be synonymous with "water-related" and the provision of a pure water supply is generally accepted as the foremost priority in domestic water planning.

The traditional classification of water-related diseases as bacterial, protozoal, helminthic and viral provides few insights into the modes of transmission of these diseases and few clear policy guidelines. The most important recent advance in understanding the relationships between water and health has been the development of a scheme by David Bradley (see White, Bradley and

White, 1972) in which diseases are classified according to the nature of their relationships to water. Water-borne diseases, such as cholera and infectious hepatitis, are contracted through the drinking of water which acts as the passive carrier for the pathogenic organism. These diseases are combatted through water quality improvements and by the prevention of the casual ingestion of water from contaminated sources. Water-washed diseases, such as shigellosis and scabies, are prevalent where hygienic practices are poor. The incidence of these diseases declines when water becomes more available and increased quantities of water, irrespective of quality, are used for hygienic purposes. The pathogens transmitting water-based diseases such as schistosomiasis and guinea worm are dependent on aquatic organisms for completion of their life cycles. Water improvement strategies for combatting these diseases include improving the quality of the water and reducing the contact of the population with infected water sources. Diseases such as sleeping sickness and malaria are transmitted by water-related insect vectors which either breed or bite near water. Control strategies include improved surface and waste water management and reduction in time spent in the vicinity of breeding sites.

When the important water-related diseases of an area are classified according to this scheme, a series of policy directions are immediately evident. In Bangladesh, "the home of cholera", water improvement programs have been exclusively focused on the provision of a pure source of drinking water. The most important diseases, the general diarrheas, are, however, usually transmitted by person-to-person contact (Gordon 1964), and their prevalence is likely to be affected more by water quantity than by water quality (Wall and Keeve 1974). The diarrheas are, therefore, properly classed as water-washed diseases (White, Bradley and White 1972). In rural Bangladesh the highest seasonal prevalence of diarrheas is not coincident with the cholera season in the post-monsoon months, but occurs, as in other areas of the world (Gordon et al 1964), during the season of low water availability. Superficial water-washed diseases are also important. In Noakhali District "scabies is a major cause of death from overwhelming infection and from nephritis subsequent to less serious infection with streptococcol organisms" (McCord 1976); in Matlab, children under 9 years old suffered from an average of 2 cases of scabies in the past three years (M. Khan, personal communication). Water-based and water-bred diseases are relatively unimportant at present (although indications are that malaria may soon be a major health problem once again).

In Matlab, then, water washed diseases (both intestinal, such as diarrhea, and superficial, such as scabies) are the most important water-related diseases. The strategies for reducing the threat of cholera and other primarily water-borne diseases discussed earlier should not be ignored, but should be considered in conjunction with the logical primary water improvement objective which is the provision of adequate quantities of water within the home, particularly during the season of low water availability.

3. <u>The use of "intermediate variables" in research and planning</u>.

Water improvement programs are expected to improve health by facilitating different patterns of water use and by altering the quality and quantity of water used by individuals. In the cholera studies we have seen how serious problems of interpretation arise from the use of intermediate variables such as distance from tubewells rather than the actual water use patterns of indiviuals.

In designing water improvement programs a priamry aim is to improve health by altering water use patterns. Since the planning and execution of these programs is the responsibility of bureaucrats and engineers, the success of such programs tends to be measured in terms of the proportion of allocated resources which have been spent and the achievement of physical targets such as the installation of tubewells. Little attention is paid to the behavioural changes induced by the program.

The result of this centralized, technocratic planning is that the association between the provision and use of water supply and sanitation facilities is often weak. This is particularly marked for rural areas. Changes are required in both research and planning methodologies. Micro-level behavioural research must be undertaken to expand the present rudimentary understanding of the factors which affect the choices of water sources for different purposes and the quantity of water used. As Navarro (1974) has shown, the health planning process reflects the distribution of political power within a country. In Bangladesh, as in many other poor countries, rural preventive health programs have been accorded low priority by the Wester trained urban elite. Where rural water improvement programs are undertaken villagers are seen as ignorant beneficiaries of the benevolence of the central government. They therefore need to be educated to change their habits and are seldom consulted on what they perceive to be their water supply problems. Until the power structure is altered and the masses become involved in the health planning process it is unlikely that the "poor correlation between investment and health" (Bradley 1974) will change.

4. The specification of water supply standards

As has been the case with the importation of technology, poor countries have frequently adopted the quality standards of Western countries. This has been particularly marked in engineering and medical practice. Water supply quality standards, and health standards in general, however, reflect the society's implicit valuation of human life, the opportunity cost of capital and the cost of water treatment (Thomas 1963). Given the existing distribution of resources, poor countries should, ceteris paribus, set lower quality standards than rich countries, since the opportunity cost of capital in poor countries is higher. While economies of scale may imply lower per capita treatment costs in urban areas and thus justify somewhat higher water supply standards in these areas, the high public expenditures on the water supply of certain groups and the much smaller per capita expenditures for the majority mean that the lives of the elite are being valued much more highly than the lives of other members of society. This fact is not surprising, but it is not generally understood that this is implicit in the frequent maintenance of "international" standards for a few while many receive little or no attention. Bradley (1974), arguing for similar changes has stated:

> (The engineer) must design less orthodox low cost systems. These increase the risk of water-borne disease and he must choose between some people catching typhoid from one of his systems, or leaving a lot of others to go on catching typhoid from unimproved wells .... The problem is strictly analogous to the struggle over community medicine in the education of doctors. The physician's view was limited to his patients, he felt no responsibility for the sick (or healthy) who did not come to see him.

DISCUSSION

An understanding of the relationships between water use and health is not new. Frontinus, the Water Commissioner of Rome, understood that health was affected by the quality and quantity of water consumed and that different water sources were appropriate for different purposes (Babcock and Matera 1973). That our knowledge has advanced, in some ways, so little — we are unable to make more precise general statements than "other things being equal, a safe and adequate water supply is generally associated with a healthier population". (International Bank for Reconstruction and Development, 1976) — should make us cautious of undertaking multi-million dollar research projects in the hope that these will provide definitive answers to all of the important questions. The literature on the subject of water and health is both quite extensive and confusing. What appears to be necessary is some serious thinking, perhaps along the lines of the analysis of the cholera studies above, on the reasons for the many apparent contradictions in the findings of published studies. These differences are frequently brushed aside too lightly with the assertion that we should not expect similar results in different study areas. Future reviews of the literature should attempt to explain why the findings of, say, the effect of improved water supplies on cholera are different in the Philippines and Bangladesh, and why the effects of water supply are different on, say, shigellosis and cholera in Bangladesh.

In water supply policy the fundamental need appears to be a reorienting and restructuring of the decision-making process. The continuation of traditional water use habits when the people of poor countries are presented with alternative sources of pure water is generally ascribed to the ignorance of the uneducated masses. The prescription then becomes education of the ignorant and the identification of communication barriers. In this paper it has been suggested that the fault lies not so much with the recipients of these programs as with the process whereby these programs are conceived. An understanding of the water use habits of the majority and the factors which affect these habits is necessary as is the incorporation of the potential users into the process of decision-making on water improvement programs.

ADDENDUM

The Matlab studies which have been analyzed in this paper indicate that cholera attack rates in families who use tubewell water are not different from the attack rates in families who do not use tubewell water. In this paper I have suggested that children in families who use tubewell water may, for a variety of reasons, drink primarily from surface water sources. If this hypothesis were true the counter-intuitive findings of the Matlab studies would be explained.

This note reports a few subsequent observations of the water consumption practices of young children in Matlab families who reported using tubewell water for drinking.

Method:

Ten families were chosen on the basis of the following criteria:

1. The villages chosen were to be easily accessible to the Matlab Hospital but were not to be part of the Matlab Bazaar area;

2. The families were to have at least 2 or 3 young children;

3. The families were to have reported using tubewell water in the 1974 census;

4. The families were to be chosen such that the socio-economic and educational status ranged from well-off and educated to poor and uneducated;

5. Both Hindu and Muslim families were to be represented.

During the month of April, 1977 two trained female field workers were employed for this brief study. Each family was observed for a full day, with one observer stationed in the house from 6 a.m. until 2 p.m. and the other observing from 1 p.m. until the children went to bed (at about 8 p.m.). One child of age 4 or 5 was chosen in each family and every interaction of that child with water was observed and the time and nature of the interaction was recorded. All interactions of other young children with water was recorded where these could be observed. Particular attention was paid to the source of the water in the various containers, the place in which the water was stored, whether the water was taken from a container inside or outside of the dwelling, whether the water was given to the child by an adult and whether water appeared to be ingested during the interaction. While the families were informed that the activities of the children were to be observed, the mothers were not aware that the specific purpose was to observe water use patterns.

Results:

In nine of the ten families the pattern of placing the water from different sources was the same — the tubewell water for drinking was stored in containers inside the house while the surface water for cooking and washing of hands and feet was stored outside of the house. In the tenth family three containers of canal water and two of tubewell water were inside the house, while one container of canal water was placed outside of the house.

Thirty-six children between the ages of six months and ten years were observed to ingest water a total of 105 times. Despite the fact that in nearly 50% of the cases the water was drawn by the children themselves, on every single occasion the water was drawn either directly from a tubewell or from a container of tubewell water.

Discussion:

In collecting these data one four or five year old child was followed throughout the day and the activities of the other children recorded when this was possible. The mobility of children under the age of five years proved to be limited and it is believed that most of the activities of all children in this age group were recorded. The older children were less accessible for observation since they played further from the home and, in some cases, went to school. It seems certain that a significant proportion of water which was ingested by these children was not observed.

Despite the fact that the sample is very small, it is striking that young children do drink tubewell water when this is stored in the drinking water vessels within their homes.

This is true when the children withdraw the water from the containers themselves and when the water is drawn for the child by an adult. While this preliminary study was conducted in April and not in the "cholera season" (November to January) it seems unlikely that these patterns would vary greatly.

We are thus left with no satisfactory explanation of the results of the tubewell studies in Matlab. A large body of epidemiological data points to water as the primary vehicle of transmission in rural Bangladesh and it appears that in those families who use tubewell water the vast majority of the water ingested by the most susceptible group — young children — comes from this safe source. Tubewell water in Matlab does not become polluted between the pump and the mouth (Spira, personal communication). Thus children who ingest, almost exclusively, water of good bacteriological quality apparently have the same cholera attack rates as those children who drink highly polluted water. Why?

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