Reviews/Analyses

Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma

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A total of 144 studies were analysed to examine the impact of improved water supply and sanitation facilities on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. These diseases were selected because they are widespread and illustrate the variety of mechanisms through which improved water and sanitation can protect people. Disease-specific median reduction levels were calculated for all studies, and separately for the more methodologically rigorous ones. For the latter studies, the median reduction in morbidity for diarrhoea, trachoma, and ascariasis induced by water supplies and/or sanitation was 26%, 27%, and 29%, respectively; the median reduction for schistosomiasis and dracunculiasis was higher, at 77% and 78%, respectively. All studies of hookworm infection were flawed apart from one, which reported a 4% reduction in incidence.

For hookworm infection, ascariasis, and schistosomiasis, the reduction in disease severity, as measured in egg counts, was greater than that in incidence or prevalence. Child mortality fell by 55%, which suggests that water and sanitation have a substantial impact on child survival.

Water for personal and domestic hygiene was important in reducing the rates of ascariasis, diarrhoea, schistosomiasis, and trachoma. Sanitation facilities decreased diarrhoea morbidity and mortality and the severity of hookworm infection. Better water quality reduced the incidence of dracunculiasis, but its role in diarrhoeal disease control was less important than that of sanitation and hygiene.

Introduction

Water and sanitation have been the subjects of considerable recent attention as a result of the declaration by the United Nations General Assembly that the 1980s were the International Drinking-Water, Supply and Sanitation Decade (IDWSSD). A major objective of this was to improve the health of populations that received the interventions. Most of the research on the health impacts of water and sanitation projects has focused on the incidences of diarrhoeal diseases, malnutrition, and mortality of young children, and evidence accumulated during the decade indicates that these rates have been reduced (*22*, *25*). Although it is generally believed that the rates of other diseases will decrease following improvements in water and sanitation, there have been no systematic reviews of this.

The present article reviews the health impact of water and sanitation interventions on the following: ascariasis (*Ascaris lumbricoides*), diarrhoeal diseases (including measures of nutritional status and child survival), dracunculiasis (*Dracunculus medinensis*), hookworm infection (*Ancylostoma duodenale* and *Necator americanus*), schistosomiasis (*Schistosoma haematobium* and *S. mansoni*), and trachoma (*Chlamydia trachomatis*). These diseases were chosen because they are widespread in developing countries, or because they constitute serious problems where they exist, or both (Table 1). All developing countries are affected by diarrhoeal diseases and ascariasis; the

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Table 1: **Incidence and effects of selected diseases in developing countries (excluding China)**

	Estimated number of:	
	Cases per year ($\times 10^6$)	Deaths per year
Ascariasis[a]	900	20 000
Diarrhoeal diseases[b]	875	4.6 million
Dracunculiasis[c]	4	—[f]
Hookworm infection	800	—[f]
Schistosomiasis[d]	200	—[f]
Trachoma[e]	500	—[g]

[a–e] See ref. *96*, *80*, *97*, *57*, and *18*, respectively.
[f] Usually causes debilitation rather than death.
[g] The major disability is blindness (8 million).

other four diseases are somewhat more restricted in their range, although they are all prevalent in some developing countries, except dracunculiasis, which only occurs in parts of Africa and Asia.

These diseases also illustrate the variety of mechanisms through which improved water and sanitation can promote health (Table 2). Four basic aspects were considered: sanitation (i.e., human excreta disposal), water quality, personal hygiene, and domestic hygiene. Personal hygiene refers to water used for cleaning the body, including water for the face, hands, and eyes; domestic hygiene refers to water used to keep the home clean (e.g., food, utensils, and floors). Each disease is affected by one or more of these interventions. For example, providing safe, potable sources of drinking-water will probably prevent transmission of dracunculiasis, while using larger quantities of water for personal hygiene will probably interrupt the spread of trachoma. The incidence, prevalence, and/or severity of all these diseases are reduced by water and sanitation interventions.

Table 2: **Illustration of the potential relation between water and sanitation interventions and morbidity from selected diseases[a]**

	Intervention			
	Improved drinking-water	Water for domestic hygiene	Water for personal hygiene	Human excreta disposal
Ascariasis	+	++	—	++
Diarrhoeal diseases	+	++	++	++
Dracunculiasis	++	—	—	—
Hookworm infection	—	—	—	++
Schistosomiasis	—	++	++	++
Trachoma	—	+	++	—

[a] Interventions marked with one or two pluses have an impact on a particular disease: an intervention marked "++" will have a stronger impact than one marked "+"; "—" = the intervention 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 intervention alone.

Methods

Computer searches of articles on each of the diseases considered were carried out using the MEDLINE and MEDLINE 500 systems, which cover the period from 1966 and 1986, respectively. For schistosomiasis, an additional computer search was performed on CAB Abstracts (period, 1984–89). For hookworm infection and ascariasis, Index Medicus was searched for 1976–86, and the Science Citation Index for 1970–84. Because a thorough review of diarrhoeal diseases was published in 1986 (*22*), only studies published since then were sought. For trachoma, additional references were provided by a recent review (*72*).

References cited in the articles identified, but which were not located in the computer search, were also sought. Only studies published in English in peer-review journals were used; this methodology excluded technical reports, mimeographs, and agency documents. An exception was made for studies carried out by Miller et al.,[a,b] because although they had been published in peer-review journals, the unpublished documents upon which they were based contained more information. Finally, the review was restricted to studies that presented data on the effect of water and sanitation conditions on one of the six diseases.

Specific criteria that we have reported previously were used to identify the rigorous studies from the large number reviewed (*22*). First, studies were divided into those that reported a statistically significant positive association between the provision of improved water or sanitation and better health and those that did not. Studies were excluded from the rigorous category if they had a single major flaw or several known or suspected minor flaws that could have biased their results. Each disease is treated in turn, with the discussion focusing on the rigorous studies.

The median reductions in morbidity (i.e., incidence and prevalence) and a range of reductions attributable to improved water and sanitation were

[a] **Miller, F.D. et al.** *Human intestinal parasitic infections and environmental health factors in rural Egyptian communities.* (EPA Research Reporting Series EPA-600/1-80-024), 1980.
[b] **Miller, F.D. et al.** *Schistosomiasis in rural Egypt: a report of U.S.-Egyptian River Nile and Lake Nasser research project.* (EPA Research Reporting Series EPA-600/1-78-070), 1978.

calculated for each disease, based on all the studies reviewed. The same calculations were also made for only the rigorous studies, the results from which more accurately represent the reductions that may be achieved by water and sanitation interventions. The results reported in some studies did not permit determination of the median reduction in morbidity, and such studies were not included in the calculations. The average reduction for each disease category was expressed as the median value for all the studies considered, and not as the mean, because medians are not influenced by extreme values, while means are.

The definitions of morbidity reported in the articles reviewed included incidence, point and period prevalence, infection, and indicators of severity (e.g., duration). As far as possible, changes in incidence and prevalence have been used in the present review, but the discussion of specific studies also includes changes in infection and severity of disease.

Results

Ascariasis

For ascariasis, nine studies that reported a positive effect for water supply or sanitation were reviewed (*3*, *15*, *31*, *37*, *63*, *66*, *76*, *77*)[c] together with five negative studies (*28*, *44*, *78*, *85*, *89*). Three studies (*63*, *66*)[c] examined differences in excreta disposal facilities, and five (*3*, *15*, *37*, *76*, *77*) investigated various combinations of water supply and sanitation conditions. All five negative studies reported on excreta disposal facilities, while only one study (*37*) investigated the influence of water supplies alone. One study (*31*) reported both positive and negative findings; for ascariasis, significant differences were found among users of different types of excreta disposal facilities. The median reduction in morbidity estimated from all studies was 28%, while that for only the rigorous studies (*3*, *37*, *76*, *77*) was 29% (Table 3).

Water supplies with sanitation. The four rigorous studies (*3*, *37*, *76*, *77*), all of which reported positive effects, investigated the combination of water supplies and excreta disposal facilities. The rate of morbidity reduction was dependent on the level of service provided, and indoor facilities were associated with larger reductions than public facilities. In the USA the prevalence of *Ascaris* spp. among all age groups was reduced by 71% for people with flush toilets and indoor plumbing compared with a group that had lavatories but no well-water (*77*). In Saint Lucia the prevalence of *Ascaris* spp. was reduced by 31% for a cohort of children with household water and latrines compared with a control group without such facilities (*37*). In Iran the provision of a courtyard latrine

[c] See footnote *a*, p. 610.

Table 3: **Expected reduction in morbidity and mortality from improved water and sanitation for selected diseases**[a]

	All studies[b]		Rigorous studies[b]	
	n[c]	Median reduction (%)	*n*[c]	Median reduction (%)
Ascariasis[d]	11	28 (0–83)[e]	4	29 (15–83)
Diarrhoeal diseases				
Morbidity	49	22 (0–100)	19	26 (0–68)
Mortality	3	65 (43–79)	—	— —
Dracunculiasis	7	76 (37–98)	2	78 (75–81)
Hookworm infection[d]	9	4 (0–100)	1	4 —
Schistosomiasis[d]	4	73 (59–87)	3	77 (59–87)
Trachoma	13	50 (0–91)	7	27 (0–79)
Child mortality[f]	9	60 (0–82)	6	55 (20–82)

[a] The reduction for each individual study was calculated, if possible, directly from the data reported, usually prevalences. However, this was not possible for studies that reported results as odds ratios or graphically. To convert the odds radios, we used prevalences, if they were known; for the data in graphical form, estimates of the reductions were made. If a study reported the results from more than one comparison, the largest reduction in disease was used to highlight the benefits of water and sanitation under optimal conditions. The results from studies that reported reductions that were not statistically significant were used. If studies showed an increase in disease, this was taken to be a reduction of zero; because medians were used, this did not affect the results.

[b] For every disease category, all available studies that met the criteria described in "Methods" are summarized.

[c] The number of studies may not equal the number of studies reviewed. For some studies, reductions could not be calculated because data were not available or prevalences could not be determined from the odds ratios.

[d] Although the presence of eggs in stools was used as an indicator of the prevalence of ascariasis, hookworm infection and schistosomiasis, data for the reduction in egg count (an indicator of the severity of these diseases) were not used in the calculations.

[e] Figures in parentheses are the range.

[f] Results from several studies were excluded from the child mortality calculations. One study (*13*) used the same data as two others (*23*, *33*), and so these three were grouped as one study. Another study (*4*) did not isolate the effect of water and sanitation on mortality; and reduction levels could not be estimated from another study (*98*).

and public standpipes was associated with a reduction of 16% in the prevalence of ascariasis compared with a control group with no such facilities (*76*).

In two studies in Iran the reduction in the severity of ascariasis was greater than that of its prevalence (*3*, *76*). In one of these studies the baseline infection rates and egg counts in four villages that had a household latrine and a community water supply were compared with the infection rates and egg counts in three control villages (*3*). After 3–4 years, the prevalence of infection with *Ascaris* spp. in the group with latrines and water supply had decreased by 28% and the egg counts by 60%. For the control group, the prevalence of infection and the egg counts decreased by 19% and 29%, respectively. In the second study, courtyard latrines and public standpipes reduced egg counts by 62% over a 1–2-year period, but the prevalence of ascariasis dropped by only 16% (*76*).

Water supplies. The effect of water supplies on infection with *Ascaris* spp. was compared in two studies (*37*, *77*). In the USA the reduction in the prevalence of infection was 37% for a group that had lavatories and indoor plumbing, and 12% for those with lavatories and a yard well, in both cases relative to a control group that had only lavatories, but no well-water (*77*). In Saint Lucia the provision of household piped water supplies produced a 30% reduction in ascariasis over a 2-year period among children under 3 years of age (*37*).

Water and sanitation plus chemotherapy. The reduction in ascariasis was greater if chemotherapy was used in conjunction with water and sanitation than if only water and sanitation were provided. In the study in Iran described above (*3*), four villages were supplied with a household latrine and a community water supply plus chemotherapy, four others with only chemotherapy, and three villages remained as a control group. For the group with latrines, water, and chemotherapy, the prevalence of *Ascaris* spp. among all age groups decreased by 79% and egg counts by 88%, while the corresponding reductions for the chemotherapy-only group were 84% and 90%. These were considerably greater than the reductions for the group with only water and sanitation (28% and 60%, respectively). The reductions in the prevalence of ascariasis and in egg counts for the control group over the 3–4-year study period were 19% and 29%, respectively.

Diarrhoeal diseases

We have updated a previous review of 67 studies on diarrhoeal morbidity, nutritional status, and mortality (*22*) by including 17 more recent studies (*1*, *6*, *7*, *23*, *24*, *26*, *27*, *33*, *39*, *51*, *52*, *65*, *81–83*, *95*, *103*). The median reduction in diarrhoeal morbidity calculated from all the studies was 22%, and from the rigorous studies only, 26% (Table 3).

Water and sanitation. Eleven studies examined the combined effect of water and sanitation without considering the effect of each separately; the median reduction determined from the seven that provided appropriate data was 20% (Table 4). Two studies reported on specific pathogens, one on nutrition, and one on mortality. Of the 11 studies, seven were flawed (three of which reported positive impacts). In two of the rigorous studies, an average of 30% reduction in diarrhoea was associated with improved water and sanitation conditions (*47*, *73*). A third study reported fewer malnourished children from families with a sewage system and a household bath than from families with latrines and no bath (*16*). In Malawi, the combination of water and sanitation was associated with a lower prevalence of diarrhoea, but the results were not statistically significant because of small sample sizes (*103*). Only one of the 11 studies examined mortality: among infants in Malaysia, the addition of toilets and water versus no facility was associated with an 82% reduction in infant mortality, particularly if the child was not breast-fed (*33*).

Sanitation. The impact of sanitation was examined in 30 studies (12 of which were flawed), and 21 reported health improvements. Overall, a 22% reduction in morbidity was calculated for 11 of the 30 studies, whereas the reduction determined using data from

Table 4: **Expected reduction in diarrhoeal disease morbidity from improvements in one or more components of water and sanitation**

	All studies		Rigorous studies	
	n	Reduction (%)	*n*	Reduction (%)
Water and sanitation	7[a]/11[b]	20	2[a]/3[b]	30
Sanitation	11/30	22	5/18	36
Water quality and quantity	22/43	16	2/22	17
Water quality	7/16	17	4/7	15
Water quantity	7/15	27	5/10	20
Hygiene	6/6	33	6/6	33

[a] The number of studies for which morbidity reduction calculations could be made.
[b] The total number of studies that related the type of facility to diarrhoeal morbidity, nutrition, and mortality studies.

five of 18 rigorous studies was 36% (Table 4). Of the remaining rigorous studies, two reported on nutritional status and 11 on mortality. Of the studies that compared the relative importance of water and sanitation, most reported that sanitation had a greater impact on child health, based on mortality, growth, and morbidity indicators. Some mortality studies reported that the method of disposing of excreta determined the magnitude of the health impact. Mortality was reduced to a greater extent by flush toilets than by pit latrines (*2*, *34*, *98*), which nevertheless were associated with mortality reductions compared with no sanitation facilities at all. Sanitation has also been reported to produce a differential health impact depending on the presence or absence of other risk factors. For example, sanitation was most effective in reducing mortality among nonbreast-fed infants (*13*) and infants of illiterate mothers (*23*) than among breast-fed infants or literate mothers.

Water quality and quantity. In most of the studies reviewed, it was difficult to determine whether the differences in health conditions were due to increased amounts of water, improvements in its quality, or both; these studies have therefore been grouped together. Of the 43 studies that compared groups with different types of water supplies, 24 reported a positive impact, and for the 22 studies for which morbidity calculations could be made, a median reduction of 16% was calculated (Table 4). Of the remaining studies, four reported on pathogens, four on nutritional status, 11 on mortality, while two had insufficient information. Fourteen of the studies were rigorous. Only two of the 22 morbidity studies were rigorous (median reduction, 17%). Nine of the rigorous studies reported on mortality and three on nutritional status. Of these, a modest benefit for particular, but not all, age groups was found. In the studies that reported a health benefit, the water supply was piped into or near the home, whereas in those that reported no benefit, the improved water supplies were protected wells (*2*), tubewells (*74*), and standpipes (*27*, *51*, *52*, *69*, *98*).

Water quality. Sixteen studies (10 of which reported positive effects) examined the health impacts of pure versus contaminated water supplies. Of the seven studies for which calculations could be made, a median reduction in the prevalence of diarrhoea of 17% was found (Table 4). Four of the other nine studies reported on pathogens, two on nutritional status, two on diarrhoeal mortality, while one had insufficient information. In several of the studies, impacts were found only for certain age groups. Among the seven rigorous studies, a median reduction of 15% in diarrhoeal disease morbidity was found for the four studies for which this could be calculated. Of these, one reported little or no association between the quality of drinking-water and the occurrence of diarrhoea in children (*39*), another reported an 8% reduction in the prevalence of *Shigella* spp. (*87*), while two found some association with child nutritional status, but not with diarrhoea (*24*, *55*). Because diarrhoea has many causes, drinking-water constitutes only one of many sources of infection. In areas where environmental faecal contamination is high, little or no health impact from water improvement can be expected. For example, studies in Lesotho (*30*) and Guatemala (*79*) failed to detect reductions in the prevalence of diarrhoea following improvements in water quality. Also, a recent study in Brazil (*95*) found no association between water quality and diarrhoea mortality, as did an earlier study in India (*104*).

Water quantity. Of the 15 studies that examined the effect of increased amounts of water specifically and independently of water quality, all but one reported a positive impact. The median reduction for seven studies for which this could be calculated was 27% (Table 4). Of the other eight studies, five reported on pathogens and three on nutritional status. Of the 10 rigorous studies, a median reduction of 20% was found for the five for which this could be calculated. Health benefits were greater for children whose families used more water than for those whose families used less, but, in some instances, the differences were small or significant only for selected age groups. In Ethiopia, the prevalence of diarrhoea among under-2-year-olds from families with higher water usage rates per person was less than that among comparable children from families with lower rates (*32*). In Lesotho, use of smaller amounts of water was associated with higher rates of infection with *Giardia lamblia* (*26*). In both of these studies, the amount of water used was more important than its source. No studies relating water quantity and mortality were identified.

Hygiene. Only six studies were found that reported on the impact of hygiene interventions on diarrhoeal morbidity (*1*, *6*, *12*, *45*, *82*, *93*). All were rigorous, and the median reduction was 33% (Table 4).

Several studies focused specifically on handwashing. In Burma, a 30% reduction in diarrhoea was reported when mothers and children were provided with soap and encouraged to wash their hands after defecation and before preparing meals (*6*). In day-care centres in the USA (*12*), a handwashing regimen reduced the incidence of diarrhoea by 48% compared with a control group; and in Bangladesh

(*45*), a 35% reduction in the incidence of diarrhoea caused by *Shigella* spp. occurred following an intervention to promote handwashing.

Other studies have examined not only handwashing, but combinations of handwashing and other hygienic behaviours. For example, an educational intervention in Bangladesh (*82*) emphasized proper handwashing before preparing food, defecating away from the house at a proper site, and suitable disposal of waste and faeces; the investigators reported a 26% reduction in the incidence of diarrhoea. Another study in Bangladesh provided hand pumps and health education to promote personal and domestic hygiene (*1*); a greater than 40% reduction in the incidence of diarrhoea was found among groups with good hygiene practices (irrespective of whether or not they received the intervention), compared with individuals with poor practices. The reduction attributable to the intervention itself was 17%. In Guatemala the incidence of diarrhoea was reduced by 14% following a programme to promote health awareness and hygienic behaviour (*93*).

Dracunculiasis

Seven studies (*11*, *21*, *36*, *41*, *54*, *75*, *94*), two of which were rigorous (*21*, *36*), examined the impact of improved water supplies on the prevalence of dracunculiasis. All reported a positive impact, with similar median reductions being reported for all studies combined and for the rigorous studies only (76% and 78%, respectively).

Water source. The two rigorous studies (*21*, *36*), both of which were from Africa, compared the use of borehole water and of water from unimproved sources. In Nigeria (*21*), the impact of a UNICEF-assisted rural water project that provided boreholes and hand pumps, along with health education, was evaluated. Prior to the intervention 8600 subjects, and 3 years after its installation, over 10 000, were examined. The study comprised 20 serviced and five unserviced communities. Use of borehole water reduced the incidence of dracunculiasis by 81%. The greatest reduction in the prevalence occurred in those villages where the boreholes were conveniently sited and close by, but the effect was less if the wells were distant. The impact was also less dramatic in villages where the water was unpalatable or the supply erratic.

A study in Uganda reported data from a pre-intervention survey (*36*). Over 2000 people were interviewed in the north-west of the country to determine the relationship between water use and disease. The results were analysed by season because the attack rate of dracunculiasis peaked twice during the year. During the rainy season the attack rate among borehole users was one-tenth of that among non-users, while during the dry season it was two-fifths that of non-users.

Seasonal transmission. A number of studies on dracunculiasis have investigated the seasonal nature of its transmission. In West Africa, attack rates correlated positively with periods of below-average rainfall or the dry season, when the copepod vectors reached their highest density in ponds that were drying up (*9*, *20*). In Nigeria, the prevalence of the disease remained high if the piped-water supply was intermittent or unreliable during the dry season (*40*). The problem of unreliable tube-wells or boreholes which fail, particularly during the dry season, is frequently cited as an important factor that contributes to transmission of dracunculiasis (*11*, *84*).

Hookworm infection

Eleven studies (*3*, *15*, *17*, *31*, *44*, *63*, *77*, *78*, *86*, *89*)[d] were reviewed that related hookworm infection to excreta disposal facilities, with or without water supplies. Five studies reported positive findings, two involving water supply and sanitation (*15*, *77*) and three sanitation only (*17*, *44*, *89*). Only one study, which examined the influence of sanitation facilities in conjunction with chemotherapy, was considered to be rigorous (*3*). The median reduction in the prevalence of the disease calculated from all studies was 4%, which was the same as that calculated from the rigorous study alone (*3*).

Excreta disposal. In the study in Iran referred to under ascariasis (*3*), villages where sanitation improvements were carried out had a 4% decrease in the prevalence of hookworm infection, while there was a 26% reduction in egg counts among those infected. For the group that received the sanitation and chemotherapy intervention, the reduction in prevalence of infection was 69%, while the egg count was reduced by 88%; for the chemotherapy-only group, the reductions were 73% and 87%, respectively; and for the control group, 11% and 12%. However, each cohort began with a different prevalence of hookworm infection, e.g., at the outset 77% of the sanitation cohort and 44% of the control group were infected.

Schistosomiasis

Twelve studies were found that examined water and sanitation facilities and rates of schistosomiasis (*8*,

[d] See footnote *a*, p. 610.

29, *38*, *43*, *46*, *49*, *50*, *53*, *59*, *64*, *86*)[e]. All four of the rigorous studies examined the degree of protective efficacy of water supplies (*8*, *43*, *50*, *59*). Extensive water supply and washing facilities were provided to the study populations. One study also examined the effect of water supply and the provision of latrines (*8*). For all studies combined, the median reduction in morbidity was 69%, and for the rigorous studies only, 77% (Table 3).

Water supplies. The presence of piped-water in the home (*43*, *50*) was associated with larger reductions in the prevalence of schistosomiasis than that produced by community water supplies (*59*). In Saint Lucia over a 5-year period following the provision of household piped-water and community washing and showering facilities, the overall prevalence of schistosomiasis was reduced by 27% and that among children aged under 10 years of age, by 59% (*43*). In south-east Brazil, children aged 5–14 years were 2.3 times more likely to be infected if they had no piped-water in their home (*50*).

In Zimbabwe the prevalence of *S. mansoni* among schoolchildren who lived on communal lands without a piped-water supply was 4.8% and of *S. haematobium*, 4.4% (*59*). Among children who lived on the same lands, but with piped water, the prevalence of *S. mansoni* and *S. haematobium* was 0.8% and 0.4%, respectively.

In Brazil the severity of schistosomiasis was reduced more than was its prevalence (*50*). Children aged 5–14 years were 7.3 times more likely to have splenomegaly (an indication of severe schistosomiasis) if they had no piped water in their home. Malaria, which can also cause splenomegaly, was not a confounder, because its prevalence in the study area was low. The risk of severe infection (7.3) was much greater than the risk of the prevalence of schistosomiasis (2.3).

Sanitation and water supplies. One study in north-east Brazil reported the prevalence of *S. mansoni* before and after a water, sanitation, and health education campaign (*8*). In the treatment villages, latrines were built for each house, and communal taps, laundry facilities, showers, latrines, and hand pumps were installed. Over a 7-year period, children under 14 years of age exhibited a net drop in the prevalence of schistosomiasis, and this was 77% greater in the treatment than in the control villages.

Water contact. One of the primary mechanisms through which improved water supplies have an impact on schistosomiasis is by reducing human contact with infected water. A distinction should therefore be made between possession of an improved water supply and having contact with pathogen-laden water. In Saint Lucia (*42*, *43*) and south-east Brazil (*50*), access to improved supplies that included laundry and shower facilities was associated with reduced contact with infected waters and thus reduced infection. In Saint Lucia, this led to an 82% reduction in the frequency that people had contact with infected water and a 96% reduction in water-contact time. In Kenya, the installation of boreholes, without laundry or shower facilities, failed to reduce the reliance on high-risk marshes and ponds for bathing (*46*).

Water supplies and chemotherapy. Reinfection can rapidly diminish or negate health improvements brought about by community-wide schistosomiasis programmes devoted exclusively to drug therapy (*10*, *101*). Drug treatment combined with improved sources of water produces a greater reduction in the prevalence of schistosomiasis than that resulting from provision of water facilities alone (*43*, *60*, *64*, *68*). Programmes that adopt a multifaceted approach have repeatedly been successful (*64*, *67*, *90*), and the provision of adequate water supplies to those who have been treated with drugs can prevent reinfection (*43*). For example, in Saint Lucia oxamniquine caused a precipitous drop in the rates for infection with schistosomiasis and a 4-year follow-up provided no evidence for reinfection (*43*).

Trachoma

Sixteen studies on the role of water, sanitation, and/or hygiene in the reduction of trachoma were reviewed. Thirteen reported positive effects (*5*, *14*, *19*, *35*, *56*, *58*, *61*, *62*, *71*, *88*, *91*, *92*, *99*) and three, negative (*48*, *70*, *102*). Five of the rigorous studies were positive (*5*, *61*, *91*, *92*, *99*) and two, negative (*48*, *102*). The median reduction in trachoma calculated for all studies was 50% and for the rigorous studies only, 27%.

Distance and time to water source. Four studies (*5*, *61*, *92*, *99*) reported a 30% median reduction in trachoma that was associated with shorter distances or time to water sources. In China (Province of Taiwan) the prevalence of trachoma among people with household water connections was 45% less than among those whose water source was over 500 m away (*5*); and in India those who had a water supply within 200 m exhibited 30% less trachoma than those who obtained water from a more distant source (*61*). In Malawi there was 26% less trachoma among

[e] See footnote *b*, p. 610.

children whose water was less than 5 minutes away than among those who required a trip of more than 1 hour to obtain water (*92*). In the United Republic of Tanzania, 26% fewer households had trachoma that affected all the children if the source of water was less than 30 minutes away, compared to a water source that was more than 2 hours distant (*99*). Two other studies (one in Morocco (*48*) and one in Mexico (*91*)) failed to find such an association between the prevalence of trachoma and distance to water supply.

Distance to water has been taken to be a proxy for the amount of water used, but the above-mentioned Tanzanian study did not find a direct association between the distance to water and the amount of water brought into the household (*99*). Also in the study in Morocco there was no correlation between distance to the source and the per capita use of water (*48*). Similarly, several studies of diarrhoeal diseases have reported no significant association between improved water or distance to water and the amount of water used (*27, 51, 100*).

Personal hygiene. In India people with good hygiene practices had 79% less trachoma than those whose practices were poor (*61*). In Mexico a study of the relationship between the prevalence of trachoma and a variety of possible risk factors reported a significant association only for the frequency of face-washing (*91*). Children who washed their faces seven or more times a week had 69% less trachoma than those who washed their faces less frequently; however, the importance of this aspect of personal hygiene was not confirmed in a follow-up investigation in Mexico near the original study site (*102*). The different findings in these two studies might be accounted for by the different conditions: in villages included in the follow-up study, almost twice as many children washed their faces frequently as did those in the original villages.

In the United Republic of Tanzania observations of hygiene practices indicated that a child was 1.7 times more likely to have trachoma if all the children in the family had unclean faces (*99*). Also, distance to water was related to the proportion of children with unclean faces. There were 14% fewer households where all the children had unclean faces when the source of water was less than 30 minutes away, compared with more than 2 hours away.

Conclusions

The results of this review indicate that improvements in one or more components of water supply and sanitation can substantially reduce the rates of morbidity and severity of ascariasis, diarrhoeal diseases, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. Despite the mix of both positive and negative studies, the overwhelming evidence is in favour of positive impacts, with the exception of hookworm infection, for which the impact was negligible. The reduction in morbidity from the rigorous studies ranged from 26% for diarrhoea, 27% for trachoma, and 29% for ascariasis to 77% for schistosomiasis and 78% for dracunculiasis. For the rigorous studies the median reduction in diarrhoea-specific mortality was 65% and in overall child mortality, 55%, which suggests the important role that water and sanitation play in enhancing child survival.

Studies that reported reductions for one disease (or even more than one) most probably 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 simultaneously in the intervention area. Even though studies often report on only one indicator of health for a selected age group, other health indicators may also be changing for other age groups.

In addition to reducing the incidence or prevalence of disease, improvements in water and sanitation can be expected to affect other aspects of health. When infection rates are reduced by chemotherapy, as was the case for some parasitic diseases, water and sanitation facilities prevented infection rates from increasing again to pretreatment levels. Furthermore, the severity of infection was often reduced more than that of the incidence or prevalence. For example, the reductions in egg counts for ascariasis, schistosomiasis, and hookworm infection were greater than those in the incidence or prevalence of these diseases. In addition, reductions in childhood diarrhoea and overall mortality rates were greater than for diarrhoea incidence or prevalence, which suggests that the severity of diarrhoea was reduced more than its incidence.

The expected reductions in disease rates provide a guide. The studies reviewed were of variable quality, and therefore reductions may be smaller or larger depending on several factors; for example, 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 reduce transmission of disease agents. If the interventions do not work, break down, remain underused, or do not change behaviour sufficiently, they will probably result in small impacts at best. No study, irrespective of how well it is conducted, can produce substantial impacts under such conditions. On the other hand, considerable impacts will probably result if the intervention was successfully imple-

mented, properly utilized, and the population disease rates were high enough for benefits to be measured.

Results published since 1986 on diarrhoeal diseases concur with previous findings (*25*), and the rigorous studies conducted in the last few years show a greater reduction in disease: while this may reflect better studies, it may also indicate better-conceived interventions. Interventions to improve excreta disposal and water quantity, which are associated with better hygiene practices, produce greater impacts than improvements in water quality. This is particularly so in highly contaminated environments where diarrhoea rates are high. Because the use of more water is not automatic following the installation of water supplies, hygiene education is a necessary part of the intervention.

The following recommendations can therefore be made:

- to achieve broad health impact, greater attention should be given to safe excreta disposal and proper use of water for personal and domestic hygiene rather than to drinking-water quality;
- sanitation facilities should be installed at the same time as water facilities when faecal-related diseases are prevalent;
- access to the water supply should be as close to the home as possible, in order to foster the use of larger amounts of water for hygiene practices;
- water supply and health programmes should emphasize hygiene education to encourage the use of more water for personal and domestic hygiene;
- sanitation facilities should be culturally appropriate to ensure their use;
- use of facilities is essential during critical seasonal transmission periods for diseases such as dracunculiasis; and
- water and sanitation programmes should complement those in other sectors (e.g., chemotherapy) to reduce disease rates.

Issues for future research

Despite the accumulation of knowledge during the IDWSSD, questions remain about the health benefits associated with water and sanitation. Many of these issues could be examined using well-established epidemiological methods (*22*) in areas where water and sanitation systems are working and used by the recipients. Rigorous studies should focus on the following issues:

- the maximum travel distance/time that will result in appropriate use of an improved water supply under a variety of socioeconomic and environmental conditions;
- the minimum quantities of water that are necessary to produce positive health impacts under a variety of environmental conditions (e.g. peri-urban, rural, etc.);
- the hygienic behaviours most conducive to better health;
- appropriate methods for introducing and reinforcing behavioural change;
- the conditions under which water and sanitation facilities are likely to be sustained;
- the possibility of increasing the amount of water used and of changing behaviours in the absence of interventions to install piped supplies;
- the conditions (including environmental, cultural, and level of development) under which installation of water and sanitation facilities are likely to produce the greatest health benefits; and
- the health indicators that are most susceptible to change and most related to disease.

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Résumé

Amélioration de l'approvisionnement en eau et de l'assainissement: conséquences sur l'ascaridiase, la diarrhée, la dracunculose, l'ankylostomiase, la schistosomiase et le trachome

On analyse ici les résultats de 144 études portant sur l'impact de l'amélioration de l'approvisionnement en eau et des installations d'assainissement sur l'ascaridiase, les maladies diarrhéiques, la dracunculose, l'ankylostomiase, la schistosomiase et le trachome. On a choisi ces affections parce qu'elles sont très répandues, constituent des risques graves pour la santé et illustrent bien la diversité des mécanismes par lesquels l'amélioration de l'approvisionnement en

eau et de l'assainissement peut protéger les populations. On a calculé pour l'ensemble des études la diminution médiane du nombre de cas de chaque maladie qu'elle entraîne et l'on a tiré des études les plus rigoureuses sur le plan méthodologique une deuxième valeur de la diminution médiane.

Les résultats montrent que l'approvisionnement en eau et l'assainissement entrainent une amélioration de la santé des populations concernées. En ce qui concerne la diarrhée, le trachome et l'ascaridiase, la diminution médiane de la morbidité (c'est-à-dire de l'incidence et de la prévalence) a été respectivement de 26%, 27% et 29% dans les études rigoureuses. La diminution correspondante pour la schistosomiase et la dracunculose a été plus importante, à savoir 77% et 78%, respectivement. Toutes les études sur l'ankylostomiase ont été défectueuses, à l'exception d'une seule dans laquelle on a trouvé une diminution de 4% de la prévalence.

Pour l'ankylostomiase, l'ascaridiase et la schistosomiase, on a observé une diminution plus importante du nombre d'œufs que de la prévalence. Les interventions pratiquées au niveau de l'approvisionnement en eau et de l'assainissement on également eu un impact important sur la survie des enfants. Neuf études ont indiqué une diminution médiane de 60% de la mortalité infantile générale, et on a calculé qu'elle était de 55% dans les six études rigoureuses; malheureusement, aucune de ces dernières études ne s'est précisément intéressée à la diminution de la mortalité due aux maladies diarrhéiques.

Dans la plupart des pays en développement un meilleur approvisionnement en eau et des efforts d'assainissement peuvent donc avoir des conséquences importantes et démontrables sur la santé dans tous les groupes d'âge. Les diminutions observées dans la gravité de la maladie sont parfois plus importantes que celles relevées dans son incidence ou sa prévalence; cependant, on néglige trop souvent l'importance de cet impact.

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