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Chapter **41**

Water Supply, Sanitation, and Hygiene Promotion

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Water supply in the context of this chapter includes the supply of water for domestic purposes, excluding provision for irrigation or livestock. *Sanitation* is used here in the narrow sense of excreta disposal, excluding other environmental health interventions such as solid waste management and surface water drainage.

The effect of these other measures on disease burden is largely confined to urban areas and is considerably less than that of water supply, sanitation, and hygiene promotion (Cairncross and others 2003). More fundamentally, expenditure on solid waste disposal and drainage is rarely seen as forming part of a portfolio of investments in public health or competing with public health investments. Rather, it is generally perceived by decision makers as comparable with other investments in municipal infrastructure and services, such as roads or public transportation, which are not considered to be public health interventions.

This chapter focuses on water supply, excreta disposal, and hygiene promotion and considers the costs and benefits of each in turn. Water supply and sanitation can be provided at various levels of service, and those levels have implications for benefits. Water supply and sanitation offer many benefits in addition to improved health, and those benefits are considered in detail because they have important implications for the share of the cost that is attributable to the health sector. From the point of view of their effect on burden of disease, the main health benefit of water supply, sanitation, and hygiene is a reduction in diarrheal disease, although the effects on other diseases are substantial. In the concluding sections, the percentage reductions arrived at in the discussion throughout the chapter are used together with data on existing levels of coverage to derive estimates of the potential effects of water supply and excreta disposal on the burden of disease, globally and by region, and with cost data to derive cost-effectiveness estimates.

WATER SUPPLY

What constitutes a perfectly satisfactory water supply to some consumers leaves others, even in developing countries, considering themselves unserved. In much of rural Africa, a hand pump 500 meters from the household is a luxury, but most residents in urban Latin America would not consider themselves served by a water supply unless they had a house connection. In Asia, urban planners would consider a community served if there were sufficient standposts on the street corner; however, if the water only flows for a few hours per week, producing lengthy nighttime queues, the residents may regard this situation as a lack of service and opt to buy water expensively from itinerant vendors. As these examples illustrate, water supply is not a single, well-defined intervention, such as immunization, but can be provided at various levels of service with varying benefits and differing costs.

Levels of Service and Their Costs

Many public health workers unfamiliar with the water sector assume that the most important characteristic of a water supply is its improved *quality*. However, most of the benefit is attributable to improved convenience of access to water in *quantity*. Moreover, global statistics are not available on the coverage and costs of provision of water in terms of its quality. The *Global Water Supply and Sanitation Assessment 2000 Report* (WHO and UNICEF 2000), the most recent compilation of global statistics on water supply, changed the way that such data are compiled, from the previous unreliable estimates by provider agencies to consumers' responses in population-based surveys. The change required a departure from the old definition of *reasonable access to safe water,* because most consumers cannot tell whether their water supply is safe. They can, however, state the type of technology involved, and that fact was used to define a new indicator of *improved* water supply. In the main, improved water supplies could be expected to provide water of better quality and with greater convenience than traditional *not improved* sources. The report treated the following technologies as improved: household connection, public standpipe, borehole, protected (lined) dug well, protected spring, and rainwater collection. Unprotected wells and springs, vendors, and tanker-trucks were considered unimproved. Bottled water was also considered unimproved because of concerns about the quantity of water supplied, not because of concerns over the water quality.

Reasonable access was defined as the availability of at least 20 liters per capita per day from a source within 1 kilometer of the user's dwelling. Within the broad category of those with reasonable access to an improved water supply, two significantly different levels of service can be distinguished:

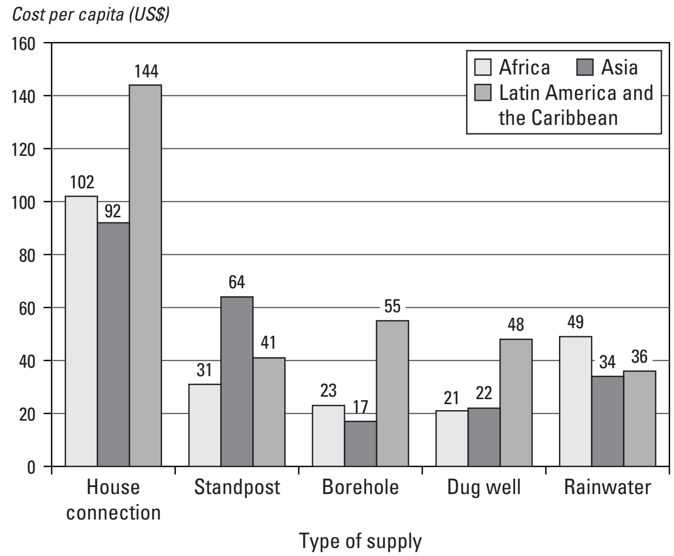
- house connections
- public or community sources.

In most settings, these subcategories correspond to very different levels of water consumption, different amounts of time spent collecting water, and as discussed in later sections, different health benefits.

The *Global Water Supply and Sanitation Assessment 2000 Report* also gives median construction costs per person served for the various technologies in the three main regions of the developing world. These costs are shown in figure 41.1. However, local conditions, such as the size of the community to be served and the presence of suitable aquifers, can cause tremendous variations in the unit cost of water supply.

For a community of given size, there are no significant returns to scale in the number of house connections made. Most of the investment in major works must be made before house connections can be offered, so that the marginal cost of each connection is only a fraction of the total. For those and other reasons, water supply is a natural monopoly requiring "lumpy" investments, which makes the unit costs difficult to calculate.

The cost of house connections may be representative in Latin America and the Caribbean, where they are often provided in rural areas. In Asia and Africa, however, the reported



Source: WHO/UNICEF 2000.

Figure 41.1 Median Construction Cost of Water Supply Facilities for Africa, Asia, and Latin America and the Caribbean

costs of house connections relate almost exclusively to urban areas because such connections are only rarely provided in smaller communities. The smaller size of rural communities means that piped systems in general—and house connections in particular—will tend to be more expensive per capita there than in urban areas. An overall unit cost figure of US$150, just above the highest of the three continental medians, is therefore taken for house connections in the cost-effectiveness calculations.

For public water points corresponding to improved water supply, hydrogeological and other constraints mean that the cheapest technology is not feasible in every community. A cost figure of US$40 per capita is about the middle of the range offered by different technologies (standpost, borehole, and dug well) providing this level of service for each continent (figure 41.1) and, therefore, seems reasonable for this level of service, although it can be expected to vary between US$15 and US$65 or more, depending on local conditions. The range of costs reported by individual countries for the *Global Water Supply and Sanitation Assessment 2000 Report* varied by more than an order of magnitude.

In calculating the cost-effectiveness of investment in water supplies, one must amortize these capital costs over an appropriate lifetime. Most major components of an urban water supply system have a potential lifetime of 50 years or more, but a prudent utility would aim to amortize them within about 20 years. A reasonable basis for calculation, for both urban and rural supplies, is to allow an amount of 5 percent of the capital cost as an annual straight-line amortization of the construction cost of the water supply.

Construction costs do not represent the full cost of water supplies. The *Global Water Supply and Sanitation Assessment 2000 Report* also gives median reported production costs per cubic meter for urban (house connection) water supplies as US$0.20 for Asia and US$0.30 for Africa and Latin America and the Caribbean. If we assume a mean daily water consumption of 100 liters per capita by those with household connections, those figures give annual per capita operation and maintenance costs of US$7.30 and US$10.95, respectively, or 8 to 10 percent of the capital cost of construction. In this chapter, a generic figure of US$10 is used for the annual per capita operation and maintenance cost.

Reliable figures for the annual maintenance costs for rural water supplies are harder to find, particularly because much of the maintenance is carried out by the volunteer labor of villagers. Arlosoroff and others (1987), after reviewing a wide range of rural water supply projects in various countries, concluded that with a centralized maintenance system, the annual per capita cost of maintenance of a hand pump–based supply can range from US$0.50 to US$2.00, while well-planned, community-level maintenance can bring that figure down as low as US$0.05 per capita per year. A nominal annual figure of US$1.00 per capita is therefore used in this chapter. A similar figure can be applied to urban public standposts, for which volunteer labor is less forthcoming but transport costs are lower. This maintenance cost represents 2.5 percent of the construction cost arrived at above.

The Time-Saving Benefit

Benefits to health are not normally foremost in the minds of those provided with new water supplies. An exhaustive study of the economics of rural water supply by the World Bank concluded that "the most obvious benefit is that water is made available closer to where rural households need it. . . . It is not clear that rural populations think much about the relationship between water and health" (Churchill and others 1987, 21–22).

The Value of Time. The saving in time and drudgery of carrying water home from the source is substantial, and several reasons exist to attribute a money value to it. The most powerful argument for the money value of poor women's time is that households often pay others to deliver their water, or pay to collect from nearby rather than from more distant sources that are free of charge. Thompson and others (2001) found that, of urban East African households lacking a piped supply, the proportion paying for water had increased from 53 percent to 80 percent over 30 years. In a survey of 12 sites in 10 countries, Zaroff and Okun (1984) found that households were spending a median of over 20 percent of their income on the purchase of water from vendors. The prices charged by vendors are typically more than 10 times—and can be up to 50 times—the normal tariff charged by the formal water supply utility.

Cairncross and Kinnear (1992) found that vendor prices increased with the time required to collect the water, showing that households pay more as the alternative of collecting water themselves becomes more burdensome. If the amount paid to the vendor for bringing the water is divided by the time saved from collecting it, the implicit value that people ascribe to their time can be calculated. Whittington, Mu, and Roche (1990), working in rural Kenya, showed in this way that the implicit value of the time saved was roughly US$0.38 per hour, very close to the average imputed wage rate for such households of US$0.35 per hour.

Because the poorest urban households typically spend more than 90 percent of their household budget on food, the money they spend on water is sacrificed from their food budget (Cairncross and Kinnear 1992). The provision of water more cheaply thus offers a substantial nutritional benefit to the poorest.

Assessing the Time Saved. The cost of water collection in rural areas is usually in time and effort rather than in money paid to vendors. The saving in time and drudgery underlies many social benefits. Given the relevance of the time-saving benefit to water supply policy and the fact that the benefit is usually uppermost in the mind of the consumer, it is remarkable how few data have been collected on the amounts of time spent collecting water.

Working in 334 study sites in Kenya, Tanzania, and Uganda, Thompson and others (2001) found a mean distance from rural unpiped households to their water sources of 622 meters. In urban areas, the distance was only 204 meters, but queuing at the tap meant that a water collection journey took almost as long.

Feachem and others (1978) found in 10 villages of the densely populated lowlands of Lesotho that the installation of a water supply had saved the average adult woman 30 minutes per day. In one-third of the villages, the saving per woman was more than an hour a day. Lesotho has many springs, so that time saving is likely to be on the low side compared with Africa as a whole.

These time-saving benefits are confirmed by the Multi-Indicator Cluster Surveys of the United Nations Children's Fund (UNICEF). A recent analysis of the responses in 23 African countries has produced a more representative account of water collection journey times in that continent (G. Keast, UNICEF, personal communication 2003). Nearly half the households interviewed (44 percent) required a journey of more than 30 minutes to collect water, implying that the women in such households spent an hour or more each day in water collection. At almost any reasonable level of service, most of that time would be saved by an improved water supply.

In Asia, an Indian national survey for UNICEF found that women spent an average of 2.2 hours per day collecting water from rural wells (Mukherjee 1990). A study in Sri Lanka, which is generally considered to be well provided with water sources, found that 10 percent of women had to travel more than 1 kilometer to their nearest source (Mertens and others 1990).

Valuation of the Time-Saving Benefit. Putting a precise figure on the money value of the time of poor people is a tricky task, even for the most self-confident economist. In 1987, Churchill and others took US$0.125 per hour as an illustrative but not unrealistic figure. To take the same figure today could hardly be described as extravagant. Assuming this valuation of an hour of time—and that a water supply bestows a mean saving of only 15 minutes per person per day—yields a conservative estimate of the value of the time-saving benefit of US$11.40 per year. The data presented earlier indicate that, at least in Africa, the true figure is nearer to double that amount, enough to justify the full construction cost of a dug well or borehole supply in a single year. In Latin America and the Caribbean, costs are higher, and time savings may be less, but rural incomes are also higher—and so, therefore, is the value of people's time. Little doubt exists that, in all three regions of the developing world, the value of time saved is sufficient on its own to justify both the investment costs (at any reasonable rate of amortization) and the operation and maintenance costs of water supplies.

Even in settings where water vending is not common, contingent valuation surveys have widely demonstrated a willingness to pay for water supplies, particularly at the level of service of house connections (World Bank Water Demand Research Team 1993). In general, such measured willingness to pay has exceeded the cost of providing the supplies, and payment to vendors often exceeds it by many times.

Policy Implications. Whether the consumers actually pay for the full value of the time-saving benefit, it is what makes water supplies popular and largely it is what motivates politicians to invest in them. More than half the total annual investment in water supply in the developing countries of Africa, Asia, and Latin America and the Caribbean is from domestic sources (WHO and UNICEF 2000). Most of the investment is from the public sector. In general, investments in water supply—whether by the governments of developing countries or by external support agencies—do not come from health sector budgets and are not compared with other health interventions when investment decisions are made, even though health benefits do arise from water supply improvements.

Water supply is thus a health-related intervention that comes without cost to the budgets of the health sector. Although it undoubtedly offers health benefits, it has a sufficient economic and political rationale in other social benefits associated with time saving. The health benefits are a positive externality to this rationale. However, this fact does not mean that the authorities responsible for public health should ignore the water sector. The function of the health sector is one of regulation, advocacy, and provision of supplementary inputs, as appropriate, to ensure that potential health benefits of water supply are realized to the optimal extent.

For example, the regulatory role of the health sector in quality surveillance of drinking water is well known and widely accepted. Substantial and largely unexploited additional potential is present in this role if quality is interpreted in the wider sense of *quality of service* rendered by the water supply utility, in terms not only of water quality but also of quantity, continuity, coverage, control of sanitary hazards, and cost. Those other aspects, as will be argued in the following sections, are no less important for health.

Where a regulatory role is not available to the health sector or agencies concerned with public health, advocacy can be no less cost-effective. For example, connection charges are a major barrier to house connections for low-income groups. In many cities of the developing world, the individual connection charge is about a month's basic wage. Advocacy of lower connection charges, with the amount recovered from the monthly water tariffs, can therefore help achieve an increase in the number of people who have house connections and who can benefit from the corresponding health gain at no cost to the public purse. Finally, the health sector can provide important complementary services, such as hygiene promotion and promotion of low-cost sanitation to increase coverage; because of the nature of such services, the water sector, with its focus on technology, is ill-equipped to offer them.

The unit costs of such regulation and advocacy are minimal. One example is the case of UNICEF's participation over the past 30 years in India's rural water supply program. UNICEF's investment has represented no more than 1 percent of the total, but its influence has played a central part in the evolution of the technical and institutional model of the program that supplies water to 1 in 10 members of the human race.

An example of the effectiveness of such measures is provided by the interventions of the Mexican Ministry of Health in June 1991. Fostered by fear of the devastating effects of cholera, these measures included the chlorination of water supplied for human consumption and the prohibition of sewage irrigation of fruit and vegetables. As a result, the incidence of diarrhea in children under five years of age fell from 4.5 to 2.2 episodes per child-year, and the corresponding mortality rate fell from 101.6 to 62.9 per 100,000 children (Gutiérrez and others 1996).

The current rate of annual investment per capita in water supply and sanitation, including both national investment and external aid funds, is reportedly US$2.25 in Asia, US$7.53 in Africa, and US$8.87 in Latin America and the Caribbean (WHO and UNICEF 2000). One percent of the water sector's investment would, therefore, be US$0.02 to US$0.10 per capita. If each ministry of health in the developing world were to invest such a sum in public health advocacy and regulation related to water supply, the sector's performance, at least where low-income groups are concerned, could be transformed. It is hard to put a figure on the health effects of such investment, but the Mexican example suggests that they would be substantial. For the sake of cost-effectiveness estimation, such spending is arbitrarily assumed to have the effect of ensuring improved water supplies for an additional 10 percent of the population to which it refers.

Direct Health Effects

The full list of water-related infections is large and varied, but most are only marginally affected by water supply improvements. The first effort to simplify the relationship between water supplies and health in developing countries was made by David Bradley (White, Bradley, and White 1972), who developed a classification of disease transmission routes in terms of whether they were

- *waterborne,* in the strict sense in which the pathogen is ingested in drinking water
- *water-washed*—that is, favored by inadequate hygiene conditions and practices and susceptible to control by improvements in hygiene
- *water-based,* referring to transmission by means of an aquatic invertebrate host
- *water-related insect vector* routes, involving an insect vector that breeds in or near to water.

Whereas the prevention of waterborne disease transmission requires improvements in water quality, water-washed transmission is interrupted by improvements in the availability—and hence the quantity—of water used for hygiene and the purposes to which it is put. Water supply may affect water-based transmission (for example, if it reduces the need for people to enter schistosomiasis-infected water bodies) or water-related insect vectors of disease (for example, if a more reliable supply averts the need for the water-storage vessels in which dengue vectors breed), though that will depend on the precise life cycle of the parasite involved and the preferred breeding sites and behavior of the vector.

Classification and Burden of Water-Related Diseases. Before Bradley's classification can be applied to diseases (rather than transmission routes), it requires a small adjustment (Cairncross and Feachem 1993) to allow for the fact that practically all potentially waterborne infections that are transmitted by the feco-oral route can potentially be transmitted by other means (contamination of fingers, food, fomites, field crops, other fluids, flies, and so on) all of which are water-washed routes. In addition to the feco-oral infections, a number of infections of the skin and eyes can be considered water washed but not waterborne. The final classification is shown in table 41.1.

The classification can now be used to assess how the disease burden prevented by water supply is distributed among disease groups. Bradley himself did this, a time long before the disability-adjusted life year (DALY) had been invented as a unit of benefit measurement (White, Bradley, and White 1972, 191). He used official statistics on the number of cases of each disease diagnosed and treated by health services in East Africa and combined them with notional percentages by which morbidity and mortality caused by each condition could be expected to fall if water supply were "excellent."

Those notional reductions were based on subjective assessments of the literature available at the time and were described by their author as "little more than guesses," but it is hard to prove many of them seriously at fault, even today. A selection is presented in table 41.2.

The result of these calculations was that the feco-oral disease group accounted for 91 percent of the deaths preventable by water supply, 50 percent of inpatient bed nights, and 33 percent

Table 41.1 The Bradley Classification of Water-Related Infections

Transmission route	Description	Disease group	Examples
Waterborne	The pathogen is in water that is ingested	Feco-oral	Diarrheas, dysenteries, typhoid fever
Water-washed (or water-scarce)	Person-to-person transmission because of a lack of water for hygiene	Skin and eye infections	Scabies, trachoma
Water-based	Transmission via an aquatic intermediate host (for example, a snail)	Water-based	Schistosomiasis, guinea worm
Water-related insect vector	Transmission by insects that breed in water or bite near water	Water-related insect vector	Dengue, malaria, trypanosomiasis

Source: Cairncross and Feachem 1993.

Table 41.2 Percentage Reductions in Disease Rates Assumed by Bradley

Diagnosis	Percentage reduction expected from excellent water supply
Most diarrhea and dysentery	50
Typhoid fever	80
Paratyphoid, other *Salmonella*	40
Trachoma	60
Scabies	80
Skin and subcutaneous infections	50
Urinary schistosomiasis	80
Intestinal schistosomiasis	40
Malaria	0

Source: White, Bradley, and White 1972.

of outpatient consultations. Rosen and Vincent (2001) have made a similar calculation for the whole of Africa in 1990 and found that the feco-oral group accounted for 85 percent of the preventable DALYs. When measured in terms of deaths or DALYs, feco-oral infections account for the vast majority of the impact, because of the high mortality caused by diarrheal diseases among young children. Most deaths from diarrheal diseases are of children younger than age five, and most of those are among children younger than two. A child death averted is worth 30 DALYs. Varley, Tarvid, and Chao (1998) have calculated that for diarrhea morbidity reduction to have the same effect in DALYs as averting one such death, it would have to prevent 115,000 child-days of diarrhea. After the diarrheal diseases, the next most important category in terms of DALYs (12 percent of the total) is the water-based group, primarily schistosomiasis. The purely water-washed diseases, mainly skin infections, represent a more conspicuous portion only when compared in terms of the burden placed on health services by inpatients or outpatients.

How representative is this African breakdown of the developing world as a whole? Diarrheal disease among poor communities is cosmopolitan. A global review of studies of the incidence of diarrhea morbidity could find no clear geographic or climatic trend (Bern and others 1992), so the burden of disease is no doubt similar around the developing world. The second most important disease group is represented by schistosomiasis, which is absent from much of Asia and Latin America. The relative importance of feco-oral disease is, therefore, likely to be still greater in the poor communities of Asia and the Western Hemisphere than it is in Africa.

Epidemiological Questions and Problems. The predominant contribution of feco-oral diseases to the burden of disease attributable to water supply raises an important question, because this group can be transmitted by both waterborne and water-washed routes. It is important for the water engineer to know whether scarce funding should be spent on improved water treatment and measures to protect water quality or instead on providing a limitless supply of water at a high level of access and convenience and encouraging its use for improved hygiene practices. We need to know, that is, whether the feco-oral infections endemic in poor communities are mainly waterborne or mainly water washed.

Moreover, the fact that some diarrheal diseases are still prevalent in communities with a high level of water supply service indicates that water supply alone cannot completely prevent these diseases. A further question then, is this: by how much do water supply improvements reduce diarrheal diseases?

Numerous studies have sought to answer these questions, but they are hard to answer rigorously, for several reasons. First, it is almost impossible, ethically and politically, to randomize the intervention. Where the intervention is an improvement in the level of access to water, it cannot be blinded; no placebo exists for a standpost. Where quasi-experimental studies have been used—opportunistically exploiting an intervention allocated by political or technical means—significant confounding has frequently been found (Briscoe, Feachem, and Rahaman 1985).

Confounding has been especially intractable in studies in which the allocation of facilities has been on a household basis, so that the exposure groups are self-selected—for instance, studies in which individual households that have chosen to install a private tap are compared with others that have chosen not to do so. The former households are likely to be wealthier, better educated, and more conscious of hygiene than their neighbors, so it would not be surprising if they were also more likely do many other things that protect their families from feco-oral disease. The more sophisticated studies have used multivariate models to control for confounding, but where relative risks are low and the exposure groups are self-selected, even those models do not guarantee that confounding is eliminated (Cairncross 1990).

A further difficulty arises from the fact that cases of feco-oral disease in a given community cannot be considered independent events, because such diseases are infectious. The sample size, it can be argued, is the number of such villages rather than the number of individuals enrolled in the study. Yet a number of important studies in the literature compare a single intervention area with only one control area.

Other epidemiological weaknesses exist in the data. Blum and Feachem (1983) reviewed 50 studies of the health effect of water supply and sanitation projects and noted that every one contained one or more of these basic errors of methodology. A further weakness in the evidence for the effect of water supply on diarrheal disease burden is that most of it relates to diarrheal disease morbidity, and significant assumptions are

Table 41.3 Median Reductions in Diarrhea Morbidity Reported from Different Water Supply and Sanitation Interventions

Intervention (object of improvement)	Number of rigorous studies from which morbidity reductions could be calculated	Median reduction in diarrheal morbidity (percent)
Water quality only	4	15
Water quantity only	5	20
Water quantity and quality	2	17
Sanitation only	5	36
Water and sanitation	2	30
Hygiene promotion only	6	33

Source: Esrey and others 1991.

needed to extrapolate such evidence to an effect on diarrheal mortality.

Effect on Diarrheal Disease. Esrey and Habicht (1985) and Esrey and others (1991) reviewed the same literature from a different perspective. Though conscious of the methodological shortcomings of most studies, they sought to assess the overall reductions in diarrheal disease that water supply could be expected to cause. They applied a number of criteria of epidemiological rigor and took the median reduction in morbidity reported from each type of intervention. Their conclusions are summarized in table 41.3.

For more than a decade, this review has remained the most authoritative on the subject. However, the small reductions in disease that it reports for water supply conceal an important heterogeneity. Though these overall results are frequently quoted, the following remark by Esrey and others (1991, 613) has usually been overlooked:

> 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, tubewells, and standpipes.

In the studies in the two reviews by Esrey and Habicht (1985) and Esrey and others (1991) in which the water supply was provided in the home, the median reduction in diarrheal disease is 49 percent (from 12 studies), and the reduction from the two better studies is 63 percent. Those reductions are several times greater than the overall median impacts in table 41.3. The 63 percent figure will be used in the burden of disease calculations that follow. In the two better studies, the members of the comparison group were using not an unimproved water supply, but a protected water source away from the home. The reductions they found are, therefore, in addition to those resulting from a public standpost level of service.

Some subsequent studies have confirmed this pattern. For example, Bukenya and Nwokolo (1991) showed in Papua New Guinea that use of a household tap was associated with 56 percent less diarrhea than use of public standposts providing water of good quality.

Conditions for Health Effect. Providing a public water point appears to have little effect on health, even where the water provided is of good quality and replaces a traditional source that was heavily contaminated with fecal material. By contrast, moving the same tap from the street corner to the yard produces a substantial reduction in diarrheal morbidity. How is this pattern to be understood?

The first step to an explanation is an understanding that most endemic diarrheal disease is transmitted by water-washed routes and is not waterborne. Although waterborne epidemics of diarrheal diseases such as cholera and typhoid have been notorious in the history of public health, the endemic pattern of transmission seems to be different, particularly in poor communities. Five types of evidence support this view:

- *Negative health impact studies.* As mentioned earlier, Esrey and Habicht (1985) and Esrey and others (1991) cite a number of studies of the health impact of water supplies in which water quality improvements have failed to have a significant effect on diarrheal disease incidence.
- *Food microbiology.* Studies of the microbiology of foods in developing countries—particularly the weaning foods fed to children in the age group most susceptible to diarrheal disease—have shown such food to be far more heavily contaminated with fecal bacteria than is drinking water (Lanata 2003), even when the water has been stored in open pots.
- *Seasonality of diarrhea.* In countries with a seasonal variation in temperature, bacterial diarrheas peak in the warmer season, whereas viral diarrheas peak in the winter. This pattern suggests that the bacterial pathogens show environmental regrowth at some stage in their transmission route, which means that they must have a nutritional substrate. Water is, thus, a less likely vehicle than food.

- *Fly-control studies.* Trials in rural Asia and Africa have shown that fly control can reduce diarrheal disease incidence by 23 percent (Chavasse and others 1999).
- *Hand-washing studies.* A recent systematic review of the effect of hand washing with soap has shown that this simple measure is associated with a reduction of 43 percent in diarrheal disease and 48 percent in diarrheas with the more life-threatening etiologies (Curtis and Cairncross 2003).

Those five types of evidence suggest that domestic hygiene—particularly food and hand hygiene—is the principal determinant of endemic diarrheal disease rates and not drinking water quality.

The second step is an understanding of how the level of service and convenience of a water supply influence such hygiene practices in the home. Taking the amount of water used per capita as an indicator of hygiene changes, other things being equal, one finds that providing a source of water closer to the home—and therefore more convenient to use—has very little effect on water consumption unless the old source was more than 1 kilometer (30 minutes' roundtrip journey) away from the user's dwelling (Feachem and others 1978).

However, water consumption doubles or triples when house connections are provided (White, Bradley, and White 1972), and reason exists to believe that much of the additional consumption is used for hygiene purposes. For example, Curtis and others (1995) found that provision of a yard tap nearly doubled the odds of a mother washing her hands after cleaning her child's anus and more than doubled the odds that she would wash any fecally soiled linen immediately.

In conclusion, water supplies are likely to have an effect on diarrheal disease when they lead to hygiene behavior change—that is, when the old source of water was more than 30 minutes' roundtrip away or when house connections are provided.

By a happy coincidence, then, the health benefits of water supply are most likely to be realized in exactly those cases in which the time-saving benefit is greatest—when the old source of water is farthest away, and when the new one is on the plot of the individual household. Though water supplies offering house connections are more expensive, the additional time savings offered by this level of service mean that people are willing to pay more for them. Moreover, collecting revenue from households with private connections is far simpler than collecting it from public taps because the sanction of disconnection can be used against households that default on payment of the tariff.

Calculating the burden of disease associated with inadequate water supply requires a figure for the reduction associated with the levels of service for which coverage statistics are available. The following burden of disease calculations are based on a reduction of 17 percent from an improved public water supply (table 41.3) and of a further 63 percent from house connections.

The effect of water supply improvements (and of hygiene practices such as hand washing) on diarrhea mortality can be expected to be at least as great as—and probably greater than—their effect on morbidity for several reasons. A theoretical argument for this improvement pattern is given by Esrey, Feachem, and Hughes (1985) in terms of infectious doses. Esrey and others (1991) also reported a median reduction of 65 percent in diarrhea mortality attributable to water supply, sanitation, or both in three studies, compared with 22 percent from 49 studies of morbidity. The effect of hand washing on life-threatening diarrheas—shigellosis, typhoid, cholera, and hospitalized cases—is greater than that on diarrhea morbidity as a whole (Curtis and Cairncross 2003). Finally, the two known direct studies in the literature of the effect of house connections on diarrhea mortality ("Serviço Especial da Saúde Pública," an unpublished study in Palmares, Pernambuco, Brazil, cited by Wagner and Lanoix 1959; Victora and others 1988) found reductions of 65 percent (relative to a public standpost) and 80 percent (relative to various communal sources, some polluted), respectively.

Effect on Other Disease Categories. Water supplies have a beneficial effect on a number of disease groups other than diarrhea, although the corresponding burden of disease is far less. The median reductions in morbidity from other water-related conditions, reported by Esrey and others (1990), are shown in table 41.4.

Table 41.4 Median Reductions in Morbidity Associated with Improved Water Supply and Sanitation: Conditions Other Than Diarrhea, Related Most Closely to Water Supply

	All studies		Better studies		
Disease	**Number of studies**	**Median reduction (percent)**	**Number of studies**	**Median reduction (percent)**	**Range (percent)**
Dracunculiasis	7	76	2	78	75–81
Schistosomiasis	4	73	3	77	59–87
Trachoma	13	50	7	27	0–79

Source: Esrey and others 1990.

To be effective in controlling schistosomiasis, the water supply must be so convenient as to discourage water contact for laundry and bathing. It is unlikely that this level of convenience can be achieved without house connections.

Evidence suggests that water availability and hygiene can produce substantial reductions in trachoma (Emerson and others 2000). Because the reductions come from hygiene improvements such as hand and face washing, they are also likely to be greatest with house connections. Dracunculiasis is affected by water quality, but the simplest improved water supply is adequate to prevent transmission.

Conflicting evidence exists about whether water supply or improved water-washed hygiene affects the transmission of intestinal helminths. On one hand, Henry (1981) found in an intervention study in St. Lucia that piped water supplies were associated with a 30 percent reduction in ascariasis among children under age three over a two-year period. On the other hand, Han and others (1988) showed in Burma that an intervention to promote hand washing with soap had no effect on prevalence or intensity of infection with *Ascaris* spp. However, the potential contribution of water supply to reducing the burden of disease through its effect on these other infections is relatively minor when compared with its effect on diarrheal disease.

EXCRETA DISPOSAL

In much the same way as with water supply, care is needed to ensure that different people who talk about sanitation are referring to the same thing. When the WHO-UNICEF Joint Monitoring Program was compiling the *Global Water Supply and Sanitation Assessment 2000 Report* (WHO and UNICEF 2000), a major effort was needed to persuade some of the Latin American partners that a pit latrine, considered a status symbol in much of rural Africa, was an acceptable form of excreta disposal. In some countries, even engineered sewerage systems are considered unacceptable if not connected to a functioning wastewater treatment plant.

Levels of Service, Technologies, and Their Costs

A wide range of technologies is used, particularly for settings in which low-cost solutions are required, and this variation has led some to inquire whether the different types of latrine might confer differing health benefits. In the early 1980s, the World Bank established a Technology Advisory Group for low-cost sanitation, and this question was among those it was asked to investigate. Using field studies and a thorough literature review, the group concluded that all types of systems can be operated hygienically, and that

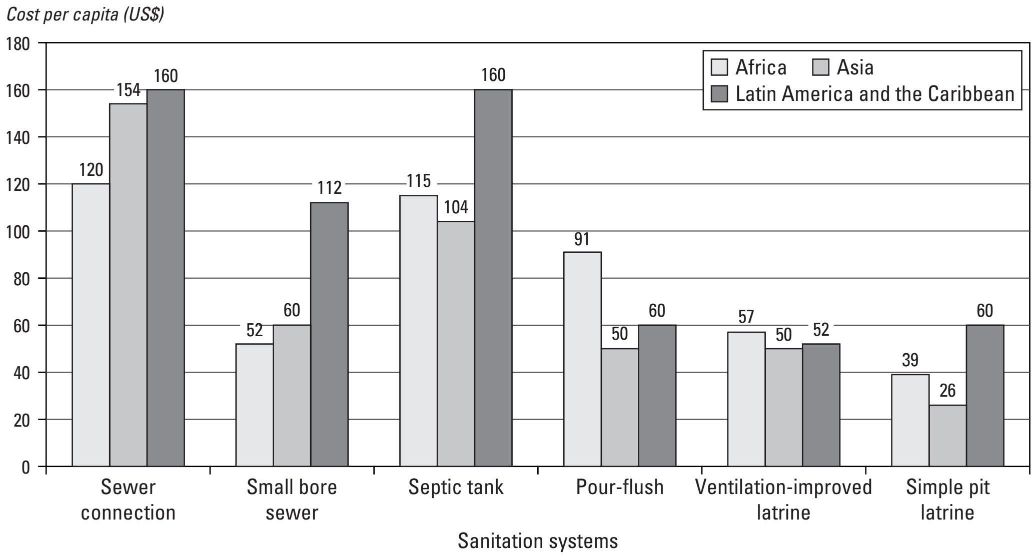
> The greatest determinants of the efficacy of alternative facilities are, first, whether they are used by everyone all the time, and second, whether they are adequately maintained. . . . Pit latrines would, from the viewpoint of health rather than convenience, approximate the same rating as a waterborne sewerage system. (Feachem and others 1983, 49–50)

The group therefore judged it most appropriate not to distinguish between sanitation technologies and to consider all of them as providing adequate access to sanitation as long as they were private or shared (but not public) and hygienically separated human excreta from human contact. This definition was followed in the *Global Water Supply and Sanitation Assessment 2000 Report,* which accepted only sewerage, septic tanks with soakaways, pour-flush latrines, and pit latrines as improved technologies. Service or bucket latrines and latrines with an open pit were not accepted. The effect of technology type on health benefit is discussed further in the sections that follow.

Public latrines, however, do not provide an adequate solution to the excreta disposal needs of a community. Quite apart from the notorious and widespread inadequacies in their maintenance, they are not usually accessible at night or by the elderly, by those with disabilities, or—if there is an entry charge—by young children. Thus, some promiscuous defecation continues to be practiced, particularly by children, in communities where public latrines are the only level of service available.

Figure 41.2 shows the regional median construction costs per capita of the various sanitation technologies found by the *Global Water Supply and Sanitation Assessment 2000 Report.* Although the simple, on-site systems tend to be cheaper than systems such as sewerage and septic tanks, the difference is less than might be expected. For example, a World Bank survey in several developing countries found the mean cost of conventional sewerage to be 10 times that for on-site systems such as improved pit latrines and pour-flush toilets (Kalbermatten, Julius, and Gunnerson 1982). It is likely that the off-site costs of sewered systems and the cost of the additional water needed for them to function have not been fully included in national reports to the *Global Water Supply and Sanitation Assessment 2000 Report.* For the purposes of calculating cost-effectiveness, a construction cost of US$60 per capita seems adequate for basic sanitation facilities (a household pit latrine, ventilation-improved latrine, or a pour-flush toilet) in any region of the developing world. Taking a relatively short lifetime of five years for a latrine and straight-line amortization gives an annual cost of US$12 per capita per year. In such a short lifetime, very little maintenance is normally required, other than occasional cleaning; the cost of maintenance is, therefore, considered to be included in the amortized annual cost.

That said, it should be borne in mind that substantially cheaper solutions are often feasible, such as the "15 taka latrine"



Source: WHO/UNICEF 2000.

Figure 41.2 Median Construction Cost of Sanitation Technologies in Africa, Asia, and Latin America and the Caribbean

(costing only US$0.27 per household) developed in Bangladesh, which includes a pour-flush pan made of tin sheet and an odor- and insect-proof seal made of flexible plastic pipe.

Social Benefits

Like water supply, sanitation offers a number of social benefits in addition to direct health gains, which tend to feature more prominently in the minds of the users. This outcome is illustrated by the responses given by a sample of householders in rural Benin when asked to rate the importance they ascribed to the various benefits of latrines on a scale of 1 to 4 (table 41.5). Health-related benefits (shown bold in table 41.5) were rarely mentioned spontaneously and generally rated among the less important benefits.

With sanitation as with water supply, strong gender differences exist in the perception of the social benefits of sanitation. For male heads of household in Benin as in other countries around the world, enhanced social status figures highly among the benefits of latrine ownership, whereas for women, security, convenience, and aesthetic factors count for more. Women who lack sanitation often risk sexual harassment on the way to and from their defecation site. In some cultural settings, women are constrained to go out for defecation and urination only during the hours of darkness, effectively becoming prisoners of daylight. Though no systematic study has been made of the health implications of such practices, they are likely to include an increased prevalence of urinary tract infections. The emancipation that a latrine bestows on such women cannot lightly be dismissed.

Table 41.5 Benefits of Latrine Ownership as Perceived by 320 Households in Rural Benin

Benefit	(Average importance rating, scale 1–4)
Avoid discomforts of the bush	3.98
Gain prestige from visitors	3.96
Avoid dangers at night	3.86
Avoid snakes	3.85
Reduce flies in compound	3.81
Avoid risk of smelling or seeing feces in bush	3.78
Protect my feces from enemies	3.71
Have more privacy to defecate	3.67
Keep my house or property clean	3.59
Feel safer	3.56
Save time	3.53
Make my house more comfortable	3.50
Reduce my family's health care expenses	**3.32**
Leave a legacy for my children	3.16
Have more privacy for household affairs	3.00
Make my life more modern	2.97
Feel royal	2.75
Make it easier to defecate because of age or sickness	2.62
Be able to increase my tenants' rent	1.17
For health (spontaneous mention)	**1.27**

Source: Jenkins 1999.

Willingness to Pay. The governments of developing countries cannot afford to provide heavily subsidized sanitation to all—or even to the majority—of their populations. The 2.6 billion people in Africa, Asia, and Latin America who do have adequate sanitation—53 percent of the population of those regions—have paid most of the cost themselves. Even those of the urban poor who do not have sanitation have expressed a willingness to pay for its full cost—or at least the local cost (excluding major interceptor sewers and treatment works, if required)—in a number of surveys, as long as credit is available on reasonable terms to smooth the cash flow (Altaf 1994). With regard to the rural poor, the success of well-conceived sanitation promotion programs in achieving coverage close to 100 percent, without a substantial subsidy, in some of the poorest rural communities in the world (Allan 2003) shows that people are willing to pay for sanitation if a suitable product is offered to them on suitable terms.

Why then do 2.4 billion people still lack sanitation? Several factors constrain the expression of the existing demand.

The constraint most frequently mentioned by unserved householders is cost, but this factor is usually more a perceived constraint than an objective one, for several reasons. First, many households are unaware of the true cost of latrines in their area, or the lower-cost models are not offered because local suppliers and artisans do not know about them or are attracted by the greater margins to be made on the more expensive technologies. Second, the high cost of capital to the poor rules out their borrowing the cost of a latrine, which to them would be a substantial investment. Third, they may be wary of investing in a property that belongs to their landlord, lest it be used as an excuse for a rent increase or even eviction. They may also feel, with some reason, that it is for the landlord to make the investment, rather than themselves, and they may be waiting for the landlord to do so. This belief has a similar effect to the common misapprehension of citizens, often encouraged by politicians, that the local government is responsible for sanitation and will eventually come to their aid; in either case, the outcome is inaction.

Other constraints include lack of ready access to necessary techniques and skills or to specific building materials and components. Where the skills exist locally, residents may lack confidence in the quality of work and value for money offered by the local artisans, or they may not know how to contact the right artisans. In many urban areas, local building regulations make low-cost sanitation technologies illegal.

Those constraints are compounded by the fragmentation of governmental responsibility for sanitation. Often it is devolved to local governments with little capacity to implement sanitation improvements. At the national level, one ministry may be responsible for sewerage and another for low-cost technologies; one may be responsible for construction, another for promotion, and a third for enforcing building codes and planning regulations.

Policy Implications. There are important externalities to households' investment in sanitation. Households are protected from their own feces by their sanitation facilities, but so, too, are their neighbors, and this factor is probably more important in epidemiological terms. If households are not fully aware of the health benefit—or if much of it accrues to others—a case exists for public intervention to increase coverage because these externalities exist.

This public intervention need not be in the form of subsidy. Strong arguments can be marshaled against a subsidy for low-cost sanitation (Cairncross 2003a). Subsidy limits the number of facilities that are built to the size of the subsidy budget; it encourages the design and marketing of unaffordable sanitation systems; it frequently leads to capture by the better-off, who install expensive toilets while the poor go without; and it distorts the market, diverting the efforts of latrine builders who would otherwise be seeking to meet the needs of low-income groups.

The intervention can be by regulation. National and local governments have substantial regulatory powers that can be used to increase sanitation coverage without significantly increasing costs or public expenditure. For example, more than 90 percent of households in the town of Bobo Dioulasso, Burkina Faso, have their own latrine (Traoré and others 1994) as a direct result of the local administration's practice in the past of withdrawing rights of land tenure from owners who did not build a latrine on their plot within a specified time. Another regulatory intervention is to enforce the obligation of landlords to provide sanitation for their tenants.

An alternative strategy is to provide support to the marketing of sanitation. This strategy can be undertaken in a number of ways that are not feasible for the existing producers, mainly artisan builders and small component manufacturing workshops. Those interventions would aim principally at overcoming the constraints to the expression of effective demand for sanitation and could include the following:

- advertising and other forms of promotion
- facilitation of building regulation approval
- brokerage to put potential purchasers in touch with providers
- quality assurance and guarantee schemes
- training in low-cost construction techniques and in marketing
- centralized production of essential components
- provision of pit emptying and desludging services.

Promotion of improved hygiene practices, including appropriate use and maintenance of the sanitation facilities, is another possible intervention by the public sector. All of those measures will help increase sanitation coverage and health benefits and are appropriate interventions for the health sector. The costs of several of them are recoverable (after an initial launch period) as fees, so that public intervention need not require public expenditure.

Costs of Promotion. The costs of promotion and administration found in two government-run rural sanitation programs documented by the World Bank were US$16.80 (Zimbabwe) and $20.00 (the Philippines) per latrine, respectively (Cairncross 1992). Because these costs are largely fixed, the cost per unit falls as the number of units built increases. Unit costs will therefore be high in relatively unsuccessful programs. Successful programs, on the other hand, often engender the construction of more latrines than they can account for, which also gives an upward bias to the promotional costs per unit built. For example, for every latrine built by Lesotho's rural sanitation program in the late 1980s, four others were built independently but as a result of its promotional activities.

More recently, successful sanitation programs managed by nongovernmental organizations (NGOs) have documented slightly lower unit costs for promotion. For example, the Zimbabwean NGO AHEAD (Applied Health Education and Development), working through district-level health staff and a network of community health clubs, achieved the construction of 3,400 latrines in Makoni district within two years at a total promotional cost of US$45,660, or US$13.43 per unit, equivalent to US$2.24 per household member served (Waterkeyn 2003). In Bangladesh, WaterAid and its partner, a local NGO named VERC (Village Education Resource Centre), have developed an approach that has successfully achieved 100 percent sanitation coverage and the elimination of open defecation in more than 100 villages in six districts at a cost of US$8 per household, or US$1.50 per capita (Allan 2003). Both programs also promoted domestic hygiene practices in addition to the construction and use of latrines. In Bangladesh, all (and in Zimbabwe, most) of the costs of latrine construction were paid by the population themselves.

The programs in Bangladesh and Zimbabwe were particularly successful and well managed. The promotion cost is taken as US$2.50 per capita for cost-effectiveness calculations, which is slightly above the higher of the two, to allow for the imperfections of sanitation programs in the real world.

Direct Health Benefits

Evidence supports the claim that improved excreta disposal helps prevent a number of diseases, including diarrhea, intestinal worm parasites, and trachoma. Of these, the effect that accounts for the largest burden of DALYs is that on diarrheal disease.

Diarrheal Disease. The effect of sanitation on diarrhea morbidity has already been mentioned. Table 41.3 shows the results of Esrey and others' (1991) review, attributing a median reduction in incidence of 36 percent to sanitation. Although this figure is the median of the five "better" studies, it must be interpreted with great care because almost all the known studies on the health effects of sanitation are observational studies that use self-selected exposure groups. Confounding by a sense of hygiene is likely to be a significant problem in any such study. From Brazil to Bangladesh, the owners of latrines have been observed to behave more hygienically than their neighbors in practices such as hand washing that are not affected by the presence of a latrine (Hoque and others 1995—see table 41.6;

Table 41.6 Factors Associated with Hand-Washing Behavior by 90 Women in Bangladesh

Associated factor	Hand-washing behavior observed after defecation: Good	Hand-washing behavior observed after defecation: Poor	Ratio of prevalences of good practice (95 percent confidence interval)
Uses own sanitary latrine			
Yes	22	11	1.73
No	22	35	(1.15–2.59)
Uses tubewell water exclusively			
Yes	18	10	1.53
No	26	36	(1.03–2.29)
Owns agricultural land			
Yes	36	24	2.25
No	8	22	(1.20–4.22)
Believes that washing hands prevents diseases			
Yes	26	27	1.01
No	21	18	(0.66–1.55)

Source: Hoque and others 1995.

Strina and others 2003). It is thus impossible to prove, except by an intervention study, that any health benefit associated with latrine ownership is due to the latrine and not to the hygiene habits of latrine owners.

The overall reduction in diarrhea from sanitation quoted by Esrey and others (1991) likely disguises considerable heterogeneity in terms of the context rather than the type of sanitation technology. For example, sanitation is likely to have a greater effect on diarrheal disease in high-density urban areas, where open defecation leads to gross fecal pollution of the neighborhood, and less effect in rural communities, where all but the youngest children use communal defecation sites some distance away from their homes.

For example, Moraes and others (2003), working in urban *favelas* in northeast Brazil, found that diarrhea incidence among children in households with a toilet was half that in households that did not have one. This comparison is likely to be affected by confounding because the households with toilets were a self-selected group. Comparison between communities is less likely to be affected by confounding, but Moraes and others found a greater reduction. The mean incidence of diarrhea in young children in communities with sewers was only one-third of that in the communities that, for administrative and technical reasons, did not have sanitary drainage.

Thus, although the quality of the studies reviewed by Esrey and others (1991) was in general poor and the range of reductions wide, little doubt exists that excreta disposal can be associated with significant reductions in diarrhea morbidity. Studies showing that proximity to open or overflowing sewers (Moraes and others 2003), failure to dispose hygienically of children's stools (Traoré and others 1994), or the presence of excreta on the ground in the household compound (Bukenya and Nwokolo 1991) is a risk factor for fecal-oral infections provide supporting evidence for the likely effect of sanitation infrastructure, particularly in urban settings, on diarrheal disease transmission.

In conclusion, there are some reasons, such as the likelihood of confounding, to believe that Esrey and others' (1991) median reduction is an overestimate, but reasons exist also to believe that the reductions measured were not as great as they might have been had the provision of sanitation been accompanied by hygiene promotion to ensure that the facilities were fully and appropriately used (especially by young children) and maintained. A systematic review of the effect of sanitation on diarrheal disease is urgently required. Meanwhile, and on balance, Esrey and others' median reduction of 36 percent in diarrhea incidence is the most authoritative estimate available.

Interaction with Water Supply. The results of Esrey and others' (1991) review suggest that the effect of water supply and sanitation combined is no greater than that of either on its own. However, that conclusion is based on only two studies, and the percentage reductions found in the individual studies of each type of intervention exhibit a wide range. Reflection on how in practice each of the two interventions interrupts the transmission of fecal-oral pathogens would suggest that their effects would be largely independent: whereas water supply helps prevent contamination of drinking water, hands, and food, excreta disposal helps prevent contamination of the household yard and surroundings, including children's play areas. Esrey and others (1990) reported three other studies in which sanitation and water supply had a greater effect together than individually, but the reductions in diarrhea incidence in those studies could not be calculated.

For the purpose of burden of disease calculations, therefore, the effects of water supply and sanitation improvements on diarrhea are considered here to be independent and additive, which has the advantage of simplicity.

Effect on Other Disease Categories. The first evidence for the health benefits of excreta disposal related not to its effect on diarrheal disease but on intestinal helminths.

A prolonged series of in-depth studies from 1920 to 1930 by researchers of the Rockefeller Foundation established beyond doubt that promiscuous defecation, especially in the household surroundings and particularly by children, played a major role in the transmission of *Ascaris* spp., *Trichuris* spp., and hookworms in a range of settings from Panama to China and the southeastern United States. By implication, the use of sanitary toilets should interrupt transmission by that route.

However, more recent attempts to measure the reductions in parasite prevalence or intensity attributable to improved sanitation have often suffered from the same shortcomings as the studies of their impact on diarrheal disease; many have been cross-sectional studies and, therefore, subject to confounding.

Esrey and others (1991), in reviewing this literature, found that water supply and sanitation reduced the prevalence of ascariasis by a median of 28 percent (range 0 to 83 percent) and of hookworm infection by 4 percent (0 to 100 percent). Those reductions are likely caused by the sanitation rather than by the water-supply improvements. Indeed, three of the nine positive studies of ascariasis and three of the five positive studies of hookworm involved sanitation alone. It is also likely that the effect of excreta disposal on *Trichuris* infection is similar to that on ascariasis (Henry 1981).

Much emphasis has been placed in recent years on chemotherapy as a control intervention for intestinal helminths, particularly the chemotherapy of schoolchildren. However, that option is not always sustainable because the children are quickly reinfected by the eggs and larvae that remain in the environment. Sanitation, particularly school sanitation, has been adopted by the major international donor agencies as an integral component of the FRESH (Focusing Resources on Effective School Health) framework to ensure its sustainability.

A study in Bangladesh (Mascie-Taylor and others 1999) suggested that chemotherapy was more cost-effective (though less effective) as a helminth control intervention than a health education program that included the promotion of sanitation. However, the health education program was excessively labor intensive and, therefore, expensive; it involved the constant deployment of six health educators and a supervisor in each study area of only 550 households, resulting in a cost of Tk 1600 (US$30) per household, compared with Tk 330 (US$6) per year for chemotherapy. That cost compares with the total cost of US$8 per family for WaterAid's successful "100 percent sanitation" approach in rural Bangladesh (Allan 2003). Whereas the promotion of sanitation is a one-time cost, the cost of chemotherapy is a recurrent annual expenditure. Allowing for such a sanitation promotion initiative once every five years—and using the chemotherapy costing of Mascie-Taylor and others (1999)—sanitation promotion is more cost-effective against helminths in Bangladesh than is chemotherapy. If the cost were apportioned between the effect on diarrheal disease and the effect on helminths, sanitation would be far more cost-effective than chemotherapy.

Sanitation can also help prevent trachoma. More than 70 percent of the incidence of this infection has been shown to be caused by flies, mainly of the species *Musca sorbens*, which breeds preferentially in scattered human feces. Pit latrines have been shown to reduce the population of these flies by depriving them of their breeding sites (Emerson and others 2004).

HYGIENE PROMOTION

To a greater degree than with water supply and sanitation, lamentably little reliable evidence exists on the cost or the effectiveness of interventions to change hygiene behavior and still less on the relative cost-effectiveness of different approaches to the design of such interventions.

The Shortage of Evidence

With regard to effectiveness, Loevinsohn (1990) reviewed health education interventions in developing countries and applied four relatively modest criteria of scientific rigor to the 67 published studies he found:

- a description of the intervention in sufficient detail to allow its replication
- an objective outcome measure, based either on health status or on behavior change
- a control group and a sample size greater than two clusters or 60 individuals
- a description of the target population (in terms of their level of education and other factors) adequate to permit a judgment of the relevance of the study to other contexts.

Only three studies were found to meet all four criteria. One (Stanton and Clemens 1987) dealt with environmental hygiene promotion and raises some doubts—although the hygiene behavior of the intervention group was better than the control, both were significantly worse than they had been before the intervention.

A subsequent review of 31 studies (Cave and Curtis 1999) found 5 more studies that could be considered methodologically sound, but none showed a clear effect on behavior. Of a further 11 studies of "reasonable" rigor, only two showed a major effect on behavior.

Shortcomings also exist in the cost data. Many costings are based on budget forecasts and not on real expenditures. Even when actual expenditures are used, major difficulties exist in apportioning the overhead costs that make up a significant proportion of the total. Health educators and the resources they use (such as vehicles) are rarely dedicated exclusively to health education. A further problem in the derivation of unit costs is agreeing on the denominator, which can be the number of people attending health education sessions, the number of members in their households, or the number of people in the target catchment area. For those reasons, different analysts are likely to derive different unit costs from the same data; indeed, the same authors have on occasion arrived at widely differing unit cost figures from the same data.

Time adds a further dimension to this discussion. Do interventions to promote hygiene behavior change have to be implemented continuously, or at least annually, if their effect is to be sustained, or are such changes self-sustaining?

Sustainability

We will take the last question first. Wilson and Chandler (1993) returned after two years to a population in which a four-month intervention to promote hand washing with soap had included provision of free soap. They found that 79 percent of mothers, the original target group, had continued the practice despite the fact that they now had to buy the soap.

Further evidence of the sustainability of new hygiene behaviors was found by Cairncross and Shordt (2003) in a collaborative study with partner organizations in six developing countries in Africa and South Asia. Target populations of previous hygiene promotion projects were visited at 12-month intervals, and various indicators of hygiene behavior were assessed and compared. In four of the six countries, indicators for populations in which the intervention had ended relatively recently were also compared with those in areas where the last intervention had ended several years previously. Those two types of comparison, with the various indicators assessed in each country, allowed a total of 46 comparisons to be made. Only in three such comparisons was there any indication of a falling-off of hygiene with time since the intervention ended; in one case, the falling-off was attributable to the deteriorating condition of the latrines from wear and tear rather than to a decline in compliance.

In some cases, new hygiene practices have become stronger or more prevalent after the ending of external intervention to promote them, as they become self-propagating and consolidated in the community's material culture (Allan 2003).

It is likely that hygiene promotion activities need to be repeated from time to time—say, every five years—but are not required on a continuous basis. It follows from this observation that calculations of cost-effectiveness should take into account the morbidity and mortality averted not only during the implementation of the intervention, but also for a number of years—perhaps five—thereafter.

Costs

Cases in which the costs as well as the effectiveness of hygiene promotion programs have been documented objectively are few indeed. In the absence of suitable data, Varley, Tarvid, and Chao (1998) calculated a costing for a typical program from first principles, arriving at a cost of US$3 (range US$2 to US$3) per household per year, or US$0.60 per capita.

One of the few cases in which data exist is a program in urban Burkina Faso described by Borghi and others (2002). Their data show that the total cost to the provider of the three-year intervention was US$0.65 per capita, or US$4.54 per seven-person household, after deducting the cost of the international research component. Of this total, 63 percent is composed of administration and undifferentiated start-up costs of the project. Most of the remaining costs were accounted for in roughly equal measure by house-to-house visits, discussions in health centers, hygiene lessons in schools, and street theater presentations.

Additional costs were incurred by the 18.5 percent of households that complied, practicing improved hygiene as a result of the program, amounting to US$8 per household per year. More than 90 percent of that sum was the cost of soap for hand washing.

However, on the basis of the observed increase in prevalence of hand washing with soap, the intervention was estimated to have averted sufficient diarrhea morbidity and mortality to save US$2.80 per household per year (US$15 per compliant household per year) in direct costs of medical care and indirect costs attributable to lost productivity. Of this total, 93 percent represented the lost future productivity associated with the deaths of young children.

Waterkeyn (2003) provides an example from rural Zimbabwe. In the two districts in which the Community Health Clubs approach was examined, it was successful in increasing the prevalence of hand washing with soap among the club members by 6 percent and 37 percent, respectively, and it was successful in reducing the prevalence of open defecation by 29 percent and 98 percent, respectively. The marginal cost of the intervention, which used existing health staff, was US$4.00 per club member, or an average of US$0.67 per member of an affected household. Including the salaries of staff members would roughly double the figure to about US$1.40 per capita.

Those figures can be compared with an estimate of US$5.00 per mother (in 1982 dollars) by Phillips and others (1987) based on a review of several programs. Assuming that roughly 1 in 10 members of the population are mothers of young children, this cost is equivalent to about US$0.50 per capita. For cost-effectiveness analysis, a nominal cost of US$1.00 per capita is, therefore, taken because it is roughly the midpoint of the range of recent estimates.

Effect on Diarrhea

Esrey and others (1991) found only six studies of the effect of hygiene promotion interventions on diarrhea morbidity, with a median reduction of 33 percent. A subsequent review by Huttly, Morriss, and Pisani (1997) arrived at a similar result—a median reduction of 35 percent.

The interventions promoting the single hygiene practice of washing one's hands with soap tended to achieve greater reductions in disease than those that promoted several different behaviors. That finding was confirmed by a systematic review of the literature on hand washing (Curtis and Cairncross 2003), which concluded that hand washing with soap—and interventions to promote it—could reduce diarrhea morbidity by 43 percent and life-threatening diarrhea by 48 percent. Because the effect of diarrhea prevention in DALYs is mainly attributable to the prevention of diarrhea deaths, the higher of these two figures is more appropriate for calculating the effect of hygiene promotion on the burden of disease.

It is not surprising that interventions advocating more behavior changes should have less effect, because numerous messages dilute one another in the minds of the target audience. Because some of the interventions in the systematic review were planned without an adequate prior program of formative research, it is possible that they could have had a still greater effect if they were better conceived.

Effect on Respiratory Infections

Reasons exist to believe that hand washing with soap could be a cost-effective intervention not only against diarrheal diseases, but also for the prevention of acute respiratory infections (ARIs). The intervention is plausible, given what is known about the transmission routes of ARIs, and there is also epidemiological evidence, in that all six published studies of the effect of hand washing on ARIs show a significant reduction (Cairncross 2003b).

These two disease groups are the most important causes of child mortality worldwide, and respiratory infections also cause significant adult mortality, for which no alternative preventive intervention is yet available, field-tested, and ready for implementation. A randomized, controlled trial of the efficacy of hand-washing promotion on an ARI outcome is an urgent priority for future research.

Interactions with Water Supply and Sanitation

It can be argued that there is little point in encouraging people to wash their hands if they do not have access to water or to use a latrine if they do not have one.

The argument has only limited validity where sanitation is concerned; an important role for any hygiene promotion is to promote sanitation itself. With regard to water, in the studies reviewed by Curtis and Cairncross (2003), the reductions in disease achieved by hand washing in settings with indoor piped water supply were not significantly different from those achieved elsewhere. Given that the rationale is ambivalent and the evidence inconclusive, the simplest plausible assumption is that the effects of water supply, sanitation, and hygiene promotion on diarrhea are independent and additive to one another.

EFFECT ON BURDEN OF DISEASE

The effect of water supply, sanitation, and hygiene on the global burden of disease can now be estimated, in two stages. First, the evidence presented in this chapter is used to arrive at the reductions in diarrhea that are expected to result from the various combinations and levels of service and that are assumed for the calculation. Then, these figures are applied to the coverage levels for individual countries and the burden of diarrheal disease prevailing in the different regions of the world. Because such a calculation has been done before by Prüss and others (2002) from rather different premises, it was desirable to examine the comparability of the results.

Assumptions: Reductions in Diarrheal Disease

In summary of the discussion of health effects in this chapter, water supply, sanitation, and hygiene promotion are considered to be associated, under typical conditions, with the reductions in diarrheal disease morbidity shown in table 41.7. These reductions are considered to be independent of one another, so that the relative risks for several interventions can be multiplied.

Table 41.7 Assumed Reductions in Diarrhea Attributable to Water Supply, Sanitation, and Hygiene Promotion

Intervention	Reduction in diarrhea (percent)	Corresponding relative risk
Water supply		
Public source	17	1.20
Additional, for house connection	63	2.70
Excreta disposal	36	1.56
Hygiene promotion	48	1.92

Source: Authors.

These assumptions can be compared as follows with the assumptions underlying a previous calculation of the global burden of disease from water, sanitation, and hygiene (Prüss and others 2002; WHO 2002). For that calculation, the following seven scenarios were considered:

VI. No improved water supply or basic sanitation
Va. Basic sanitation only
Vb. Improved water supply only
IV. Improved water supply and basic sanitation
III. Improved water supply and basic sanitation plus house connection water supply, or improved hygiene or water disinfected at point of use
II. “Regulated” water supply (presumably house connection) and full sanitation
I. Ideal situation, corresponding to absence of disease transmission through water, sanitation, and hygiene.

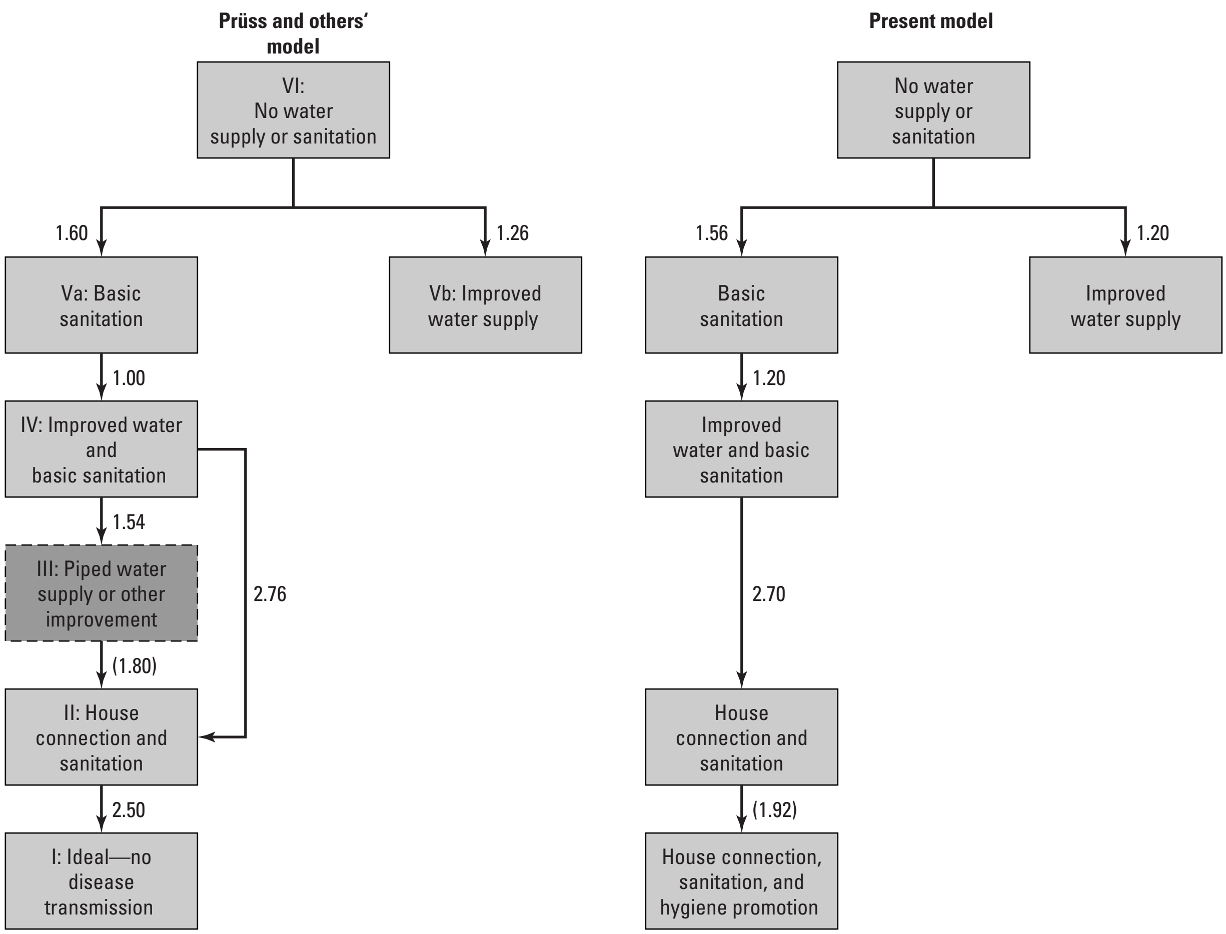
Scenario II is essentially the position prevailing in industrial countries. Leaving out scenarios I and III, which apply to only a small proportion of the population, the following scenarios are broadly equivalent to the categories considered earlier in this chapter:

VI. No improved water or sanitation
Va. Sanitation only
Vb. Improved water supply (public source)
IV. Both improved water supply and sanitation
II. House connection water supply, and sanitation.

In the Prüss model, the relative risks associated with transition from scenarios Va and Vb to VI are taken as 1.26 and 1.60, respectively, comparable with the figures of 1.20 and 1.56 in table 41.7. However, Prüss and others (2002) assume equal risks in scenarios IV and Va, whereas a relative risk of 1.20 follows from the assumption in this chapter that the effects of water supply and sanitation are independent. The Prüss model assumes a relative risk of 1.54 between scenarios III and IV, corresponding to the diarrhea reduction of 35 percent from hygiene promotion found by Huttly, Morriss, and Pisani (1997). Scenario III is essentially a theoretical construct, and between it and scenario II a further relative risk of 1.8 is assumed (in what Prüss and others term their *realistic approach*), on the basis of some recent trials of home disinfection of water, giving a total of 2.76 between scenarios IV and II. The latter figure is close to the corresponding value of 2.70 implied by the assumptions made here, for different reasons. Scenario I, like scenario III, is included not because it is prevalent in reality, but to illustrate a point. Its equivalent would be the generalized and effective implementation of a well-conceived hygiene promotion intervention. Because such hygiene promotion has hardly ever been provided to whole populations, it is similarly hypothetical. From that perspective, the corresponding relative risks of 2.5 (Prüss and others 2002) and 1.92 (table 41.7) are of a similar order of magnitude.

The similarity of the two sets of assumptions, based on rather different premises, is illustrated in figure 41.3.

To allow for the uncertainty in their assumptions, Prüss and others (2002) calculated the burden of disease attributable to water supply, sanitation, and hygiene using two approaches. The *realistic approach* used the assumptions described above and shown in figure 41.3. The *minimal approach* assumed no difference in risk between scenarios II and III. Given the ideal and hypothetical nature of scenario I and the low probability of intensive hygiene promotion being funded for a population that already benefits from high levels of water supply and sanitation provision, we consider the model on the right of figure 41.3 as *optimistic* and prefer to take for our more *realistic* approach the less ambitious baseline of house connections and full sanitation, which approximates the current position in most of Western Europe and North America. This approach responds to recent calls for "baselines and counterfactuals which should include alternative, operationalizable policy/program options (including the status quo)" (Ezzati 2003, 458). It also has the advantage of providing an estimate of burden of



Source: Authors and Prüss and others 2002.

Note: The numbers show relative risk of diarrhea in upper relative to lower boxes. Relative risks in parentheses are set to 1.0 for the minimal version of the Prüss model and for the realistic version of the present model.

Figure 41.3 Comparison of Assumptions Made by Prüss and others (2002) and in this chapter.

disease to which the industrial countries contribute only a negligible amount.

Calculation of Burden of Disease

Prüss and others (2002) worked with water and sanitation coverage data for individual countries (WHO and UNICEF 2000) to derive distributions of the population in each region between five of the seven scenarios, as shown in table 41.8. They then combined these figures with the relative risks in figure 41.3 and diarrhea incidence and case fatality rates from Murray and Lopez (1996) to derive estimates of the number of DALYs attributable to water supply, sanitation, and hygiene in each region and mortality subregion. The results are shown, for their realistic and minimal models, in the first two columns of table 41.9. The realistic estimates are those presented in the *World Health Report 2002* (WHO 2002, 225).

Using the same spreadsheets but the relative risks on the right of figure 41.3, we derive the results in the third and fourth columns of table 41.9 for the optimistic and realistic versions of the present model. The figures for the burden of disease attributable to deficient water supply, sanitation, and hygiene in the industrial countries of Europe, North America, and the Pacific are very different, but the global totals are remarkably similar.

It should be no surprise to find that the attributable burden in the industrial (that is, low-mortality) countries of Europe, North America, and the Pacific is zero or very close to zero. The realistic model was deliberately designed to take as its baseline the conditions prevailing in those countries. This finding does not mean that no diarrheal disease in those countries can be attributed to deficient water supply, sanitation, or hygiene; rather, it means that the baseline there is the current condition, because no realistic policy option is available to reduce the burden of such disease in the immediate future.

Table 41.10 shows the two realistic assessments of DALYs attributable to water supply, sanitation, and hygiene in terms of percentages of the total DALYs in each region and subregion. Again, the two estimates are close. The proportion of the total disease burden attributable to water, sanitation, and hygiene is greatest in the high-mortality countries of the Eastern

Table 41.8 Distribution of the Population between Scenarios of Water Supply and Sanitation Provision *(percent)*

Region (mortality in children and adults)	Scenario				
	II	IV	Va	Vb	VI
African					
Child high, adult high	0	54	5	6	35
Child high, adult very high	0	42	10	9	38
American (Western Hemisphere)					
Child very low, adult very low	99.8	0	0	0	0.2
Child low, adult low	0	76	1	9	14
Child high, adult high	0	68	0	7	25
Eastern Mediterranean					
Child low, adult low	0	83	5	8	4
Child high, adult high	0	66	0	16	18
European					
Child very low, adult very low	100	0	0	0	0
Child low, adult low	0	79	8	1	12
Child low, adult high	0	94	5	0	1
Southeast Asian					
Child low, adult low	0	70	3	7	19
Child high, adult high	0	35	0	53	12
Western Pacific					
Child very low, adult very low	100	0	0	0	0
Child low, adult low	0	42	1	33	24

Source: Prüss and others 2002.

Table 41.9 Distribution of DALYs Attributable to Diarrhea Caused by Poor Water Supply, Sanitation, and Hygiene by Subregion, According to Various Assumptions
(thousands)

Region (mortality in children and adults)	WHO 2002 (realistic)	Prüss 2002 (minimal)	Present model (optimistic)	Present model (realistic)
African				
Child high, adult high	6,916	6,198	6,747	5,727
Child high, adult very high	11,720	10,473	11,402	9,678
American				
Child very low, adult very low	61	61	49	1
Child low, adult low	1,290	1,143	1,232	1,009
Child high, adult high	756	673	725	613
Eastern Mediterranean				
Child low, adult low	629	548	599	482
Child high, adult high	8,303	7,318	7,983	6,653
European				
Child very low, adult very low	66	66	52	0
Child low, adult low	550	483	528	426
Child low, adult high	121	105	115	91
Southeast Asian				
Child low, adult low	1,241	1,096	1,195	982
Child high, adult high	18,487	16,595	17,856	15,545
Western Pacific				
Child very low, adult very low	27	27	21	0
Child low, adult low	3,991	3,574	3,619	3,303
Total, industrial countries	825	742	765	518
Total, developing countries	53,333	47,618	51,358	43,992
Global total	54,158	48,360	52,123	44,510

Source: See Acknowledgments.

Mediterranean region, reaching 6 to 7 percent of the total. They are followed by the high-mortality countries of Southeast Asia and Africa, where the water and sanitation complex accounts for 4 to 5 percent of the total. Globally, improvements in water supply, sanitation, and hygiene could eliminate 3 to 4 percent of the global burden of disease.

Cost-Effectiveness

The assumptions regarding effect on diarrheal disease are summarized in table 41.7. Because the effect on diarrheal disease accounts for the vast majority of the effect, no effort is made to apportion the costs between their effectiveness in preventing the other diseases affected by water supply, sanitation, and hygiene. The costs derived in this chapter are summarized in table 41.11.

The annual costs used for water supply included both the amortized construction cost and operation and maintenance costs. Given that investments in water supply and sanitation are made largely by other sectors (and for other motives) than health, an alternative cost-effectiveness estimate is made that is based only on the costs of regulation, advocacy, and promotion.

The other assumptions used to calculate the cost-effectiveness of improved water supply—of house connections, of sanitation, and of hygiene promotion—other than those set out above, are as described by Varley, Tarvid, and Chao (1998). The key parameters are as follows:

- proportion of population under age five: 17 percent
- diarrhea incidence: five cases per child under age five per year

Table 41.10 DALYs Due to Diarrhea Attributable to Poor Water Supply, Sanitation, and Hygiene by Subregion, as a Percentage of Total DALYs

Region (mortality in children and adults)	WHO 2002 (realistic)	Present model (realistic)
African		
Child high, adult high	4.7	3.9
Child high, adult very high	5.6	4.6
American (Western Hemisphere)		
Child very low, adult very low	0.1	0.0
Child low, adult low	1.6	1.2
Child high, adult high	4.3	3.5
Eastern Mediterranean		
Child low, adult low	2.7	2.1
Child high, adult high	7.3	5.9
European		
Child very low, adult very low	0.1	0.0
Child low, adult low	1.4	1.1
Child low, adult high	0.2	0.2
Southeast Asian		
Child low, adult low	2.0	1.6
Child high, adult high	5.2	4.3
Western Pacific		
Child very low, adult very low	0.2	0.0
Child low, adult low	1.7	1.4
Total, industrial countries	0.4	0.2
Total, developing countries	4.3	3.5
Global total	3.7	3.0

Source: See Acknowledgments.

- median age at onset of disease: 1 year
- average duration: 8 days
- case fatality rate: 0.5 percent
- coverage by oral rehydration therapy: 30 percent
- oral rehydration therapy reduction in case fatality rate: 50 percent

On this basis, we arrived at the cost-effectiveness values in table 41.12.

All of these figures underestimate the cost-effectiveness of investments in water and sanitation, for several reasons:

- The effects of these interventions on diseases other than diarrhea have not been taken into account; they seem to be relatively minor for water supply but may be substantial if hand washing proves to affect ARI.
- Effects on diarrhea mortality, which account for 98 percent of the DALYs, are likely to be greater than the reductions in morbidity shown in table 41.7.
- The cost figures have generally been taken so as to be sufficient for all contexts, whereas water supply and sanitation can be implemented more cheaply in favorable settings—such as where a convenient aquifer or reliable rainfall exists.
- Potential economies exist in combining the interventions; for example, sanitation promotion can be combined with hygiene promotion and water pipes laid with sewers.
- The current global initiative to promote hand washing, involving commercial marketing expertise, may identify more cost-effective approaches to hygiene promotion.
- If a sustainable low-cost sanitation industry can be developed, it will have an interest in promoting its own product.

As they stand, the cost-effectiveness values above, except for house connections and construction of latrines, are well below the US$150/DALY cutoff value proposed by the World Bank

Table 41.11 Costs Assumed for Cost-Effectiveness Calculations (US$ per capita)

Intervention	Construction cost (US$ per capita)	Amortization lifetime (years)	Amortized annual cost (US$ per capita)	Operation and maintenance cost (US$ per capita)
Water supply				
House connections	150.00	20	7.50	10.00
Hand pump or standpost	40.00	20	1.00	1.00
Water regulation and advocacy		US$0.02 to US$0.10 per capita per year		
Sanitation	≤60.00	5	≤12.00	n.a.
Sanitation promotion	2.50	5	0.50	n.a.
Hygiene promotion	1.00	5	0.20	n.a.

Source: Authors.
n.a. = not applicable.

Table 41.12 Cost-Effectiveness of Water Supply, Sanitation, and Hygiene Promotion (US$/DALY)

Intervention	Cost-effectiveness
Water supply	
Hand pump or standpost	94.00
House connection	223.00
Water sector regulation and advocacy	47.00
Basic sanitation	
Construction and promotion	≤270.00
Promotion only	11.15
Hygiene promotion	3.35

Source: Authors.

(1993) as a criterion of cost-effectiveness. Allowing only for the cost component that should fall to the health sector puts them all well within this ceiling. For comparison, the cost-effectiveness of promoting oral rehydration therapy, the principal other measure available to prevent diarrhea mortality, has been estimated at US$23/DALY. The cost-effectiveness of promoting sanitation and hygiene as derived above (US$11.15 and US$3.35, respectively, per DALY) compares favorably with that figure.

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