TECHNICAL REPORT

HEALTH BENEFITS FROM IMPROVEMENTS IN WATER SUPPLY AND SANITATION:

SURVEY AND ANALYSIS OF THE LITERATURE ON SELECTED DISEASES

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by

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RELATED WASH REPORTS

The Value of Water Supply and Sanitation in Development: An Assessment of Health-Related Interventions. September 1987. WASH Technical Report No. 43. Prepared by Daniel A. Okun. Also available in French and Spanish.

Relating Improvements in Water Supply and Sanitation to Nutritional Status. October 1982. WASH Technical Report No. 16. Prepared by Raymond B. Isely.

Linking Water Supply and Sanitation to Oral Rehydration Therapy. July 1985. WASH Technical Report No. 31. Prepared by Raymond B. Isely.

CONTENTS

FIGURES

TABLES

APPENDIX

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EXECUTIVE SUMMARY

This report reviews and analyzes the findings of a number of studies of the impact of improved water supply and sanitation facilities on six diseases: diarrheal diseases, ascariasis, dracunculiasis (guinea worm), hookworm, schistosomiasis, and trachoma. The studies were restricted to those written in the English language. These particular diseases were chosen for review because they are widespread and because they illuminate the variety of mechanisms through which improved water and sanitation may protect people. For example, providing safe, potable sources of drinking water blocks the transmission of guinea worm, while using larger quantities of water for personal hygiene helps to stop the spread of trachoma. Improving domestic hygiene practices and providing excreta disposal facilities are also important mechanisms for interrupting disease transmission.

The following table illustrates the prevalence and the adverse health consequences of these diseases in developing countries. These diseases are either widespread in the developing world, constitute serious problems where they exist, or both.

INCIDENCE AND EFFECTS OF SELECTED DISEASES IN DEVELOPING COUNTRIES (EXCLUDING CHINA)

DISEASE	ESTIMATED CASES/YEAR	ESTIMATED DEATHS/YEAR
DIARRHEA	875 MILLION	4,600,000
ASCARIASIS	900 MILLION	20,000
GUINEA WORM	4 MILLION	*
SCHISTOSOMIASIS	200 MILLION	*
HOOKWORM	800 MILLION	*
TRACHOMA	500 MILLION	**

* EFFECT IS USUALLY DEBILITATION RATHER THAN DEATH
** MAJOR DISABILITY IS BLINDNESS

A total of 144 studies were reviewed for this report. When possible, a percentage reduction in disease attributable to water, sanitation, hygiene, or any combination of these, was calculated for each study. Only those studies with identifiable reduction rates were further analyzed. Grouping the studies for each disease, a disease-specific median reduction figure was then calculated, and a second median reduction figure was derived for the more methodologically rigorous (better) studies. These figures are shown in the table below.

	All Studies			Better Studies		
	NO.	MEDIAN	RANGE	NO.	MEDIAN	RANGE
Diarrheal diseases						
· Morbidity	49	22%	0%-100%	19	26%	0%-68%
· Mortality**	3	65%	43%-79%	-	–	–
Ascariasis	11	28%	0%-83%	4	29%	15%-83%
Guinea worm	7	76%	37%-98%	2	78%	75%-81%
Hookworm	9	4%	0%-100%	-	-	–
Schistosomiasis	4	73%	59%-87%	3	77%	59%-87%
Trachoma	13	50%	0%-91%	7	27%	0%-79%
Overall impact on child mortality	9	60%	0%-82%	6	55%	20%-82%

Expected Reduction in Morbidity and Mortality from Improved Water Supply and Sanitation*

For additional information see Appendix B, Table 7.

* Indicates morbidity reduction unless noted otherwise.

** There were no "better" studies.

The results of the studies selected for analysis show that the impact of water supply and sanitation is significant. Median reductions in morbidity (i.e., incidence and prevalence) calculated from the better studies range from 26 percent for diarrhea to a striking 78 percent for guinea worm and 77 percent for schistosomiasis. In between lie ascariasis and trachoma at 29 and 27 percent respectively. All studies of hookworm were flawed with one exception—which found a 4 percent reduction in incidence. For hookworm, ascariasis, and schistosomiasis, the reduction in egg counts was greater than the reduction in incidence or prevalence, suggesting that there is also a reduction in disease severity which is often overlooked.

The substantial impact of water and sanitation on child survival is also demonstrated by the studies reviewed. For overall child mortality, nine studies indicated a 60 percent median reduction, with a figure of 55 percent emerging from the six better studies; unfortunately, none of the better studies specifically addressed diarrheal disease mortality reduction.

In summary, broad, demonstrable health impacts affecting all age groups in most of the developing world can be expected from improvements in water supply and sanitation. This review also found that reductions in disease severity are sometimes larger than reductions in incidence. However, the importance of this impact is often overlooked. To maximize the health impacts identified in this review, the following factors should be considered:

- The water supply should be as close to the home as possible—to increase the quantity of water available for hygiene practices.

- Water supply and health programs should emphasize hygiene education to encourage people to use more water for personal and domestic purposes.

- Sanitation facilities should be culturally appropriate, since use of the sanitation facility will affect its health impact—probably reflecting the importance of user acceptance.

- Use of facilities is essential during critical seasonal transmission periods for diseases, such as guinea worm, which have such periods.

- In achieving broad health impacts, safe excreta disposal and proper use of water for personal and domestic hygiene appear to be more important than drinking water quality.

- Sanitation facilities should be installed in conjunction with water facilities when fecal-related diseases are prevalent.

1

INTRODUCTION

During the International Drinking Water Supply and Sanitation Decade, most of the research on health impacts of projects has emphasized diarrheal diseases and the resulting slower growth and mortality of young children. Evidence accumulated during the Decade supports the conclusion that water supply and sanitation improvements can benefit child health (Esrey et al , 1985; Esrey and Habicht, 1986), but maximum health benefits will only occur if facilities are functioning properly and well utilized.

There is a vast range of direct and indirect benefits which water and sanitation facilities are likely to provide (Okun, 1988). Direct benefits may include reductions in morbidity or mortality from several diseases, increased time for women to engage in non-illness-related child care activities, enhancement of agriculture and commerce, improved school attendance, reduced cost for health care, freeing of health service for attention to other problems, and an easing of the physical burdens of daily life. The indirect benefits are potentially more numerous and diverse, although they may be difficult to document or quantify. Examples of these include mobilization of the community for other activities once an organization for water and sanitation has come together, and satisfaction from a ready supply of drinking water. Water supply and sanitation improvements are potentially so far-reaching that their full benefits might best be described as increasing the quality of life in a community.

A renewed interest in the broader benefits of water supply and sanitation has led to questions about the health benefits that can be expected from reducing diseases in addition to diarrhea. This paper reviews the health impact of water and sanitation interventions on six diseases. The diseases under consideration are as follows: diarrheal diseases (including measures of nutritional status and child survival), ascariasis *(Ascaris lumbricoides)*, guinea worm (*Dracunculus medinensis*), schistosomiasis (*Schistosoma haematobium* and *S. mansoni*), hookworms (*Ancylostoma duodenale* and *Necator americanus*, and trachoma (*Chlamydia trachomatis*).

1.1 The Decade

Water and sanitation have received much attention over the past 10 years as a result of the United Nations General Assembly declaration of the 1980s as the International Drinking Water Supply and Sanitation Decade. While Decade data are not yet available to assess the progress made to date, the World Health Organization has reviewed the work done through 1985. The most significant achievement was in the area of rural water supply where worldwide coverage with improved services has increased from 32 percent in 1980 to 42 percent in 1985. This trend had been underway since 1970, so greater gains as a result of the Decade emphasis would have been expected. The record in the area of urban water supply is less impressive, as coverage levels increased only to 75 percent from 73 percent in 1980. Gains were also made in urban sanitation where coverage increased from 50 percent to 59 percent. The least encouraging area of all is rural sanitation where just 16 percent of the population was served in 1985; this represents less than a doubling since 1970, when the figure was 9 percent (WHO, 1986 and 1987). Gains have been made in absolute numbers and the percentage of rural population covered, but the proportion of people covered is still low due to population increases. Progress during the Decade is in jeopardy if efforts falter during the remainder of this century.

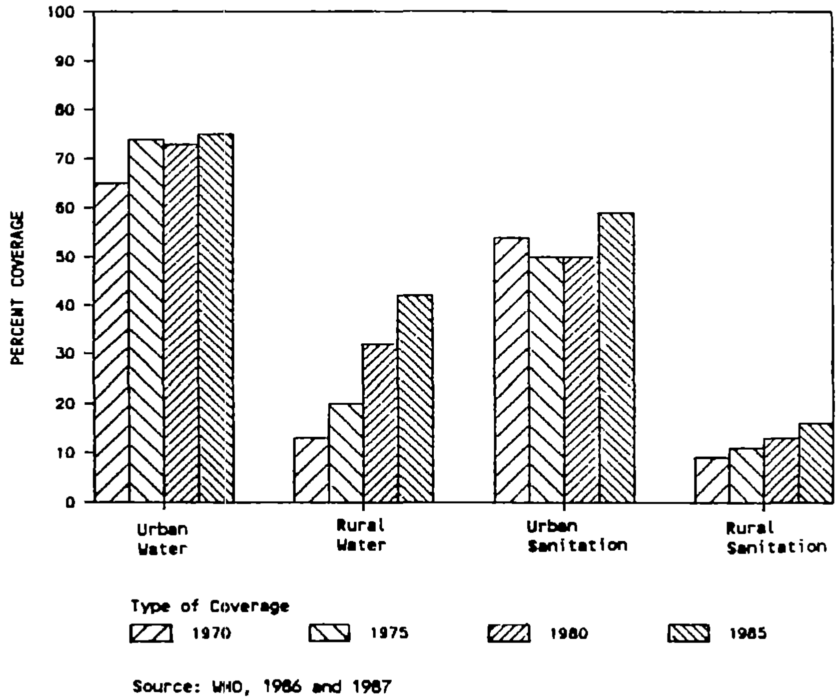

Figure 1

Water and sanitation coverage, 1970-1985, in less developed countries, excluding China

1.2 Types of Interventions

Water and sanitation are capital intensive interventions, but their success is thought to be dependent, in part, on community participation and changes in behavior, particularly changes in behavior associated with use of water. Therefore, four categories of intervention have been considered in this paper in evaluating each disease: excreta disposal, personal hygiene, domestic hygiene, and drinking water quality. The first relates to sanitation, the remainder to water supply interventions. Sanitation is defined in this paper as proper disposal of human excreta. Depending on the setting this could be a simple pit latrine, a flush toilet, or just acceptable disposal of infant feces. Water supply interventions can be separated into three components: drinking water, personal hygiene, and domestic hygiene. Improved drinking water supplies improve human health by eliminating a route through which pathogens are ingested. "Personal hygiene" refers to water used for cleaning the body, including bathing and washing the eyes, face, or hands. "Domestic hygiene" refers to the use of water in keeping the home clean, as well as cleansing those components of the home environment that are related to pathogen transmission (e.g., food, clothes, utensils, floors, counter tops, or towels). Both personal and domestic hygiene require a supply of water. Improving hygiene usually involves increasing the quantity of water available, but it may also require other changes, such as providing people with soap or encouraging frequent washing The way in which these types of interventions affect morbidity and mortality are different for each disease and are reviewed in the following chapters. Table 1 summarizes the interventions most effective for each disease.

TABLE 1

POTENTIAL RELATION BETWEEN WATER AND SANITATION INTERVENTIONS AND MORBIDITY DUE TO SELECTED DISEASES*

	Improved Drinking Water Quality	Increased Water Quantity: Domestic Hygiene	Increased Water Quantity: Personal Hygiene	Excreta Disposal
Diarrhea	+	++	++	++
Ascariasis	+	++		++
Guinea worm	++			
Hookworm				++
Schistosomiasis		++	++	++
Trachoma		+	++	

* The pluses indicate the likelihood that the intervention will impact on a particular disease. Two pluses indicate that the intervention will have a stronger impact than an intervention with only one plus A blank indicates that the specific component has little or no impact on reducing disease rates For a particular disease, a package of interventions with pluses is expected to produce a larger impact than any one alone.

In addition to these interventions, avoiding contact with pathogen-laden water or fecal matter is also important. For those diseases where the infecting organism either enters or leaves the body when people come into contact with water, reduction of such contact is an important means of improving health.

1.3 Selection of Diseases for Review

The six diseases included in this review are either widespread in the developing world (see Appendix A, figures 2-5), constitute serious problems where they exist (Table 2), or both. They are all subject to reductions in incidence, prevalence, and/or severity from one or more of the four types of intervention described above. All areas of the developing world are touched by diarrhea and ascariasis. The other four diseases are somewhat more restricted in range, although they all cover portions of two or more continents.

TABLE 2

INCIDENCE AND EFFECTS OF SELECTED DISEASES IN DEVELOPING COUNTRIES (EXCLUDING CHINA)

DISEASE	ESTIMATED CASES/YEAR	ESTIMATED DEATHS/YEAR
DIARRHEA	875 MILLION	4,600,000
ASCARIASIS	900 MILLION	20,000
GUINEA WORM	4 MILLION	*
SCHISTOSOMIASIS	200 MILLION	*
HOOKWORM	800 MILLION	*
TRACHOMA	500 MILLION	**

* EFFECT IS USUALLY DEBILITATION RATHER THAN DEATH
** MAJOR DISABILITY IS BLINDNESS

2

METHODOLOGY

2.1 Acquiring the Literature

Literature on each of the diseases considered was acquired through computer searches on the Medline and/or Medline 500[1] systems, which go back to 1966 and 1986 respectively. In the case of schistosomiasis, an additional computer search was done on CAB Abstracts[2] (1984-1989). For hookworm and *Ascaris*, the Index Medicus[3] from 1976-1986 and the Science Citation Index[4] from 1970-1984 were searched. Because a thorough review of diarrheal diseases was published in 1986 (Esrey and Habicht, 1986), only studies of diarrhea published since then were sought. A recent review of trachoma (Prost and Negrel, 1989) provided additional references for that disease.

References in the acquired literature which had not turned up in the computer search were also sought out. Although we did not purposely exclude studies in other languages, none were found in our search; accordingly only literature published in the English language was used. Further, studies that did not appear in the peer-review literature were not considered. This methodology excludes technical reports, mimeographs, and agency documents that did not appear in the peer-review literature. Two exceptions were the studies by Miller et al. (1978, 1980). Because several articles from this study were published in the peer-review literature, the technical report, which contained more information, was used. Finally, this review was restricted to studies that presented data on one of the six diseases in relation to differences or improvements in water and sanitation conditions.

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[1] Medline (and Medline 500), an on-line database produced by the U.S. National Library of Medicine, is one of the major sources for biomedical literature Over 3,000 international journals (from the U.S. and 70 other countries) are indexed.

[2] CAB Abstracts is a comprehensive on-line database of agricultural and biological information containing all records in the 26 main abstract journals published by Commonwealth Agricultural Bureaux

[3] Index Medicus is the printed version of Medline.

[4] Science Citation Index is the printed version of SCISEARCH, a multidisciplinary index to the literature of science and technology prepared by the Institute for Scientific Information. SCISEARCH covers every area of the pure and applied studies.

2.2 Analyzing the Studies

All epidemiological studies face methodological difficulties, so the degree of validity of a given study depends on its methodologic rigor. Specific criteria developed previously (Esrey and Habicht, 1986) were used to assess the value of each study. Studies were divided into those that showed a positive statistical association and those that reported either an inverse or no association (Table 3). A positive study is one that reported a statistically significant association between having improved water or sanitation and better health. An inverse study found an association between improved water or sanitation and worse health. A "no association study" reported no association between improved water sanitation and health. The two latter types of studies have been considered together, and the same criteria applied; they are referred to below as negative studies.

TABLE 3*

CRITERIA FOR EVALUATING PUBLISHED LITERATURE

STUDIES WITH POSITIVE FINDINGS:

1. WAS THERE SELF-SELECTION OF PARTICIPANTS?
2. WERE THE FOLLOWING CONFOUNDING VARIABLES CONTROLLED:
   A AGE?
   B SEX?
   C. EDUCATION?
   D. RURAL/URBAN?
   E. SEASON?
   F OTHER?
3. WERE MEASUREMENTS BLINDED FOR:
   A. RECIPIENTS?
   B. ENUMERATORS?
4. WAS CONGRUITY CONFIRMED?
   A WAS THE OUTCOME MEASURE BIASED?
   B WERE OTHER OUTCOMES MEASURED?
5. WERE DIFFERENCES IN WATER AND SANITATION CONDITIONS CONFIRMED?

STUDIES WITH NEGATIVE FINDINGS:

6. COULD THE POPULATION BENEFIT (WERE PARTICIPANTS TOO HEALTHY)?
7 WAS THE DIFFERENCE IN THE INTERVENTION (COMPARISON) GROUPS SUFFICIENT TO PRODUCE AN EFFECT?
8. WAS SAMPLE SIZE ADEQUATE TO DETECT A MEANINGFUL DIFFERENCE?
9. WERE THE FOLLOWING CONFOUNDING VARIABLES CONTROLLED:
   A. AGE?
   B. SEX?
   C. EDUCATION?
   D. RURAL/URBAN?
   E. SEASON?
   F. OTHER?
10. WAS CONGRUITY CONFIRMED?
   A WAS THE OUTCOME MEASURE BIASED?
   B. WERE OTHER OUTCOMES MEASURED?

* SEE ESREY AND HABICHT (1986) FOR A MORE DETAILED EXPLANATION

For both positive and negative studies, the following points were examined: whether confounding factors such as age, sex, education, and seasonality were controlled, whether the main measure of outcome was biased, and whether measurements were taken on other related outcomes. For studies with positive findings, in particular, three additional factors were considered: possible self-selection of participants, whether measurements were blinded, and whether the improvements in water and sanitation conditions were confirmed. In the case of studies with negative results, three more criteria were examined: whether the population was too healthy to benefit from the improvement, whether the intervention was sufficient to produce an effect, and whether there was an adequate sample size to detect an effect.

In the following pages, each of the diseases is considered in turn, with discussion focusing on the better studies in each disease category. Studies with either a single major and obvious flaw or several known or suspected minor flaws that could have biased the results were excluded from the better group. All of the studies for each disease are annotated in Tables 1-6, Appendix B. However, only the more recent studies (since 1986) are listed for the diarrheal diseases covered in Chapter 3. Whenever possible, individual components of water and sanitation interventions are highlighted. In some cases, a package of several components are examined. Further attention is given to the combination of water and sanitation plus some other type of intervention such as drug therapy when information on this is available.

Median reductions and a range of reductions attributable to improved water and sanitation were calculated for each disease, based on all the studies under review. The same calculations were also made strictly for the better studies in each disease category. The figures for the better studies more accurately represent the reductions that may be achieved by water and sanitation interventions because they are based on better research studies. No reduction figures could be generated from some studies, and these studies did not enter into the calculations. Median values instead of means were used to calculate reduction rates because medians are resistant to extreme values, while means are not. For an overview of the disease reduction rates, see Table 4, in Chapter 9.

3

DIARRHEA: MORBIDITY AND MORTALITY

Diarrheal disease is one of the leading killers of children in the world It is estimated that there are more than 875 million cases of diarrhea and 4.6 million deaths annually in Africa, Asia, and Latin America (Snyder and Merson, 1982). The disease agents are transmitted via the fecal-oral route and do not require an intermediate host. This cycle involves defecation of pathogens—bacterial, viral or parasitic—which are then ingested by consuming pathogen-laden food or water or by oral contact with dirty hands or other contaminated objects. If host factors of the individual allow the infection to occur, then diarrhea may strike, weakening the child through dehydration and loss of electrolytes. In addition, fever, malabsorption of nutrients, and anorexia result in slower growth. Most studies assessing the impact of water and sanitation on child health have, thus, focused on one or more of three major indicators of health, all of which are related. rate of diarrhea, nutritional status, or mortality. All of these indicators were considered in an earlier review of 67 studies from 28 countries (Esrey and Habicht, 1986). That review has been updated here with the addition of 17 more studies (see Appendix B, Table 1). Although nutritional status has been reported previously and recent nutrition studies appear in the appendix, only diarrheal morbidity and mortality studies are used in the text tables reporting reductions in disease.

Excreta disposal, personal and domestic hygiene, and drinking water are major interventions that interrupt transmission and reduce diarrhea morbidity and mortality and improve child growth. The size of reduction any particular project actually achieves depends largely on the interplay of two factors· the manner in which different combinations of interventions are installed and the characteristics of the people for whom the intervention is targeted. These issues are considered below through an analysis of all 84 studies under six headings: water and sanitation, sanitation, water quality and quantity, water quantity, water quality, and hygiene

3.1 Water and Sanitation

Eleven studies examined the combined effect of water and sanitation without looking separately at the effect of one or the other. Calculations could be made for only 7 studies with a median reduction of 20 percent, The other studies either reported on specific pathogens (2), nutrition (1), or mortality (1). Seven reported positive impacts. Seven of the studies—3 with positive impacts and 4 without—were flawed. In 2 of the better studies, an average of 30 percent reduction in diarrhea was associated with improved water and sanitation conditions (Koopman, 1978; Rahaman et al., 1983). A third reported fewer malnourished children in families with a sewage system and a household bath than in families with latrines and no bath (Christiansen et al., 1975). In Malawi (Young and Briscoe, 1987), the combination of water and sanitation was associated with less diarrhea, but the results were not statistically significant due to small sample sizes. Only 1 of the 11 studies examined mortality. Among infants in Malaysia, the addition of toilets and water versus no facility was associated with a large reduction (82 percent) in infant mortality, particularly if the child was not breastfed (Habicht et al., 1988).

3.2 Sanitation

The impact of sanitation was examined in 30 studies, of which 21 reported health improvements. Calculations could be made for 11 studies, and the median percent reduction was 22 percent. Twelve of these studies were flawed. The better studies consistently reported an association between improved health and sanitation. Of the 18 better studies only in 5 could reductions in morbidity be calculated. The median of these 5 was 36 percent. The other better studies either reported on nutritional status (2) or mortality (11). Of the studies that compared the relative importance of water and sanitation, most reported that sanitation had the greatest impact on child health based on mortality, growth, and morbidity indicators. Some mortality studies reported that the method of excreta disposal determined the magnitude of the health impact. For instance, flush toilets reduced mortality more than did pit latrines (Anker and Knowles, 1980; Haines and Avery, 1982; and Waxler et al., 1985), which were nevertheless associated with mortality reductions when compared with no sanitation facilities. The increasing effect associated with an upgrading of facilities may be related to the number of family or community members using the facility or the number of times in which it is used by each individual. Sanitation has also been reported to produce a differential health impact depending on the presence or absence of other risk factors. For instance, sanitation was most effective in reducing mortality among non-breastfed infants (Butz et al., 1984) and infants of illiterate mothers (Esrey and Habicht, 1988a) than among breastfed infants or literate mothers.

3.3 Water Quality and Quantity

Of the 43 studies that compared groups with different types of water supplies, 24 found a positive impact. Of the 22 studies for which morbidity calculations could be made, a median reduction figure of 16 percent was calculated. Of the remaining 21 studies, 4 reported on pathogens, 4 reported on nutritional status, 11 reported on mortality, and 2 had insufficient information. In most of these studies, it was difficult to know if the difference in health conditions was due to increased amounts of water, improvements in the quality of water, or both. Therefore, these studies have been grouped together. Fourteen of the studies are in the "better" category. Only 2 of the 22 morbidity studies were better studies with a median reduction of 17 percent. Most of the better studies reported on mortality (9) or nutritional status (3). Of these, a modest benefit for particular, but not for all, age groups was found. In the studies reporting a health benefit, the water supply was piped into or near the home, whereas in those studies reporting no benefit, the improved water supplies were protected wells (Anker and Knowles, 1980), tubewells (Rahman et al., 1985), and standpipes (Waxler et al., 1985; Popkin, 1980; Lindskog et al., 1987 and 1988; and Esrey et al., 1987).

3.3.1 Water Quality

Sixteen studies examined the health impacts of pure versus contaminated water supplies. Of the 7 studies for which calculations could be made, a median reduction in diarrhea of 17 percent was found. In the other 9 studies, pathogens (4), nutritional status (2), diarrheal mortality (2), or insufficient information (1) were reported. Ten of the 16 studies reported positive impacts, but in several the impacts were found only for certain age groups. Seven of the studies are in the "better" category. Of these studies, a median reduction figure of 15 percent was found for 4 calculable studies. Of these, 1 found little or no association between the quality of drinking water and diarrhea in children (Huttly et al., 1987), another found an 8 percent reduction in *Shigella* rates (Stewart et al., 1955), and 2 found some association with child nutritional status, but not with diarrhea (Magnani et al., 1984; Esrey et al., 1988b) Since diarrhea is multifactorial in origin, drinking water constitutes only one of many sources of infection. In areas where environmental fecal contamination is high, little or no health impact from water improvement can be expected. For instance, studies in Lesotho (Feachem et al., 1978) and Guatemala (Shiffman et al., 1978) failed to detect reductions in diarrhea following water quality improvements A recent study in Brazil (Victora et al., 1988) also failed to find an association between water quality and diarrhea mortality as did an earlier study in India (Zaheer et al., 1962)

3.3.2 Water Quantity

Of the 15 studies that examined the issue of increased amounts of water specifically and independent of water quality, all but one reported positive impacts. The median reduction for 7 studies was 27 percent. The other 8 studies reported on pathogens (5) or nutritional status (3). Ten better studies reported greater health among children whose families used more water than among children whose families used less water, but, in some instances, the differences were small or significant only for selected age groups. The median reduction for 5 better studies was 20 percent. In Ethiopia (Freij and Wall, 1977), children under two years old from families with higher water usage per person had less diarrhea than comparable children from families with lower water usage per person. In Lesotho (Esrey et al., 1989b), use of smaller amounts of water was associated with higher infection rates from *Giardia lamblia* than use of larger amounts. In both of these studies, the amount of water used was more important than the source of the water. No studies relating water quantity and mortality were found

3.4 Hygiene

Studies of the impact of hygiene interventions are few in number. Only 6 were found, all dated in the 1980s, all reporting on morbidity—not mortality. All of them are of good quality (Torun, 1982; Khan, 1982; Stanton and Clemens, 1987b; Aung Myo Han and Thein Hlaing, 1989; Alam et al., 1989; Black et al., 1981). A median reduction of 33 percent was reported in these studies. Several studies focused specifically on handwashing. In Burma (Aung Myo Han and Thein Hlaing, 1989), a 30 percent reduction in diarrhea was reported when mothers and children were provided with soap and encouraged to wash their hands after defecation and before preparing meals. Black et al. (1981), in a study conducted at day-care centers in the United States, found that a handwashing regimen reduced the incidence of diarrhea by 48 percent as compared to a control group. In Bangladesh (Khan, 1982), a 35 percent reduction in the attack rate of diarrhea caused by *Shigella* was found following an intervention to promote handwashing.

Other studies have examined hygiene by looking not only at handwashing, but at packages of handwashing plus other hygienic behaviors. Another educational intervention in Bangladesh (Stanton and Clemens, 1987b) emphasized proper handwashing before food preparation, defecation away from the house and in a proper site, and suitable disposal of waste and feces. The investigators reported a 26 percent reduction in diarrhea incidence but no change in the nutritional status of the target group. A third group in Bangladesh (Alam et al., 1989) provided handpumps and health education to promote personal and domestic hygiene. They found a more than 40 percent reduction in diarrhea incidence among groups that practiced good hygiene (irrespective of whether or not they received the intervention) compared to those with poor practices. The reduction attributable to the intervention itself, however, was 17 percent. In Guatemala, Torun (1982) found a 14 percent reduction in the incidence of diarrhea following a program to promote health awareness and hygienic behavior.

3.5 Summary

The median reduction for total child mortality was 60 percent. Based on the 6 better studies, the median reduction in total child mortality was 55 percent. The range of reductions in mortality rates from the better studies was 20 to 82 percent, depending on the type of intervention and on the presence or absence of risk factors such as poor feeding practices and maternal illiteracy. Most mortality studies examined either sanitation or the combination of quality and quantity of water. The mortality studies were generally better conducted than were the morbidity studies.

When all relevant studies were considered, the median reduction in general diarrhea morbidity was 22 percent, but the reduction based on the better studies was 26 percent. The range of reductions in morbidity rates in the better studies was 0 to 68 percent.

Other interventions that reduce diarrhea rates include promotion of breastfeeding (Feachem and Koblinsky, 1984); immunization for rotavirus (de Zoysa and Feachem, 1985), cholera (de Zoysa and Feachem, 1985) and measles (Feachem and Koblinsky, 1983b), and possibly promotion of food hygiene (Esrey and Feachem, 1989a). The use of growth monitoring to promote these preventive measures could also achieve beneficial impacts. Oral rehydration, although it does not protect against the ingestion of diarrhea pathogens, is effective in preventing death due to diarrhea. Improving a child's nutritional status may reduce the severity or duration of episodes when they occur (Black et al., 1984).

In summary, the literature published since 1986 concurs with the conclusions obtained earlier (Esrey and Habicht, 1986), and the better studies in the last few years show a higher reduction in disease. This may reflect better studies, but it may also reflect better projects. It is still true that interventions to improve excreta disposal and water quantity will produce larger impacts than improvements in water quality. This is particularly so in highly contaminated environments where diarrhea rates are high. Because the use of more water following the installation of water supplies is not automatic, hygiene education is a necessary part of the package of intervention.

4

ASCARIASIS

Ascariasis is caused by a parasitic worm which follows the fecal-oral route of transmission. It is endemic in virtually the entire developing world and infects about one-fifth of the world's population (Markell et al., 1986). There are an estimated 900 million diagnosed cases of the disease (this excludes the majority of cases referred to as infection) and 20,000 deaths annually in Africa, Asia, and Latin America (Walsh, 1984). This parasite cannot be transmitted directly from person to person because embryonated eggs require development in soil as part of their life cycle. A minimum of two weeks is needed for excreted eggs to become infective. In some instances, eggs may remain viable for months or even years.

Once ova are ingested, embryos migrate from the small intestine through the body in a well defined route only to re-enter the intestines where they reach maturity one month after ingestion. Most infections are symptomless, but during migration those infected may experience cough, dyspnea, fever, and sometimes blood in the sputum. Heavy worm loads may obstruct the intestines, and worms may wander into bile ducts, appendix, liver, or stomach. Death may occur. Less severe infections may contribute to malnutrition through loss of protein, vitamin deficiencies, and poor growth in children.

Fourteen studies relating water supply and/or sanitation to *Ascaris* infection were reviewed (see Appendix B, Table 2). Of 9 positive findings, 3 (Moore et al., 1965; Miller et al., 1980; Pimentel et al., 1961) examined differences in excreta disposal facilities, and 5 (Chandler, 1954; Sahba and Arfaa, 1967; Arfaa et al., 1977; Henry, 1981; Schliessmann et al., 1958) investigated various combinations of water supply and sanitation conditions. All 5 negative studies looked only at excreta disposal facilities. Henry (1981) was the only study to investigate the influence of water supplies alone. One additional study (Feachem et al., 1983a) reported both positive and negative findings; significant differences were found in ascariasis among users of different types of excreta disposal facilities.

4.1 Water Supplies with Sanitation

Four studies (Henry, 1981; Schliessmann et al., 1958; Arfaa et al., 1977; and Sahba and Arfaa, 1967), which were all positive, and which all looked at combinations of water supplies and excreta disposal facilities, merit further description. In St. Lucia (Henry, 1981), three cohorts of children less than three years old were identified, each being associated with a specific geographic area. Their *Ascaris* infection rates were initially similar. Over a two-year period, one cohort was supplied with household water supplies, another with household water and latrines, and a third served as a control. Four years after baseline rates were taken, the prevalence of *Ascaris* infection in the water supplied group had gone down 30 percent, the rate in the water and sanitation group had dropped 31 percent, while the prevalence in the control group had increased.

In the United States, Schliessmann et al. (1958) compared the *Ascaris* prevalence among groups with different levels of water and sanitation. Using those with privies and no well as a baseline, he reported reductions of 71 percent for people with flush toilets and indoor plumbing, 37 percent for privies and indoor plumbing, and 12 percent for privies and a yard well.

Two other superior studies were both carried out in Iran (Arfaa et al., 1977; Sahba and Arfaa, 1967). The 1967 study found that the provision of a latrine per courtyard and public stand pipes in a village produced a 16 percent drop in prevalence and about a 62 percent decrease in egg counts in stool, a measure of disease severity, over a one- to two-year period. Arfaa et al. (1977) measured infection rates and egg counts in 15 villages, shortly after which four villages were supplied with a household latrine and a community water supply, four villages were supplied with the same plus chemotherapy, four others were supplied with just chemotherapy, and three remained as a control group. At the end of three to four years, the control group's prevalence had decreased 19 percent, and egg counts were reduced 29 percent. The latrine and water group's prevalence and egg counts had decreased 28 percent and 60 percent, respectively. For the latrine, water and chemotherapy group, these rates had decreased 79 percent and 88 percent, and for the chemotherapy only group, 84 percent and 90 percent, respectively.

4.2 Water Supplies

The work of Henry (1981) in St. Lucia provides the only evidence regarding the provision of water supplies alone. Household piped water supplies produced a 30 percent reduction in ascariasis among children under 3 over a two-year period. This is similar to the 31 percent reduction found among a cohort provided with piped water and latrines.

4.3 Summary

The provision of water supplies (Henry, 1981) or water supply and sanitation facilities (Arfaa et al., 1977; Henry, 1981; Schliessmann et al., 1958) can typically reduce *Ascaris* prevalence by about 30 percent over two or more years, and average egg output by about 60 percent (Arfaa et al., 1977; Sahba and Arfaa, 1967). The lack of difference between water supplies alone and water supplies with latrines (Henry, 1981) indicates that water has an important role in ascariasis prevention. It is likely that hygiene practices involving water (e.g. handwashing, food-washing, and floor-washing) are more important in preventing the transmission of the worm than excreta containment.

5

GUINEA WORM

Guinea worm was included in this review because it is related to the quality of drinking water but not to other types of water and sanitation interventions. Guinea worm is far more restricted in distribution than other diseases considered in this paper. It is found in parts of East, Equatorial and West Africa, and arid parts of India and Pakistan (Appendix A), where between 50 and 80 million people are at risk of infection (Markell et al., 1986) and an estimated 4 million persons in Africa and Asia have active disease (Watts, 1987). To acquire the disease one must ingest the infective larvae in their minute crustacean host, *Cyclops, cyclopoid copepods*, which can be found free-living in open water. About a year after a person drinks pathogen-laden water, the adult worms develop and cause painful ulcers, usually on the feet and legs. The worms emerge through these ulcers when the infected person enters water, releasing free-swimming larval forms to continue the cycle of transmission. New worms may continue to emerge over several months, incapacitating those afflicted. Transmission is strongly seasonal and usually peaks in a one- or two-month period, which in some places coincides with the peak agricultural season (Belcher et al., 1975).

All of the 7 studies (see Appendix B, Table 3) of guinea worm were positive. In India, Reddy et al. (1969) associated prevalence of the disease with the extent of use of unprotected step-wells More recently in India, Johnson and Joshi (1982) found high prevalence in villages totally dependent on unprotected ponds. In Burkina Faso, Steib and Mayer (1988) were able to demonstrate the presence of infected *copepods* in large ponds which people used as reliable sources of water all year round. The ponds most likely to be sources of infection must be large enough to hold water during the critical transmission period, usually prior to the onset of the rains, and large enough for people to wade into when they draw water.

5.1 Water Source

The 2 better studies (Edungbola et al., 1988; Henderson et al., 1988), both from Africa, compared use of bore holes to use of unimproved sources. In Nigeria (Edungbola et al., 1988), an evaluation was done of the impact of a UNICEF-assisted rural water project which provided bore holes and handpumps, along with health education. The study comprised 20 serviced and 5 unserviced communities in Kwara State and examined over 8,600 subjects prior to, and over 10,000 subjects after, provision of the project package. Three years after installation, bore hole water supplies reduced the incidence of guinea worm disease by 81 percent, from a mean prevalence of 58.9 percent over all age groups to a mean prevalence of 11.9 percent. The greatest reduction in prevalence occurred in those villages where bore holes were convenient and close by, but the effect lessened if wells were distant. The impact was also less dramatic where the water was unpalatable or the supply erratic.

Henderson's study in Uganda (1988) was also done in conjunction with a UNICEF project, but in this case the data came from a baseline pre-intervention survey. Just over 2000 people were interviewed in the northwest part of the country to ascertain disease rates and the relationship between water use and disease. Results were analyzed by season as it was found that the attack rate of the disease peaked twice during the year. Bore hole users were found to have one-tenth the attack rate of non-users in the rainy season and two-fifths the attack rate of non-users in the dry season.

5.2 Seasonal Transmission

A number of studies on guinea worm have investigated the seasonal nature of transmission, as Henderson did in Uganda (1988). In West Africa (Belcher et al., 1975), a Ghanaian study associated attack rates with periods of below-average rainfall when the *copepods* reached their highest density in ponds that were drying up. Surveys have been done in Nigeria (Edungbola and Watts, 1985) that showed a particularly high attack rate in the dry season in villages with little or no access to protected water. This seasonal deficiency in water supply was stressed by Ilegbodu et al. (1987) who showed that prevalence of guinea worm disease remained high in Nigerian villages provided with piped water if the supply was intermittent or unreliable during the dry season. The problem of unreliable tube wells or bole holes which fail, particularly during the dry season, is frequently cited as an important factor contributing to transmission of guinea worm disease (Bhatt and Palan, 1978; Steib and Mayer, 1988).

5.3 Summary

Reductions in guinea worm disease due to improvements in water supplies are in the range of 75-81 percent, with a median of 78 percent. The conclusions which can be drawn from these and other studies bear primarily on the seasonal patterns of transmission and the need for protected wells or bore holes to provide adequate water during the critical transmission period. A supply which is consistent for nine months, but which fails only during the critical transmission period, will not reduce the incidence of guinea worm disease.

6

HOOKWORM

Hookworm is endemic throughout the developing world (Appendix A). Estimates of global prevalence suggest that from 700 to 900 million people are infected (Markell et al., 1986). The infection is a good indicator of life in squalid conditions, where the prevalence is sometimes as high as 80 percent. The distribution of hookworm is extensive in tropical areas, particularly where it is wet enough for the transmission of the helminth.

Hookworm is a parasite which is passed in stool and develops in moist soil over a period of one or two weeks. The infective larvae which live up to two weeks climb to the highest point covered by moisture and extend their bodies into the air seeking a human host. The worm infects individuals by boring through the skin, especially the skin of the foot Infection produces lethargy and anemia through blood loss. The severity of the effects depends largely on the severity of the infection. Proper disposal of feces is a primary strategy used in controlling this disease because if feces are not deposited on the ground, the worm will be unlikely to reach people's feet.

6.1 Excreta Disposal

Eleven studies (see Appendix B, Table 4) relating hookworm infection to excreta disposal facilities with or without water supplies were reviewed. Five studies reported positive findings: 2 involving water supply and sanitation (Chandler, 1954; Schliessmann et al., 1958) and 3 involving sanitation only (Khalil, 1931; Cort et al., 1929; Sweet et al., 1929). Only 2 studies are worthy of further description (Schliessmann et al., 1958; Arfaa et al., 1977); they both examine the influence of water supplies in conjunction with sanitation facilities.

Schliessmann et al. (1958) identified three cohorts in the United States with contrasting sanitary conditions. No hookworm was found in the group with the best sanitary conditions, where everyone had indoor plumbing, flush toilets, and good housing. The hookworm prevalence for the group with moderate housing and sanitary conditions was 0.5 percent, and the prevalence in the least sanitary households was 1.9 percent.

In the Iran study (Arfaa et al., 1977) referred to earlier, villages which received sanitation improvements had a 4 percent decrease in hookworm prevalence, and a 26 percent reduction in egg count among those infected. These prevalence and egg count reduction values for the group receiving sanitation and chemotherapy were 69 percent and 88 percent respectively; for the chemotherapy only group, 73 percent and 87 percent; and for the control group, 11 percent and 12 percent. The results are confounded because each cohort began with a different hookworm prevalence. The sanitation-only cohort started with 71 percent infected, while the control group began with 44 percent. The way in which interventions were assigned to the villages was not stated.

6.2 Summary

The above studies suggest that severity of hookworm is more affected by sanitation than is incidence, and that, following chemotherapy, sanitation may keep incidence low. An increase in wearing shoes and an improvement in general living conditions should also be effective.

7

SCHISTOSOMIASIS

Schistosomiasis is related primarily to personal and domestic hygiene and improved sanitation. Like several of the other diseases covered, it is widespread and debilitating. Schistosomiasis has an extensive distribution (see Appendix A), with a global prevalence estimated to be more than 200 million (Markell et al., 1986). Occurrence in many regions has increased dramatically as people have altered natural water bodies. The construction of dams and irrigation systems, in particular, tends to promote habitats well-suited for the intermediate host snail, and results in increased spread of infection.

For transmission to occur, eggs must exit the body of an infected individual in feces (*S. mansoni* and *S. japonicum*) or urine (*S haematobium*). The eggs hatch in an aquatic environment, and the emerging miracidium finds its way to an intermediate snail host. Eventually the cercariae leave the snail and bore through the skin of individuals who enter or come in contact with infected fresh water. Use of improved water supplies, and of facilities for personal and domestic hygiene, should slow disease transmission by reducing the amount of contact people have with local water bodies Latrines should reduce the amount of egg-containing feces and urine that reach the waterways.

Eleven studies (See Appendix B, Table 5) were located that examined water and sanitation facilities and rates of schistosomiasis All 4 of the better studies reviewed (Barbosa et al., 1971; Jordan et al., 1982; Lima E Costa et al., 1987; Mason et al., 1986) examined the degree of protective efficacy of water supplies Extensive water supply and washing facilities were provided to the study populations. One study (Barbosa et al., 1971) also examined water supply with the addition of latrines.

7.1 Water Supplies

In St. Lucia (Jordan et al., 1982), each household in five villages was provided with piped water along with community washing and showering facilities. Over a five year period, the overall prevalence of schistosomiasis was reduced by 27 percent, and the prevalence in the under-10 year olds was reduced by 59 percent.

In southeast Brazil (Lima E Costa et al., 1987), a case-control study examined the relationship between water piped into the home and splenomegaly, as well as between piped water and schistosomiasis infection. Splenomegaly in endemic areas is a sign of severe schistosomiasis infection. Children 5 to 14 years old were 7.3 times more likely to have splenomegaly and 2.3 times more likely to be infected if they had no piped water in their home than those who did have piped water in their home. Malaria, which can also cause splenomegaly, was not a confounder, as it was reported to be of low prevalence in the study area.

Mason et al. (1986) compared *S. mansoni* and *S. haematobium* from two rural cohorts of Zimbabwian school children. Children on communal lands without a piped water supply had a 4.8 percent prevalence of *S. mansoni* and a 4.4 percent prevalence of *S. haematobium*. Those with piped water, and living on the same lands, had a prevalence of 0.8 percent and 0.4 percent respectively.

7.2 Latrines with Water Supplies

In northeast Brazil, Barbosa et al. (1971) measured *S. mansoni* prevalence in a community from 1961 to 1968. In 1963, a health education program was begun. The following year, latrines were built for each house and communal taps, laundry facilities, showers, latrines, and handpumps were installed. Over the seven-year period, prevalence in children under 14 showed a net drop of 77 percent more than the reductions in three control villages.

7.3 Water Contact

One of the primary mechanisms by which improved water supplies have an impact on schistosomiasis is by reducing human contact with infected water. Therefore, a distinction between having an improved water supply and having contact with pathogen-laden water should be made. Access to improved supplies was associated with reduced contact with infected waters and thus reduced infection in St. Lucia (Jordan, 1972 and Jordan et al., 1982) and southeast Brazil (Lima E Costa et al., 1987). In St. Lucia, the provision of piped water, laundry, and shower facilities led to an 82 percent reduction in the number of occasions in which people had contact with infected water and a 96 percent reduction in water contact time. Thus, not only were people entering infected bodies of water on fewer occasions, but when they did enter the water, they remained there for shorter periods. Kvalsvig and Schutte (1986) and Chandiwana (1987) documented the importance of swimming, bathing, and washing activities in promoting contact with infected water, and the importance of creating facilities for these activities to reduce contact as part of a water development scheme.

7.4 Water Supplies in Conjunction with Other Measures

Evidence indicates that drug treatment produces a more precipitous drop in schistosomiasis prevalence than water facilities alone (Pitchford, 1970; Mason and Tswana, 1984; Jordan, 1977; Jordan et al., 1982; Negron-Aponte and Jobin, 1979). The addition of adequate water supplies to those who have been treated with drugs can prevent reinfection (Jordan et al., 1982). In St. Lucia, for example, oxamniquine treatment resulted in a precipitous drop in the infection rate and a four-year follow up displayed no indication of reinfection. Reinfection can rapidly diminish or negate health improvements brought about by a community-wide program devoted exclusively to drug therapy (Wilkins et al., 1987; Bensted-Smith et al., 1987). Programs using a multifaceted approach, on the other hand, have repeatedly been shown to be successful (Tameim et al., 1985; Negron-Aponte and Jobin, 1979; Pitchford, 1966).

7.5 Summary

Water supply is a significant factor in the determination of schistosomiasis prevalence. The better studies consistently found that water supplies in conjunction with related facilities, such as showers, were associated with reductions of about 77 percent in schistosomiasis rates. The range revealed by these studies is 59 to 87 percent.

8

TRACHOMA

Trachoma has been included in this review because it is specifically related to the amount of water used for personal and domestic hygiene. This disease is found primarily in the more arid parts of Africa, the Middle East, South Asia, and Australia (See Appendix A). It infects about one-half billion people, of whom at least eight million become blind (Dawson et al., 1981). Trachoma has no intermediate host, although it is thought to be carried at times from eye to eye by flies. It may also be transmitted by hands, clothes, or washrags. The transmission of the disease agent, *Chlamydia trachomatis*, is not as well understood as the transmission of other pathogens examined in this review

The damage caused by trachoma does not generally result from the action of *Chlamydia trachomatis* alone. Other bacterial infections of the conjunctiva of the eye often are present at the same time and increase the level of damage (Jones, 1975). Repeated reinfection, over a period of many years, leads to scarring of the conjunctiva of the underside of the eyelid as well as associated eyelid deformities such as inturned eyelashes. This may cause the cornea of the eye to become scratched and cloudy, a condition which, when severe enough, leads to blindness While the prevalence of active disease may be as high as 70-100 percent among very young children in endemic areas, a far smaller percentage goes on to suffer disability in middle and old age (Dawson et al., 1981).

Several studies document the decline in trachoma associated with improved general living conditions (Royal Australian College of Ophthalmologists, 1980; Tedesco, 1980; Prost and Negrel, 1989), but it is often difficult to isolate changes in water supply and sanitation from improvements in other areas. Sixteen studies looked specifically at the role of water, sanitation, and hygiene in the reduction of trachoma. Thirteen of them were positive and three were negative. Five of the better studies were positive (Mathur and Sharma, 1970; Tielsch et al., 1988; Taylor et al., 1985; Assaad et al , 1969; West et al., 1989); two were negative (Kupka et al., 1968; Wilson et al., 1987). (See Appendix B, Table 6.)

8.1 Distance to Water Source

Four studies (Assaad et al., 1969; Mathur and Sharma, 1970; Tielsch et al., 1988; West et al., 1989) showed significant reductions associated with shorter distances to water sources. A study from Taiwan (Assaad et al., 1969) showed that people whose water was attached to the home had 45 percent less trachoma than those with a source 500 or more meters away. Two hundred yards was the reference distance in an Indian study (Mathur and Sharma, 1970). Those with access to water within that distance had 30 percent less trachoma than those who used water from a more distant source. In Malawi (Tielsch et al., 1988), when water was less than five minutes away, children had 26 percent less trachoma than when it required a more than 60-minute trip. In neighboring Tanzania (West et al., 1989), there were 26 percent fewer households where all the children were infected when water was less than 30 minutes away as compared to a water source more than two hours distant. Two other studies failed to find this association between prevalence and distance, one in Morocco (Kupka et al., 1968) and one in Mexico (Taylor et al., 1985).

Distance to water has been considered a proxy for amount of water used, but a study in Tanzania (West et al., 1989) did not find a direct association between the distance to water and the amount of water brought into the household. The study in Morocco (Kupka et al., 1968) found no correlation between distance to source and per capita use of water. Similarly, several diarrheal disease studies have found no significant association between improved water or distance to water and amount of water used (Esrey et al., 1987; Lindskog et al., 1988).

8.2 Personal Hygiene

In India, Mathur used a rating system to classify people according to three levels of hygiene. People with good hygiene had 79 percent less trachoma than people with poor hygiene. The Mexico study (Taylor et al., 1985) examined the relationship between trachoma prevalence and a variety of possible risk factors and reported a significant association only for frequency of face-washing. Children who washed their faces seven or more times a week had 69 percent less disease than those who washed their faces less frequently. The importance of this aspect of personal hygiene was not confirmed, however, in a follow-up study in Mexico conducted in an area near the prior study site (Wilson et al., 1987). The follow-up study showed no association between trachoma rates and face-washing. The differing results might be explained by differing conditions. In villages included in the follow-up study, almost twice as many children were frequent face-washers as in the original villages. This made it difficult to find differences.

The investigators in Tanzania (West et al., 1989) made observations to examine face washing, instead of relying on responses to a questionnaire. They recorded whether or not children's faces appeared clean. A child was 1.7 times more likely to have trachoma if all the children in his or her family had unclean faces. This study also reported that distance to water was related to the percentage of unclean faces among children. There were 14 percent fewer households where all the children had unclean faces when the water was less than 30 minutes away, as compared to more than two hours away.

8.3 Summary

While water undoubtedly plays a role in reducing trachoma, water alone is probably not enough. The mean reduction over the seven better studies was 27 percent, with a range of 0-79 percent. The largest reductions occurred where personal hygiene practices improved, suggesting that the way water is used may be as or more important than its availability.

9

SUMMARY

9.1 Conclusions

The results of this review indicate that improvements in one or more components of water supply and sanitation can substantially reduce rates of disease morbidity and severity for diarrhea, ascariasis, guinea worm, schistosomiasis, and trachoma. Only for hookworm do the results suggest that there is possibly a negligible impact from water and sanitation. With the exception of hookworm, the median reductions in the better studies in morbidity range from 26 percent for diarrhea to 78 percent for guinea worm. The median reduction in general diarrhea mortality was 65 percent and in child mortality it was 55 percent for the better studies. These latter numbers suggest the important role that water and sanitation play in enhancing child survival

TABLE 4

EXPECTED REDUCTION IN MORBIDITY AND MORTALITY FROM IMPROVED WATER SUPPLY AND SANITATION*

	ALL STUDIES			BETTER STUDIES		
	NO.	MEDIAN	RANGE	NO	MEDIAN	RANGE
DIARRHEAL DISEASES						
MORBIDITY	49	22%	0%-100%	19	26%	0%-68%
MORTALITY**	3	65%	43%-79%	-	–	–
ASCARIASIS	11	28%	0%-83%	4	29%	15%-83%
GUINEA WORM	7	76%	37%-98%	2	78%	75%-81%
HOOKWORM	9	4%	0%-100%	-	-	–
SCHISTOSOMIASIS	4	73%	59%-87%	3	77%	59%-87%
TRACHOMA	13	50%	0%-91%	7	27%	0%-79%
OVERALL IMPACT ON CHILD MORTALITY	9	60%	0%-82%	6	55%	20%-82%

FOR ADDITIONAL INFORMATION SEE APPENDIX B, TABLE 7.
* INDICATES MORBIDITY REDUCTION UNLESS NOTED OTHERWISE.
** THERE WERE NO 'BETTER' STUDIES.

Other diseases were not examined, but if they had been, they too might have been affected by water and sanitation interventions Such diseases include typhoid or other helminths.

Despite the mix of both positive and negative studies in the literature, the overwhelming evidence is in favor of positive impacts. The reasons for negative results vary, but they were often explained by methodological problems inherent in the study design. As stated earlier, all studies reviewed were evaluated according to several criteria (see Table 3). Many had flaws that weakened the validity of their findings. The available evidence, however, indicates that when water and sanitation are made available to people, substantial health impacts can be achieved.

Studies reporting reductions for one, or even more than one, disease most likely underestimated the total effect of water and sanitation in improving health. This was particularly true if several diseases that are affected by water and sanitation were prevalent at the same time in the area that received the interventions. Even though studies often report on only one indicator of health, other health indicators may also be changing.

In addition to reducing the incidence of disease, improvements in water and sanitation can be expected to affect health in other ways. When disease rates are reduced by chemotherapy, as was found for some parasitic infections, water and sanitation facilities may prevent the disease rates from rising again to pretreatment levels. Furthermore, the severity of disease was often reduced more than incidence or prevalence when both were measured. For instance, reductions in egg counts for ascariasis, schistosomiasis, and hookworm were larger than were reductions in incidence or prevalence. In addition, reductions in child mortality rates were greater than for diarrhea incidence or prevalence, suggesting that diarrheal severity is reduced more than incidence; the incidence rate, though, was also reduced.

The expected reductions in disease rates are a guide. The studies reviewed were of variable quality, and therefore reductions may be smaller or larger depending on several factors. These factors include the success with which an intervention was installed, the overall health status of the recipients, and the presence or absence of environmental factors that can also help reduce disease transmission. If the interventions do not work, break down, remain under-utilized, or don't change behavior sufficiently to reduce disease, they will likely result in small impacts at best. No study, no matter how well it is conducted, can find substantial impacts under these conditions. On the other hand, substantial impacts are likely to be found if the intervention was successfully implemented, utilized, and the population was prepared to benefit from the intervention.

9.2 Recommendations

Several recommendations can be made on the basis of the studies reviewed in this report. First, health conditions should be considered when prioritizing water and sanitation interventions. Targeting of projects to particular population groups and identifying the appropriate interventions for those groups should be possible in many situations. In most cases certain other inputs, such as provisions for maintenance or for community participation and hygiene education, will be necessary to realize the expected health benefits following the installation of water and sanitation facilities. The general recommendations listed below apply to most projects throughout the developing world.

- Access to water supply should be as close to the home as possible—to foster the use of more water for hygiene practices.

- Water supply and health programs should emphasize hygiene education to encourage people to use more water for personal and domestic hygiene.

- Sanitation facilities should be culturally appropriate, since the type of sanitation facility can have an effect on impact—probably reflecting the importance of user preference.

- Use of facilities is essential during critical seasonal transmission periods for diseases, such as guinea worm, which have such periods.

- Safe excreta disposal and proper use of water for personal and domestic hygiene appear to be more important than drinking water quality in achieving broad health impacts.

- Sanitation facilities should be installed in connection with water facilities when fecal-related diseases are prevalent.

Priority areas for receiving water and sanitation facilities include:

- Areas where breastfeeding is curtailed, education rates are low, and where crowding is a problem,

- Areas that are receiving chemotherapy for the reduction of diseases such as ascariasis, schistosomiasis, and trachoma, and

- Areas with multiple diseases that can be alleviated from water and sanitation interventions.

9.3 Issues for Future Research

Despite the accumulation of knowledge, many questions remain concerning the health benefits associated with water and sanitation. Thus, more research should be conducted in health impacts, focusing on the additional inputs and infrastructure necessary to produce impacts. Many of these issues could be examined in areas where water and sanitation systems have been shown to be working and utilized by the recipients. Future studies should more completely describe the interventions and the socioeconomic conditions of the population. This is important for extrapolating findings from one setting to another. In addition, the criteria listed in Table 3 should be incorporated into studies designing an evaluation. The epidemiologic methods to study health impacts are sufficiently well-defined and accepted. Therefore, future studies should be of sufficient rigor to address the issues below.

1. The maximum travel distance/time that will result in appropriate use of an improved water supply should be more accurately determined under a variety of socioeconomic and environmental conditions.

2. The minimum quantities of water that are necessary to produce health impacts under a variety of environmental conditions, e.g. peri-urban, rural, etc., should be determined.

3. The proper hygienic behaviors should be better defined and measured.

4. Appropriate methods for introducing and reinforcing behavioral change should be identified

5. Pre-conditions under which water and sanitation facilities are likely to be sustained should be identified.

6. The possibility of increasing the amount of water used and of changing behaviors in the absence of an intervention to install piped supplies should be investigated.

7. The conditions (including environmental, cultural, and level of development) under which installation of water and sanitation facilities are likely to produce the greatest health benefit should be identified.

8. The identification of threshold indicator levels at which water quality considerations override quantity in health impact should be undertaken.

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APPENDIX A

GEOGRAPHIC DISTRIBUTION OF SELECTED DISEASES

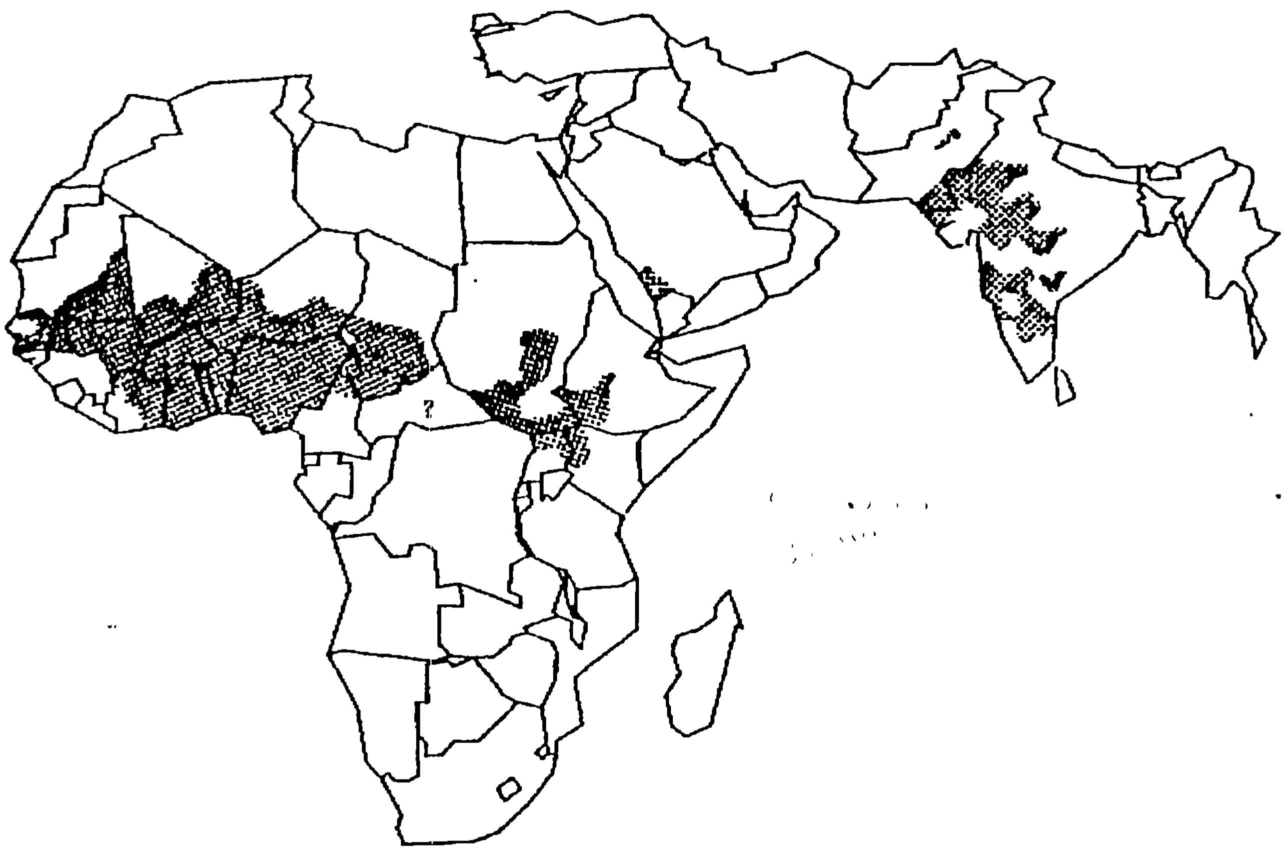
Distribution of Dracunculiasis (Guinea Worm)

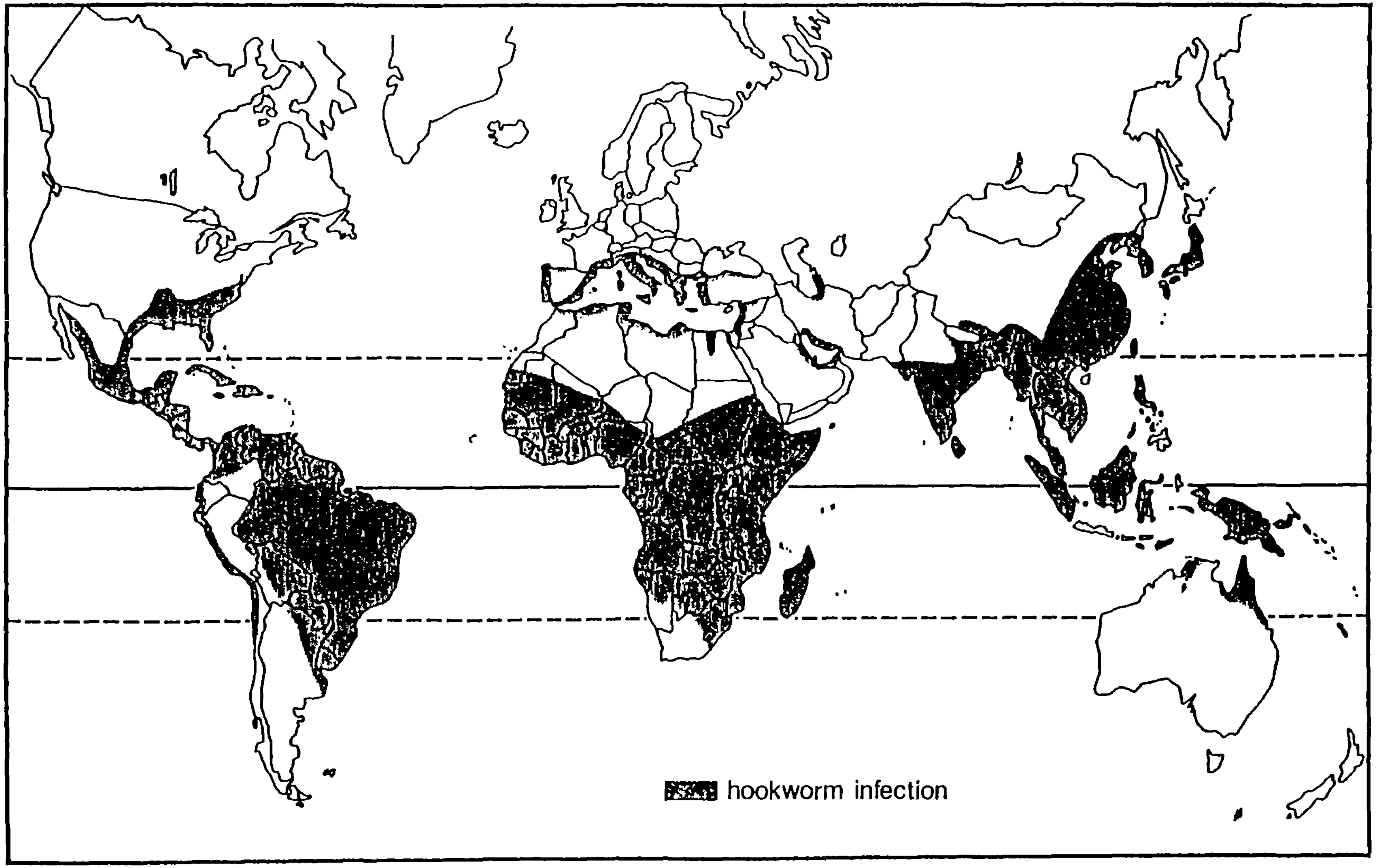
Distribution of Hookworm Infection

Distribution of Schistosomiasis

Distribution of Trachoma

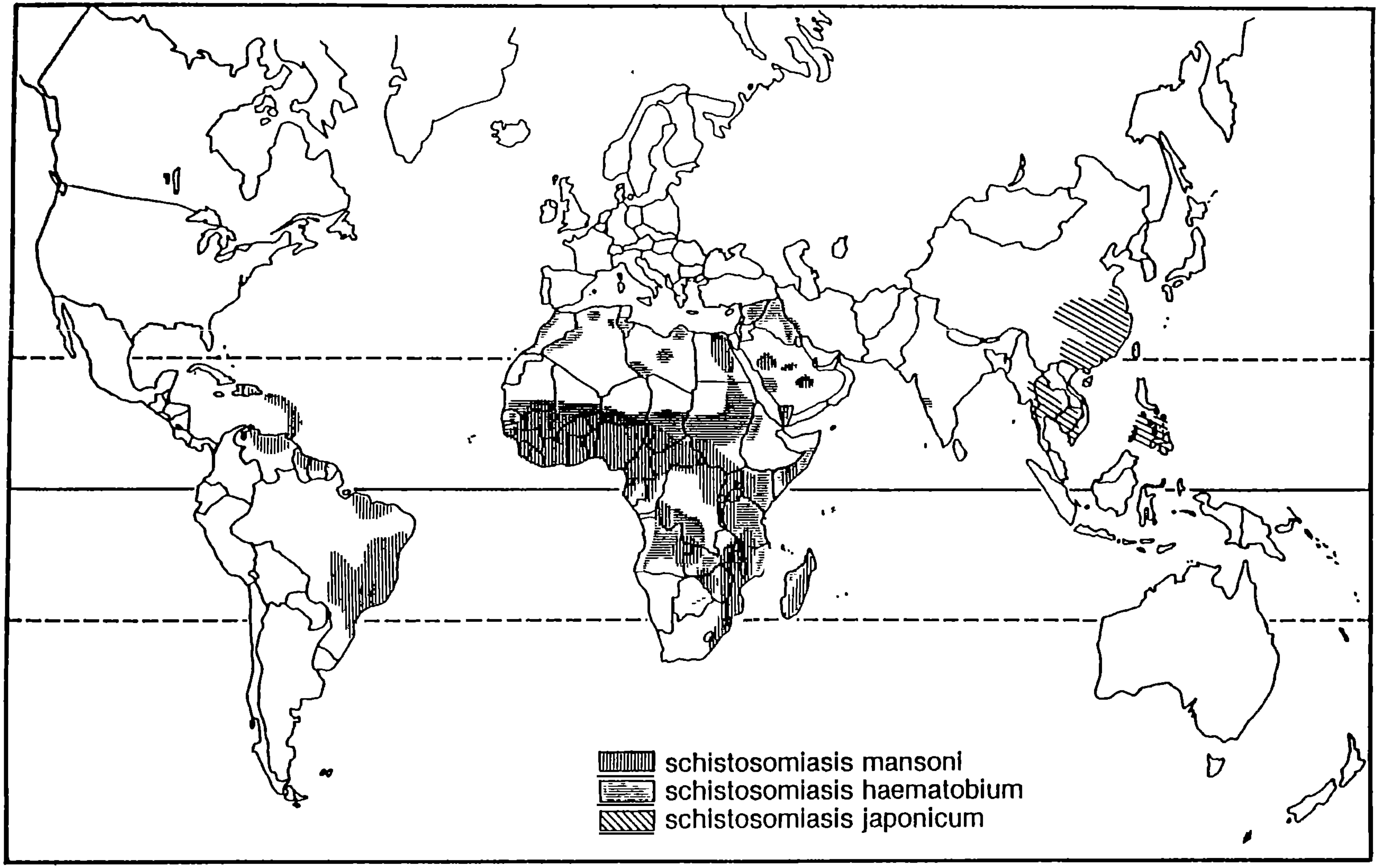
Figure 2 Map of the Distribution of Dracunculiasis (Guinea Worm)





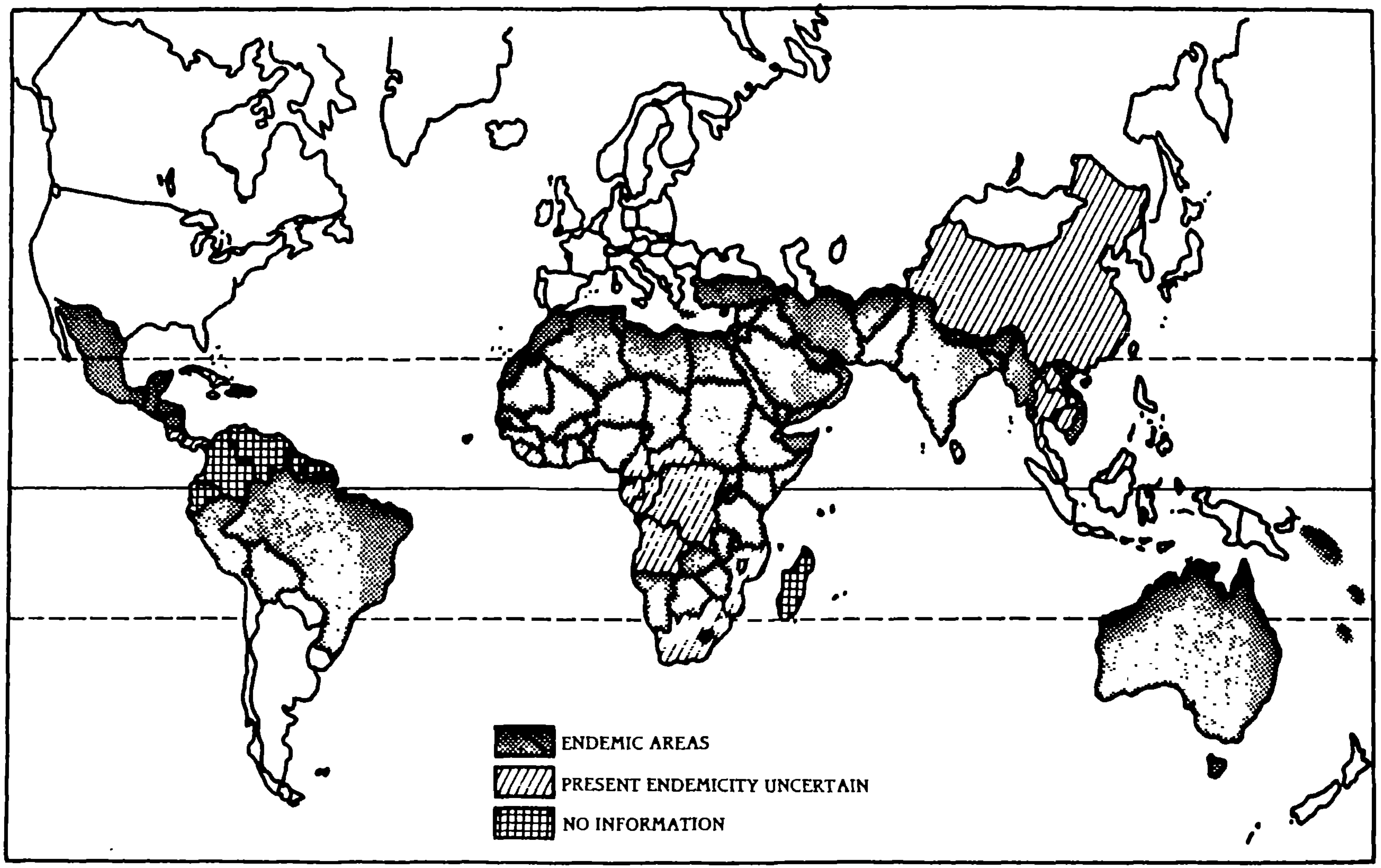
Source: Markell, 1986.

Figure 3. Map of the Distribution of Hookworm Infection



Source: Markell, 1986.

Figure 4. Map of the Distribution of Schistosomiasis



Map by Hugh R Taylor, M D.
Johns Hopkins University, 9/89

Figure 5. Map of the Distribution of Trachoma

APPENDIX B

Annotated Tables Showing All Studies

1. Catalogue of Studies (since 1986) on Diarrhea, Nutrition, and Mortality in Children

2. Catalogue of Ascariasis Studies

3. Catalogue of Guinea Worm Studies

4. Catalogue of Hookworm Studies

5. Catalogue of Schistosomiasis Studies

6. Catalogue of Trachoma Studies

7. Expected Reduction in Morbidity and Mortality from Improved Water and Sanitation

Table 1: CATALOGUE OF STUDIES (SINCE 1986) ON DIARRHEA, NUTRITION, AND MORTALITY IN CHILDREN

	Country and Reference	Year	Outcome Indicator	Comparison	Age (months)	% Reduction	Flaws	Comment
				POSITIVE STUDIES				
*	Bangladesh: Stanton and Clemens	1987b	diarrhea	educational intervention	0-60	26% reduction	4a	most pronounced in ages 2 and 3
*	Bangladesh: Alam et al.	1989	diarrhea incidence	personal and domestic hygiene (source of washing water, feces in yard, handwashing before serving food, and handwashing after defecation	6-23	46% and 43% reduction in 2 areas for children in households where 4 hygienic practices observed as compared to 0 or 1.	1	the intervention area which received handpumps and hygiene education had a 17% lower rate of diarrhea than the control area
	Brazil: Victora et al.	1988	diarrhea mortality	a. availability of piped water b. water quality c. type of toilet	0-12	a. 80% reduction for infants whose homes had piped water as opposed to those without easy access to piped water; b. no effect; c. no effect	1? 4b	simultaneous adjustment done for many social and environmental variables.
*	Burma: Aung Myo Ham and Thein Hlaing	1989	diarrhea incidence	handwashing	6-59	30% reduction for group where mothers and children washed with soap after defecation and before preparing or eating meals		no significant results for dysentery; no educational component described

* = Better Study

Table 1: CATALOGUE OF STUDIES (SINCE 1986) ON DIARRHEA, NUTRITION, AND MORTALITY IN CHILDREN (continued)

Country and Reference	Year	Outcome Indicator	Comparison	Age (months)	% Reduction	Flaws	Comment
The Gambia: Pickering et al.	1986	child mortality	water supply	children	OR of 2.1 for standpipe as opposed to having clean water available elsewhere	2,5	standpipe correlated with other variables; deaths may have occurred when conditions different from those at time of survey
Lesotho: Esrey et al.	1989b	infection	water quantity	1-60	risk of giardia infection was 2.42 times greater for low water users than for high		risks of traditional water source and no latrine were NS.
* Lesotho: Esrey et al.	1988b	infection, diarrhea, growth	water quality	1-60	Those using exclusively improved supply for drinking and cooking grow .438 cm and 235 g more in 6 months than those using improved and unimproved		difference was much greater for the >12 month age group
Malaysia: Habicht et al.	1988	mortality	a. toilets vs. nothing b. toilets + water vs. nothing c. toilets + water vs. toilets	0-12	% reduction in attributable risk (due to not breastfeeding): a. 69% b. 82% c. 40%	4b,5	synergistic effect shown for the interaction of poor sanitation and non-breast feeding
Malaysia: Esrey and Habicht	1988a	mortality	a toilets vs. no toilets b. piped water vs. no piped water	0-12	% reduction in attributable risk (due to maternal illiteracy): a. 60% b. 43%	4b,5	The impact of toilets was > among illiterates (OR=4.08) while impact of water was greater for literates.

Table 1: CATALOGUE OF STUDIES (SINCE 1986) ON DIARRHEA, NUTRITION, AND MORTALITY IN CHILDREN (continued)

Country and Reference	Year	Outcome Indicator	Comparison	Age (months)	% Reduction	Flaws	Comment
* Nigeria: Huttly et al.	1987	diarrhea morbidity	a. water quality b. water storage c. absence of soap d. feces in yard e. rubbish in yard	0-48	only rubbish in the yard during the dry season was significant; 52% reduction for rubbish free yard	2?	use of non-purified water was protective in the rainy season as were uncovered water containers in the dry season (NS)
			NEGATIVE STUDIES				
Bangladesh: Stanton et al.	1988	nutrition	educational intervention	0-60	1 year after intervention the mean weight for age of children in both groups was 76% of the NCHS standard	10a	Diarrhea was reduced but nutritional indicators didn't change.
Bangladesh: Stanton and Clemens	1987a	diarrhea	access to water and latrine	0-60	those with access to latrine 5% more likely to have diarrhea; access to drinking water associated with 16% more diarrhea	9,10a	This urban study found risk factors different from rural studies
* Lesotho: Esrey et al.	1987	infection, diarrhea, growth	improved water supply vs. traditional water	1-60	child growth significantly better (.244 cm and .098 kg) in the unimproved villages		The intervention improved the quality of water but usage didn't change
Malawi: Lindskog et al.	1987	growth	access to piped water supply	0-48	children using supply gained more weight and more in upper arm circumference, but increased less in height	7,8(?)	Water use increased from 12.8 to 15.5 liters per person per day; distance to source changed from 410 m to 270 m

Table 1: CATALOGUE OF STUDIES (SINCE 1986) ON DIARRHEA, NUTRITION, AND MORTALITY IN CHILDREN (continued)

Country and Reference	Year	Outcome Indicator	Comparison	Age (months)	% Reduction	Flaws	Comment
Malawi: Lindskog et al.	1988	mortality	access to piped water supply	0-48	relative risk for those using improved supply as compared to those without was 0.4	7,8 (?)	low number of piped water users during the rainy season when the mortality occurred
Malawi: Young and Briscoe	1987	diarrhea	environmental sanitation	0-60	20% less diarrhea for use of good quality water supplies and latrines	8,9,10a, 10b	does controlling for water quantity cloud comparison?
Philippines: Baltazar et al.	1988	diarrhea/ pathogen + diarrhea	environmental sanitation	0-24	20% less diarrhea and 40% less pathogen-positive diarrhea for adequate environmental practices	8,9,10a, 10b	results pertinent only for children using clinics during warm, rainy months.

Better studies on diarrheal morbidity from earlier review (Esrey and Habicht, 1986): Koopman, 1978; Rahaman et al., 1983; Freij and Wall, 1977; Guerrant et al., 1983; Schleissman, 1958; Cairncross and Cliff, 1987; Thacker et al., 1980; Ryder et al., 1985; Torun, 1982; Black et al., 1981; Bersh and Osoria, 1985; Khan, 1982; Pickering, 1985.

Table 2: CATALOGUE OF ASCARIASIS STUDIES

Country and Reference	Year	Outcome Indicator	Comparison	Age (years)	% Reduction	Flaws	Comment
			POSITIVE STUDIES				
Costa Rica: Moore et al.	1965	parasite survey	excreta disposal facility	all	45% reduction for privy; 62% reduction for septic tank (est. from graph)	1, 2	cross-sectional facilities probably confounded by income, crowding, animals
Egypt: Chandler	1954	stool prevalence and egg count	latrines, wells, fly control, garbage disposal vs. control	>1	34% reduction in prevalence; 29% reduction in egg count	1,2,5	prospective, 2 years follow-up; no baseline data; villages differed at start.
Egypt: Miller et al.	1980	stool survey	latrines	all	Odds Ratio for 3 of 35 villages given as 1.5*,3.6*,and .46. * = statistically significant.	1,2,5	data not analyzed to link environmental parameters to inc.;piperazine may have been widely distributed shortly before survey
* Iran: Sahba and Arfaa	1967	stool prevalence and egg count	household latrines, public taps, washing facilities	all	15% reduction in prevalence; 62% reduction in egg count	2	possible season confounding; community surveys Feb '63 and Winter '65
* Iran: Arfaa et al.	1977	stool prevalence and egg count	water and sanitation, chemotherapy, both	all	decreased prevalence w+s 28%, chemotherapy 84%, both 79%; decreased egg count w+s 60%, chemotherapy 90%, both 88%	2	cohorts different to begin with; limited intervention due to misuse; prospective over 4 years.

Table 2: CATALOGUE OF ASCARIASIS STUDIES (continued)

	Country and Reference	Year	Outcome Indicator	Comparison	Age (years)	% Reduction	Flaws	Comment
	Puerto Rico: Pimentel et al.	1961	stool prevalence	sanitation in 3 watersheds	1-17	average reduction of 32% for home taps, laundry and bathing facilities vs. area where surface water used	2	8, sequential surveys of the same children over 2 years; very different water supply facilities, but other potential confounders.
*	St. Lucia: Henry	1981	stool samples	water supply + latrines	<3	30% reduction for water; 31% reduction for water + latrines; increase in controls		prospective; growth of children better for improved areas
*	United States: Schleissmann et al.	1958	stool prevalence	flush toilet vs. privy; indoor plumbing vs. tap well	all	83% reduction for high level of w+s service vs. low level; 72% reduction for flush toilet vs. privy; 29% reduction for indoor plumbing vs. well	2	large cross-sectional surveys used to select 3 homogenous groups; afterwards data analyzed by facility; no discussion of floor type; many potential confounders elucidated by authors
	Zambia and Ghana: Feachem et al.	1983a	stool prevalence	excreta disposal facilities	all	One area showed no differences, another no ascaris; one area showed 75% reduction for pit latrines vs. aqua privies and 53% reduction for communal flush toilets vs. aqua privies	1,2,5 7,8,9	non-random, non-systematic survey; small numbers cohort comparability stated but not shown; facility differences may be minor

Table 2: CATALOGUE OF ASCARIASIS STUDIES (continued)

Country and Reference	Year	Outcome Indicator	Comparison	Age (years)	% Reduction	Flaws	Comment
			NEGATIVE STUDIES				
Egypt: Khalil	1931	stool samples	rigorously sanitary prison conditions	adult males	little change due to prison conditions	9	no adequate control; ate vegetables grown with human wastes
Egypt: Scott and Barlow	1938	stool prevalence and egg count	treatment vs. sanitation vs. treatment + sanitation vs. control	all	no significant changes found	8, 9	prospective over 4 years; scattered data
Kenya: Stephenson et al.	1983	stool	latrines	1-school age (primary)	37% reduction but not significant	8	cross-sectional designed to evaluate chemotherapy treatment; small fraction (8% of families had no
Panama: Sweet et al.	1929	stool and egg count	latrines (with treatment)	>2	sanitated villages had more initial reduction, greater reinfection	7, 9	contrasting 2 villages via surveys; differences between villages
U.S.A.: Eyles et al.	1953	stool prevalence	excretal disposal	all	42% for sanitary facilities vs. none		
			water supply	all	66% more infection with water on premises than off premises	8, 9	unrepresentative sample, not statistically significant

Table 3: CATALOGUE OF GUINEA WORM STUDIES

Country and Reference	Year	Outcome Indicator	Comparison	Age (years)	% Reduction	Flaws	Comment
			POSITIVE STUDIES				
Ghana: Lyons	1972	annual incidence	source of drinking water	all	37% reduction for boreholes, deep wells and dams, as compared to ponds, rivers, and shallow wells	2	less-risky sources were generally not used exclusively; often they were only used when ponds and pools dried up
India: Reddy et al.	1969	prevalence of infection by village	water supply	all	78% reduction for village with decreased use of unprotected step-wells	2,5	prevalence in four villages increased with proportion of the population using step-wells
India: Bhatt and Palan	1978	prevalence of guinea worm infection	water source	all	84% of affected families used pond water, 65% used well water, 38% used tubewells	2,4,5	majority of families using wells and tubewells switched to pond water in summer when improved supplies became more salty and inadequate
India: Johnson and Joshi	1982	infection rate	water source	all	98% reduction associated with draw well use as opposed to pond use	2,4b	93% of those surveyed used pond water sources
* Nigeria: Edungbola et al.	1988	prevalence of guinea worm infection	water supply intervention	all	81% reduction in 20 villages provided with boreholes and pumps, along with health education	2	less reduction in villages where boreholes were not convenient or had unpalatable water; no change in control villages

Table 3: CATALOGUE OF GUINEA WORM STUDIES (continued)

Country and Reference	Year	Outcome Indicator	Comparison	Age (years)	% Reduction	Flaws	Comment
Nigeria: Udonsi	1987	prevalence of guinea worm infection	water supply	all	72% reduction 18 months after provision of water supply	4a,4b,5	not clear how post-prevalence determined; prevalence higher in those >20 years old; reductions greater in <20 year olds
* Uganda: Henderson et al.	1988	seasonal attack rate	water source	all	~90% reduction for borehole use in rainy season; ~60% reduction in dry season	2,5	boreholes, on average, were closer than other sources; exact figures for percent reduction not given

Table 4: CATALOGUE OF HOOKWORM STUDIES

Country and Reference	Year	Outcome Indicator	Comparison	Age (years)	% Reduction	Flaws	Comment
			POSITIVE STUDIES				
Egypt: Chandler	1954	stool prevalence and egg cont	latrines, wells, fly control, garbage disposal vs. nothing	>1	town with intervention: 7% F, 12% M+, <200 e/gr/case; control: 15% F, 42% M+, 300 e/gr/case	1,2,5	prospective 2-year follow-up; only sampled at end of 2 years; villages were different to begin with
Egypt: Khalil	1931	stool samples	rigorously sanitary prison conditions	adult males	about 80% reduction in prevalence after 10 years	2	no adequate control; age and year of internment may be confounders; survey of prison population
Panama: Cort et al.	1929	stool egg count	latrines with treatment	>2	net reduction of 26% (town) and 28% (individual) 8 months after treatment	1,2	village-wide stool surveys; villages may have been different; those with latrines may not have been comparable to those without, within the sanitated village
Panama: Sweet et al.	1929	stool egg count	latrines	>10	2 villages, 62.7% and 45% fewer eggs for latrine users, 43% less in 7-year follow-up of treatment	1,2,3,5	sample selection non-systematic, not random; poor control groups

Table 4: CATALOGUE OF HOOKWORM STUDIES (continued)

Country and Reference	Year	Outcome Indicator	Comparison	Age (years)	% Reduction	Flaws	Comment
United States: Schliessmann et al.	1958	stool prevalence	flush toilet vs. privy; indoor plumbing vs tap vs. well	all	3 groups: high level of service, prevalence=0%; medium service, prevalence=.5%; low service, prevalence=1.9%	2	large cross-sectional survey used to select 3 homogenous groups; many potential confounders, primarily related to income; potential problems from floor type and shoe use differences
			NEGATIVE STUDIES				
Costa Rica: Moore et al.	1965	parasite survey	excreta disposal facility	all	no influence of privies	7,9	floor type very significant; cross-section; many with dirty floors; few with no latrine
Egypt: Scott and Barlow	1938	stool prevalence and egg count	treatment vs. sanitation vs. treatment and sanitation vs. nothing	all	no significant finding	8,9	prospective over 4 years; very scattered data; poor lab results
Egypt: Miller et al.	1980	stool survey	latrines	all	not significant	6,7,9	low prevalence; individual latrines may be insignificant or risk
* Iran: Arfaa et al.	1977	stool, prevalence, and egg count	water and sanitation, chemotherapy, both	all	decreased prevalence W+S 4%, chemotherapy 73%, both 69%; decreased egg count W+S 26%, chemotherapy 87%, both 88%	7,9	cohorts differed to start with; latrines poorly maintained in some areas, may have promoted infection

Table 4: CATALOGUE OF HOOKWORM STUDIES (continued)

	Country and Reference	Year	Outcome Indicator	Comparison	Age (years)	% Reduction	Flaws	Comment
*	Kenya: Stephenson et al.	1986	stool prevalence and egg count	latrines	7-15	9% reduction in prevalence (NS); 75% reduction in high egg count (p=.06)	8,9	case-control study; only 75 households included in hookworm portion of this study.
	Zambia and Ghana: Feachem et al.	1983a	stool prevalence	excreta disposal facilities	all	no differences found	7,8,9	non-random, non-systematic survey; small numbers; looked in 3 cities (Gaborone had a 1% prevalence): says cohorts were comparable but no floor type or shoe use data to support this

Table 5: CATALOGUE OF SCHISTOSOMIASIS STUDIES

Country and Reference	Year	Outcome Indicator	Comparison	Age (years)	% Reduction	Flaws	Comment
			POSITIVE STUDIES				
* Brazil: Barbosa et al.	1971	S. mansoni prevalence; fecal egg presence	water and sanitation intervention	0-14	77% reduction over 7 years above reductions in the controls	2,3,5	results from control villages were taken into account; a prospective study
Brazil: Lima E Costa et al.	1985	S.m. eggs/gr. feces, splenomegaly	water supply	all	water supply better in areas of low infection	1,2,3,4,5	cross-sectional; many potental confounders; cases analyzed by urban zone
* Brazil: Lima E Costa et al.	1987	S.m. egg in stool; splenomegaly	piped water	<15, >15	OR=2.3 for infection in 2-14 year olds; 7.3 for splenomegaly in 5-14 year olds; 2.4 for splenomegaly in >15 year olds, NS for infection in >15	1,2	case-control based on physicals and survey; water contact very strongly associated with infection; little malaria in area
Egypt: Miller et al.	1978	S.m. and S.h. prevalence	water source	all	piped indoor <standpipe <canal	2	2 regions, 3 villages each; looked within village
Egypt: Farooq et al.	1966	S.m. and S.h. prevalence	water source	all	in all 5 zones, piped water protective; OR for S.h.=1.6,1.2, 1.6, 1.0, 1.2; OR for S.m.=2.6, 2.4, 3.7, 1.8	1,2,3	cohorts defined by zone; cross-sectional
Kenya: Stephenson et al.	1986	S.h. egg counts	water source, water use	7-15	S.h. infection related to amount of water used, availability of safe bathing sites; latrines NS	1,2,8	case-control study, small sample size, looked at many social/cultural facets; trend toward protection from cleaner water source

Table 5: CATALOGUE OF SCHISTOSOMIASIS STUDIES (continued)

	Country and Reference	Year	Outcome Indicator	Comparison	Age (years)	% Reduction	Flaws	Comment
	Puerto Rico: Negron-Aponte and Jobin	1979	S.m. skin test	water supply snail control chemical treatment	5th graders	>70% reduction over 13 years due primarily to water supply	2	sequential cross-sectional surveys 1963, 1969, 1976; linear relationship between W.S. and prevalence reduction
*	St. Lucia: Jordan et al.	1982	S.m. prevalence	water supply, laundry, and shower facilities	all	59% reduction in 0-10 year olds in 5 years; 27% drop for all ages; more dramatic after chemotherapy	2	prospective study, pre-post comparison used while prevalence was decreasing elsewhere; water seemed to keep prevalence low after chemical treatment
	Swaziland: Logan	1983	S.m. and S.h. prevalence	water supply	6-8	estates with better water supply had less schistosomiasis in their children	2,3,4,5	systematic survey of estate residence, exams of school children; very qualitative variables
*	Zimbabwe: Mason et al.	1986	S.m. and S.h. prevalence	water source distance to infected waters	6-18	In communal areas, prevalence of S.m. and S.h. for those with piped water was 1/6th and 1/11th the prevalence of those without piped water	2	cross-sectional, interview, home observations, essentially 3 studies; distance to infected river significant also
						Prevalence in urban children with piped water = communal children without	6,7,8	Not comparable groups

Table 5: CATALOGUE OF SCHISTOSOMIASIS STUDIES (continued)

Country and Reference	Year	Outcome Indicator	Comparison	Age (years)	% Reduction	Flaws	Comment
				NEGATIVE STUDIES			
Madagascar: Howarth et al.	1988	S.m. and S.h. prevalence	Irrigation	5-14	In secondary school children, more schistosomiasis in well users; in primary school children, no significant differences for water	6,7,8,9	cross-sectional; small numbers of infected people; common swimming locations; older canal users bathed in safer area

Table 6: CATALOGUE OF TRACHOMA STUDIES

Country and Reference	Year	Outcome Indicator	Comparison	Age (years)	% Reduction	Flaws	Comment
			POSITIVE STUDIES				
Australia: Hardy et al.	1967	cytologic assessment	bathing	5-15	net improvement of 30% for children following bathing intervention	2	a separate comparison was made in this study for effects of antibiotics; the latter showed a net 50% of children improved
* India: Mathur and Sharma	1970	total trachoma prevalence	distance to water; personal hygiene	all	79% reduction for those with good hygiene as compared to poor; 30% reduction for having water within 200 yards as compared to beyond	2	possible confounding by income and living conditions, as well as age
India: Misra	1975	trachoma	water source	not stated	91% reduction in three years as use of piped water increased	2, 4a, 4b, 5	the morbidity rates at start were extremely low; methods not stated so hard to assess study
* Malawi: Tielsch et al.	1988	inflammatory trachoma	time to water, water source, latrine, facewashing	0-6	26% reduction for water < 5 min. away vs. >60 min.; 17% reduction for having latrine	5	facewashing was significant before adjustment for other risk factors but not after
* Mexico: Taylor et al.	1985	inflammatory trachoma	a. facewashing b. water source c. water quality d. use of soap e. bathing f. distance to water	0-10	a. 69% reduction for those who wash face > 6 times per week vs. less b. no assoc c. no assoc d. no assoc e. no assoc f. no assoc	5	the result is independent of many family hygiene and socioeconomic status variables

Table 6: CATALOGUE OF TRACHOMA STUDIES (continued)

Country and Reference	Year	Outcome Indicator	Comparison	Age (years)	% Reduction	Flaws	Comment
Mozambique: Cairncross and Cliff	1987	prevalence of trachoma	close stand-pipe vs. distant traditional source	all	50% reduction in village with improved supply	1?, 2, 4b	likely that environmental and other differences exist between villages because results for late-stage trachoma cannot be explained by a 2 year-old improved supply
South Africa: Pratt-Johnson and Wessels	1958	prevalence of active trachoma	water supply	adults; >2; >7	86% less active trachoma in village with abundant water than in one with drought conditions	2, 4a, 4b, 3b?	comparison made between groups with different age compositions
South Africa: Sutter and Ballard	1983	KAP (prevalence of intense upper tarsal disease)	care groups (community groups working against trachoma)	0-6; all	significant impact made on awareness of role of hygiene in trachoma prevention; NS impact on latrine construction		prevalence data not useful here because care groups used drug treatment
Sudan: Majcuk	1966	active and total trachoma prevalence	bathing	all	57% reduction in active trachoma for daily bathers vs. occasional bathers; 54% reduction in total trachoma	2	no discussion of methods used to get information on bathing
* Taiwan: Assaad et al.	1969	active trachoma prevalence	water source distance to water	all	45% reduction for those with attached water vs. those with source >500m away	2, 4b	controlled separately for age and for source but not both together and not for other factors

Table 6: CATALOGUE OF TRACHOMA STUDIES (continued)

Country and Reference	Year	Outcome Indicator	Comparison	Age (years)	% Reduction	Flaws	Comment
* Tanzania: West et al.	1989	active, inflammatory trachoma prevalence	a. water source b. distance to source c. amount used d. relation of clean faces and distance	1-7	a. no association b. 26% fewer households with all children infected when water close c. no association d. OR=1.7 for all children in family having unclean faces e. 14% fewer households with all unclean children when water close	4a, 2?	effect of distance to water source independent of amount brought into household
Tunisia: Dawson et al.	1976	intensity of infection; gravity of infection	water supply	all	significant association for adults >30	2, 4b, 5	no numbers reported for the results that concern this public fountain vs. spring comparison
United States (Ryukyu Islands): Marshall	1968	prevalence	water supply	5-15	Two comparisons show 83% and 89% reduction in two areas without piped water as compared to a supplied area	2, 4b	provision of piped water in schools thought to increase transmission through shared towels

Table 6: CATALOGUE OF TRACHOMA STUDIES (continued)

Country and Reference	Year	Outcome Indicator	Comparison	Age (years)	% Reduction	Flaws	Comment
NEGATIVE STUDIES							
* Mexico: Wilson et al.	1987	inflammatory and cicatricial trachoma prevalence	facewashing, bathing	2-10	no numbers given for results	9, 8?	this was a follow-up to the other Mexico study
* Morocco: Kupka et al.	1968	prevalence of active trachoma prevalence of grave trachoma	distance to water; volume of water used	all	little correlation with distance; 5% reduction in active cases for greater water use; 27% reduction in grave cases	9	no correlation found between distance from water source and per capita use of water
United States: Portney and Hoshiwara	1970	active trachoma, healed trachoma	18 water and sanitation variables	all	difficult to interpret	9	study found a surprising positive relationship between available space and prevalence of trachoma

TABLE 7

(TABLE 4 EXPANDED. SEE PAGE 29 IN TEXT.)

EXPECTED REDUCTION IN MORBIDITY AND MORTALITY FROM IMPROVED WATER SUPPLY AND SANITATION

	EXPECTED REDUCTION IN DISEASE[A]					
	ALL STUDIES[B]			BETTER STUDIES		
	NO.[C]	MEDIAN	RANGE	NO[C]	MEDIAN	RANGE
DIARRHEA MORBIDITY	49	22%	0%-100%	19	26%	0%-68%
DIARRHEAL MORTALITY	3	65%	43%-79%	–	–	–
ASCARIASIS[D]	11	28%	0%-83%	4	29%	15%-83%
GUINEA WORM	7	76%	37%-98%	2	78%	75%-81%
HOOKWORM[D]	9	4%	0%-100%	-[E]	-	–
SCHISTOSOMIASIS[D]	4	73%	59%-87%	3	77%	59%-87%
TRACHOMA	13	50%	0%-91%	7	27%	0%-79%
OVERALL WS&S IMPACT ON CHILD MORTALITY[F]	9	60%	0%-82%	6	55%	20%-82%

A REDUCTION FIGURES FOR EACH INDIVIDUAL STUDY WERE CALCULATED DIRECTLY FROM THE NUMBERS PRESENTED WHEN POSSIBLE, USUALLY PREVALENCE RATES. THIS WAS NOT POSSIBLE FOR SOME STUDIES, HOWEVER, WHEN EITHER ODDS RATIOS OR GRAPHS WERE USED TO DEPICT RESULTS. TO CONVERT ODDS RATIOS, PREVALENCE RATES WERE EMPLOYED IF KNOWN, TO CONVERT GRAPHS, ESTIMATES WERE MADE. WHEN A STUDY REPORTED THE RESULTS FROM MORE THAN ONE COMPARISON, THE FIGURE SIGNIFYING THE LARGEST REDUCTION IN DISEASE WAS USED AS A MEANS OF HIGHLIGHTING THE BENEFITS OF WATER AND SANITATION UNDER OPTIMAL CONDITIONS. WHEN STUDIES SHOWED REDUCTIONS THAT WERE NOT STATISTICALLY SIGNIFICANT, THE REPORTED REDUCTION FIGURES WERE USED. WHEN STUDIES SHOWED AN INCREASE IN DISEASE, THIS WAS CONSIDERED TO BE A REDUCTION OF ZERO; BECAUSE MEDIANS WERE USED, THIS DID NOT AFFECT THE RESULTS

B IN EVERY DISEASE CATEGORY ALL AVAILABLE STUDIES MEETING THE CRITERIA DESCRIBED IN THE METHODS ARE SUMMARIZED.

C THE NUMBER OF STUDIES MAY NOT EQUAL THE NUMBER OF STUDIES REVIEWED IN SOME STUDIES REDUCTIONS COULD NOT BE CALCULATED BECAUSE FIGURES WERE NOT AVAILABLE OR ODDS RATIOS COULD NOT BE CONVERTED TO PREVALENCE RATIOS

D ALTHOUGH THE PRESENCE OF EGGS IN THE STOOL WAS USED AS INDICATOR OF PREVALENCE OF ASCARIASIS, HOOKWORM INFECTION AND SCHISTOSOMIASIS, THE FIGURES FOR REDUCTION IN EGG COUNT, AN INDICATOR OF SEVERITY OF DISEASE, DID NOT FACTOR INTO THE CALCULATIONS MADE FOR THIS TABLE.

E ALL BUT ONE HOOKWORM STUDY WAS FLAWED RATHER THAN BASE EXPECTED REDUCTIONS ON ONE STUDY, THE COLUMN UNDER BETTER STUDIES WAS LEFT BLANK.

F SEVERAL RESULTS WERE EXCLUDED FROM THE CHILD MORTALITY CALCULATIONS. THEY WERE: BUTZ ET AL., 1984, WHICH USED THE SAME DATA AS ESREY AND HABICHT, 1988A, AND HABICHT ET AL 1988, AND SO THE THREE WERE COUNTED AS ONE; ASCOLI ET AL., 1967, WHICH DID NOT ISOLATE THE EFFECT OF WATER AND SANITATION ON MORTALITY, AND WAXLER ET AL., 1985, FROM WHICH REDUCTION FIGURES COULD NOT BE ESTIMATED.

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THE WASH PROJECT

With the launching of the United Nations International Drinking Water Supply and Sanitation Decade in 1979, the United States Agency for International Development (A.I.D.) decided to augment and streamline its technical assistance capability in water and sanitation and, in 1980, funded the Water and Sanitation for Health Project (WASH). The funding mechanism was a multi-year, multi-million dollar contract, secured through competitive bidding The first WASH contract was awarded to a consortium of organizations headed by Camp Dresser & McKee International Inc. (CDM), an international consulting firm specializing in environmental engineering services. Through two other bid proceedings since then, CDM has continued as the prime contractor.

Working under the close direction of A.I.D.'s Bureau for Science and Technology, Office of Health, the WASH Project provides technical assistance to A.I.D. missions or bureaus, other U.S. agencies (such as the Peace Corps), host governments, and non-governmental organizations to provide a wide range of technical assistance that includes the design, implementation, and evaluation of water and sanitation projects, to troubleshoot on-going projects, and to assist in disaster relief operations. WASH technical assistance is multi-disciplinary, drawing on experts in public health, training, financing, epidemiology, anthropology, management, engineering, community organization, environmental protection, and other subspecialties.

The WASH Information Center serves as a clearinghouse in water and sanitation, providing networking on guinea worm disease, rainwater harvesting, and peri-urban issues as well as technical information backstopping for most WASH assignments.

The WASH Project issues about thirty or forty reports a year. WASH *Field Reports* relate to specific assignments in specific countries; they articulate the findings of the consultancy The more widely applicable *Technical Reports* consist of guidelines or "how-to" manuals on topics such as pump selection, detailed training workshop designs, and state-of-the-art information on finance, community organization, and many other topics of vital interest to the water and sanitation sector. In addition, WASH occasionally publishes special reports to synthesize the lessons it has learned from its wide field experience.

For more information about the WASH Project or to request a WASH report, contact the WASH Operations Center at the above address.