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Water Supply, Sanitation, and Hygiene Promotion

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INTRODUCTION

"Water supply" is taken here to include the supply of water for domestic purposes, including drinking, cooking and food preparation, cleaning and personal washing. It therefore excludes the provision of water for irrigation or livestock. By the same token, "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.

Domestic solid waste and urban surface runoff in developing countries usually contain a degree of fecal contamination, but the direct evidence for the impact of drainage and solid waste disposal on disease burden is sparse (Heller 1999, Parkinson 2003, Prado *et al*. 2003). To the extent that such evidence exists, it suggests that the impact of these other measures on disease burden is largely confined to urban areas and considerably less than that of water supply, sanitation and hygiene promotion. Mismanaged solid waste causes a health hazard, not primarily through contamination of water supplies but by obstructing drainage and providing breeding sites for disease vectors such as rats, flies and mosquitoes.

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 transport, which are not considered to be public health interventions.

This chapter focuses on three related interventions – 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 these have implications for benefits. Water supply and sanitation offer many benefits in addition to improved health, and these are considered in detail because they have important implications for the share of the cost which is attributable to the health sector. From the point of view of their impact on burden of disease, the main health benefit of water supply, sanitation and hygiene is a reduction in diarrheal disease, though the impacts on other diseases are substantial. In the concluding section, the percentage reductions arrived at in the preceding discussion are used together with data on existing levels of coverage to derive estimates of the potential impact of water supply and excreta disposal on the Burden of Disease, globally and by region.

WATER SUPPLY

Levels of service and their costs

What is a perfectly satisfactory water supply to some consumers leaves others, even in developing countries, to consider themselves unserved. In much of rural Africa, a hand pump 500 meters from the household is a luxury, but in urban Latin America, most residents would not consider themselves to be served by a water supply unless they had a house connection. In Asia, urban planners would consider a community served if there are sufficient standposts on the street corner, but if the water only flows for a few hours per week producing lengthy night-time queues, the residents may regard this as a lack of service and opt to buy water expensively from itinerant vendors. As these examples illustrate, water supply is not single well-defined intervention such as immunization, but can be provided at various levels of service with varying benefits, and different 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, as we shall argue below, 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/Unicef 2000), the most recent compilation of global statistics on water supply changed the way in which such data are compiled, from the previous unreliable estimates by provider agencies, to consumers' responses to population-based surveys. This required a departure from the old definition of "reasonable access to safe water", since most consumers are unable to tell whether their water supply is safe. They can, however, state the type of technology involved, and this 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 "unimproved" sources. Table 1 below lists the technologies treated as "improved" or "not improved" in the Global Assessment.

Table 1. Definitions of "improved" and "not improved" water supplies used for Global Water Supply and Sanitation Assessment 2000 Report (WHO/Unicef 2000).

"Improved"	**"Not improved"**
Household connection	Unprotected well
Public standpipe	Unprotected spring
Borehole	Vendor-provided water
Protected (lined) dug well	Bottled water [1]
Protected spring	Tanker-truck provided water
Rainwater collection	

[1] Considered as "not improved" because of concerns about the quantity of water supplied, not because of concerns over the water quality.

"Reasonable access" was broadly defined as the availability of at least 20 liters per capita per day from a source within one 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, and
- public or community sources.

In most settings these correspond to very different levels of water consumption, different amounts of time spent collecting water, and as we shall see below, different health benefits.

The Global Assessment Report also gives median construction costs per person served, for the various technologies, in the three main regions of the developing world. These are shown in Figure 1. However, there are a number of reasons for treating such figures with caution.

First, local conditions such as the size of the town or city to be served, but also technical factors such as the presence of suitable aquifers or the distance to the nearest freshwater stream, can cause very large variations in the unit cost of water supply.

For a community of given size, there are not significant returns to scale in the number of house connections made. Most of the investment is in the major works for abstraction, treatment, transport and storage of the water, with typically one third in the distribution network. Most of this network must also be installed before house connections can be offered, so that the marginal cost of each connection is only a fraction of the total. For these 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 taken as representative of that level of service in Latin America and the Caribbean, where they are often provided in rural areas. In rural Africa, and Asia however, the reported costs of house connections relate almost exclusively to urban areas, as they 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 $150, just above the higher 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 $40 per capita is around the middle of the range offered by different technologies (standpost, borehole and dug well) providing this level of service for each continent (Figure 1), and therefore therefore seems reasonable for this level of service, though it can be expected to vary between $15 and $65 or more, depending on local conditions. The range of costs reported by individual countries for the Year 2000 Global Assessment varied by more than an order of magnitude.

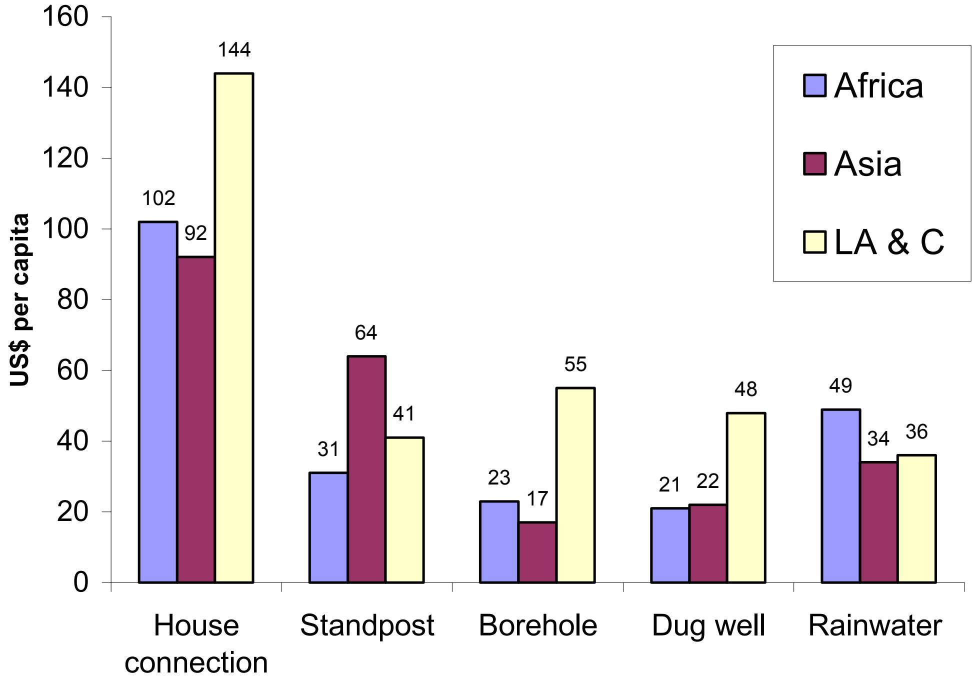

Figure 1 Median construction cost of water supply facilities for Africa, Asia and Latin America and the Caribbean
Source: WHO/Unicef (2000)

In order to calculate the cost-effectiveness of investment in water supplies as a measure, these capital costs must be amortized 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% 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 Assessment also gives median reported production costs per cubic meter for urban (house connection) water supplies as US$ 0.20 for Asia and $ 0.30 for Africa, Latin America and the Caribbean. Assuming a mean daily water consumption of 100 liters/capita by those with household connections, these figures give annual per capita operation and maintenance costs of $ 7.30 and $ 10.95 respectively, or 8% to 10% of the capital cost of construction. In this Chapter, we take a generic figure of $10 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 as much of the maintenance is carried out by the volunteer labor of villagers. Arlosoroff *et al*. (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 handpump-based supply can range from US$0.50 to $2.00, while well-planned community-level maintenance can bring that figure down as low as US$0.05 per capita per year. More recently, Unicef (2000) found that maintenance of rural water supplies costs the Government of India an annual average of US$30 per handpump, which amounts to $0.10 - $0.20 per capita if each pump serves 150 – 300 people, though it is possible that some expenditure items may not be included as they are met by lower levels of local government and volunteer labor. To allow for this and near the midpoint of the range estimated by Arlosoroff *et al.*, a nominal annual figure of US$1.00 per capita is taken 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 represents 2.5% of the construction cost arrived at above.

The time-saving benefit

Contrary to widespread belief in the health sector, the undoubted 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 important benefit of rural water supply improvements from the perspective of the people affected is generally the fact that water is brought closer to where they live…. There is no indication that rural populations expect health gains." Churchill *et al*. (1987).

The value of time

The saving in time and drudgery carrying water home from the source is substantial, and there are several reasons to attribute a money value to it. First, if time spent collecting water were not a cost, one would expect to find that many villages were located miles from their water sources, that water source choice was not affected by distance, and that water consumption was not affected by the distance the water had to be carried. While it is true that water sources are not the only determinant of village location, and water consumption is relatively insensitive to small changes in distance (Thompson *et al*. 2001), few villages are built unnecessarily far from a water source (Hoskins 1955) distance is one of the principal factors determining water source choice (Feachem *et al*. 1978; Briscoe 1985) and people carrying water for longer distances do use significantly less than others (Cairncross and Cliff 1987).

The idea that poor women's time is of little value ignores the opportunities for income generation by petty trading and handicrafts, through which they can contribute significantly to GNP and welfare if their time allows. If time saved for women from water carrying is spent, not in income generation but in child care or leisure, that is evidence that they value those pursuits more highly.

The most powerful argument of all 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 use more distant sources which are free of charge. Thompson *et al*. (2001) found that of urban East African households lacking a piped supply, the proportion paying for water had increased from 53% to 80% 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% of their income on the purchase of water from vendors. The prices charged by vendors are typically more than ten times, and can be up to 50 times, the normal tariff charged by the formal water supply utility (Whittington *et al*. 1989). Cairncross and Kinnear (1992) found that vendor prices increased with the time required to collect the water, showing that households will 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, one calculates the implicit value which people ascribe to their time. Whittington (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.

Since the poorest urban households typically spend more than 90% of their household budget on food, the money they spend on water is sacrificed from their food budget (Cairncross & Kinnear 1991). The provision of water more cheaply thus offers a substantial nutritional benefit to the poorest.

Some idea of the transformation in the quality of life, particularly of women, which accompanies provision of a water supply to a poor community, can be had from a retrospective evaluation of completed projects carried out in four countries by WaterAid using Participatory Rapid Appraisal (PRA) methods (WaterAid 2000). The principal benefits volunteered by local communities as stemming noticeably from water supply projects completed several years previously are shown in Table 2. A number of them were emphasized by beneficiary communities in all four countries. It is hard to put a money value on these, but they are clearly of immense value to the beneficiaries; several of them can be considered health benefits, in terms of the WHO definition of health as “a state of complete physical, mental and social well-being and not only the absence of disease or infirmity.”

Table 2 Benefits of rural water supply, mentioned spontaneously by local communities in the course of a participatory evaluation in four countries, 2000

	Ethiopia	Ghana	India	Tanzania
Less tension/conflict		X	X	X
Community unity			X	X
Self-esteem (e.g. of schoolchildren)	X	X	X	X
Women’s empowerment (e.g. non-domestic activities, less harassment)	X	X	X	X
Women’s hygiene (e.g. menstrual, postpartum)	X			X
Family quality time	X	X		X
Improved school attendance (especially girls)	X	X	X	X
Teachers accept posting to village		X		

Source: WaterAid (2000) Looking Back: Participatory Assessment of Older Projects. London: WaterAid. (www.wateraid.org.uk)

Assessing the time saved

The cost of water collection in rural areas is in time and effort rather than in money paid to vendors, as water vending is less common there. The saving in time and drudgery underlies most of the social benefits listed in Table 2. Considering the relevance of the time saving benefit to water supply policy, and the fact that it is usually the benefit uppermost in the mind of the consumer, it is remarkable how few data have been collected on the amounts of time spent in collecting water.

In 1966, in one of the first studies of the subject, White *et al*. (1972) found a mean distance from household to water source of 428 m among unpiped households in Kenya, Tanzania and Uganda. Thirty years later, Thompson *et al*. (2001), working in the same 34 study sites, found that the average distance from an unpiped household to its source of water had in fact ***increased*** by 31 meters. In urban areas, the distance had decreased over the decades, but the time required for a water collection journey had increased because of an increase in the length of queues at the tap, so that the total time taken to collect water was similar in urban and rural areas (Table 3). Remarkably, in spite of the undiminished labor of each water collection trip, the number of trips per day made by the average household had increased by 50%.

Table 3 Average distances and water collection journey times in East Africa, 1966 and 1996.

	Distance (m)		Return time (min.)		No. of trips/household	
	1966	1996	1966	1996	1966	1996
Rural	484	622	16.6	25.3	2.5	3.8
Urban	230	204	9.8	21.4	2.6	4.0
All sites	428	459	15.1	23.0	2.6	4.0

Source: Thompson *et al*. (2001)

Feachem *et al*. (1978) found in ten villages of the densely-populated lowlands of Lesotho, Southern Africa that the installation of a water supply had reduced the average time spent on each water collection journey from 24 to 9 minutes, a saving of 15 minutes. Average per capita daily water consumption in rural Lesotho is roughly equal to the size of a container, so that the time per journey is approximately equal to the time spent per head of population. Since each woman makes an average of two journeys per day, this means that the water supplies had saved the average adult woman 30 minutes per day. In one third of these villages, the saving per woman was over an hour a day. The landscape of Lesotho offers an abundance of springs, so that the time saving is likely to be on the low side, compared with Africa as a whole.

Confirmation of this is provided by Unicef's Multi-Indicator Cluster Surveys which now include a question on the distance to the household's water source. A recent analysis of the responses to this question from 23 African countries has produced a more representative account of water collection journey times in that continent (Figure 2). Nearly half the households interviewed (44%) 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.

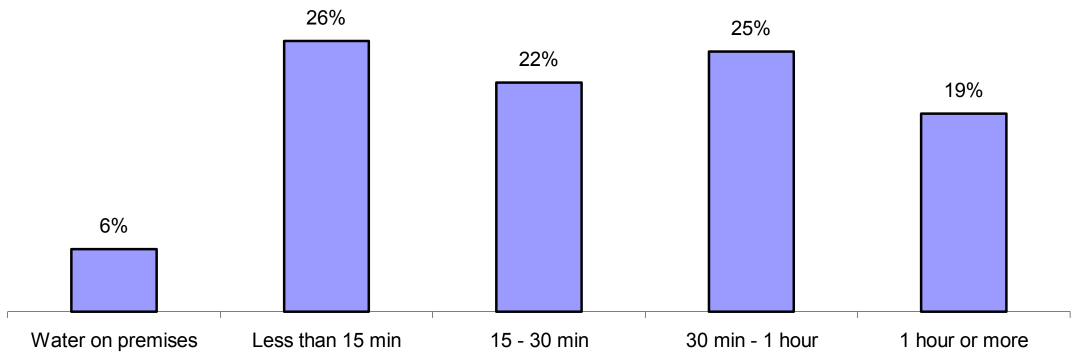

Figure 2: Water collection journey times in rural sub-Saharan Africa, 2002
Source: Analysis of Unicef MICS data from 23 countries (G. Keast, personal communication**)**

As the foregoing illustrates, almost all the representative data on water collection journey times are from Africa. An Indian national survey commissioned by Unicef found that women spent an average of 2.2 hours/day collecting water from rural wells (Mukherjee 1990). A study in Sri Lanka, generally considered to be well-provided with water sources, found that 10% had to travel more than 1 km to their nearest source (Mertens *et al*. 1990). Gorter *et al*. (1991), working in rural Nicaragua, found that only 1% of households had to go so far for water, though such conditions are not necessarily representative of the developing countries of the New World.

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. More than 15 years ago, Churchill *et al* (1987) took $0.125/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 $11.40 per year. The data presented above indicate that in Africa at least, 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. There is therefore little doubt 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, willingness to pay for water supplies, particularly at the level of service of house connections, has been widely demonstrated by contingent valuation surveys (World Bank Water Demand Research Team 1993). In general, such measured willingness-to-pay has exceeded the cost of provision of the supplies, and payment to vendors often exceeds it by many times. In fact, Whittington *et al* (1989) found that the turnover of the informal vending market exceeded the total revenue of the formal water supply agency in the community, although the vendors were largely re-selling water which the agency had originally provided!

Policy implications
Whether or not the consumers actually pay for the full value of the time-saving benefit, that 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, Latin America and the Caribbean is from domestic sources (Figure 3). Most of this 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 taken, even though health benefits do arise from water supply improvements.

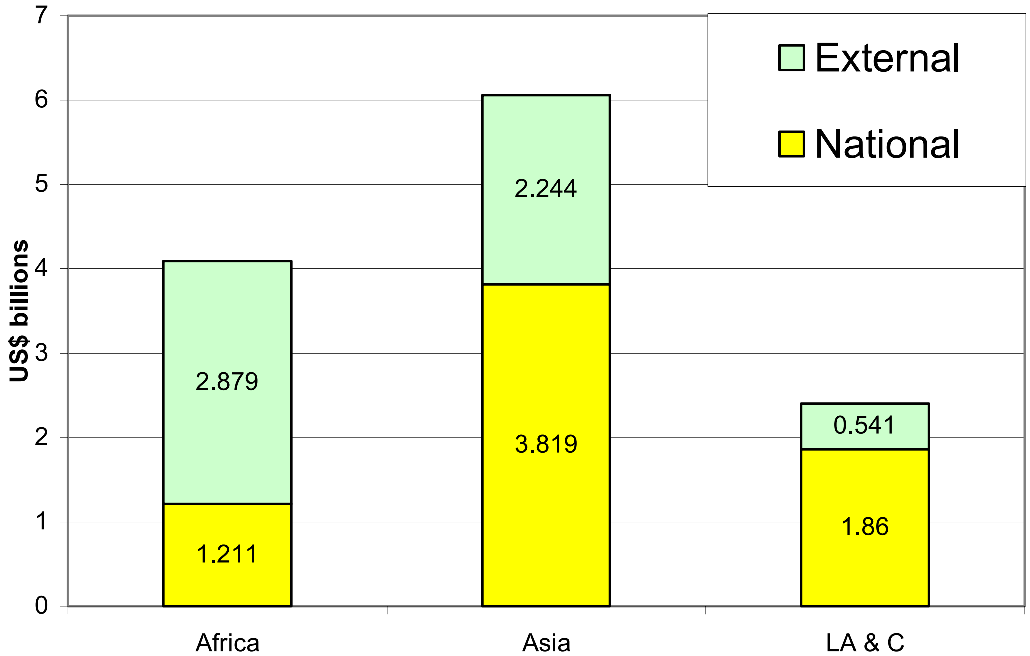

Figure 3 Total annual investments in water supplies in Africa, Asia and in Latin America and the Caribbean, 1990-2000
Source: WHO/Unicef (2000)

Water supply is thus a health-related intervention which comes “free” to the budgets of the health sector. While it undoubtedly offers health benefits, as discussed below, 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 does not mean that the water sector should be ignored by the authorities responsible for public health. The function of the health sector is one of regulation, advocacy and provision of supplementary inputs where 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 drinking water quality surveillance is well-known and widely accepted (WHO 1976). There is substantial, and largely unexploited additional potential 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 quantity, continuity, coverage, control of sanitary hazards, and cost. These other aspects, as will be argued below, 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 of the order of a month's basic wage. Advocacy of lower connection charges, with the amount recovered from the monthly water tariffs, can therefore help to achieve an increase in the number of people who have house connections, and who can therefore 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 the promotion of low-cost sanitation to increase coverage; because of their nature, the water sector with its focus on technology is ill-equipped to offer these.

The unit costs of such regulation and advocacy are minimal. One example which can illustrate this is the case of Unicef's participation over the last 30 years in India's rural water supply programme. Unicef's investment has represented no more than 1% of the total, but its influence has played a central part in the evolution of the technical and institutional model of the program which supplies water to one in ten members of the human race (Unicef 2000).

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 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 5 years old fell from 4.5 to 2.2 episodes/child-year, and the corresponding mortality rate from 101.6 to 62.9 per 100,000 (Gutiérrez *et al*. 1996).

The current rate of annual investment per capita in water supply and sanitation, including both national investment and external aid funds, is reportedly $2.25 in Asia, $7.53 in Africa and $8.87 in Latin America and the Caribbean (WHO/Unicef 2000). 1% of the water sector's investment would therefore be 2¢ to 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 its health impact, though the Mexican example above suggests that it would be substantial. For the sake of cost-effectiveness estimation, we assume arbitrarily that it has the effect of ensuring improved water supplies for an additional 10% of the population to which it refers.

Direct health impact

Classification and burden of water-related diseases

The full list of water-related infections is large and varied, but most of them 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 *et al*. 1972), who developed a classification of disease transmission routes in terms of whether they were:

- Water-borne, in the strict sense where 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 via an aquatic invertebrate host; and
- Water-related insect vector routes, involving an insect vector which breeds in or near to water.

Whereas the prevention of water-borne disease 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 have an impact on water-based infections (e.g. if it reduces the need for people to enter schistosomiasis-infected water bodies) or on water-related insect vector diseases (e.g. if a more reliable supply avoids 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.

Before this 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 of the potentially water-borne infections, which are transmitted by the feco-oral route, can potentially be transmitted by other means (contamination of fingers, food, fomites, field crops, other fluids, flies, etc.) 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 water-borne. The final classification is shown in Table 4.

Table 4 The Bradley classification of water-related infections

Transmission route	Description	Disease group	Examples
Water-borne	The pathogen is in water which 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 (e.g. a snail).	Water-based	Schistosomiasis, Guinea worm.
Water-related insect vector	Transmission by insects which breed in water or bite near water.	Water-related insect vector	Dengue, Malaria, Trypanosomiasis.

The classification can now be used to assess how the disease burden prevented by water supply is distributed between disease groups. Bradley himself did this, in a time long before the Disability-Adjusted Life Year had been invented as a unit of benefit measurement (White *et al*. 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 due to each condition could be expected to fall if water supply were "excellent".

These notional reductions were based on subjective assessments of the literature available at the time, and 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 5.

Table 5 Percentage reductions in disease rates assumed by Bradley (White *et al*. 1972)

Diagnosis	% 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

The results of these calculations are shown by water-related disease category in the first three columns of Table 6. The final column presents equivalent results in DALYs for the whole of Africa in 1990 (Rosen & Vincent 2001). When measured in terms of deaths or DALYs, the feco-oral infections account for the vast majority of the impact. This is due to the high mortality caused by diarrheal diseases among young children. Most deaths from diarrheal diseases are of children less than five years old, and most of those are among children aged less than two (Kosek *et al*. 2003). A child death averted is worth 30 DALYs. Varley *et al*. (1998) has 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 is the water-based group, mainly 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 *et al*. 1993), so the burden of disease is no doubt similar around the developing world. The second most important 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 New World than it is in Africa.

Table 6: Proportion of water-related disease preventable by water supply: Africa

Category	Deaths	Inpatients	Outpatients	DALYs
Feco-oral	91%	50%	33%	85%
Water-washed	3%	32%	62%	3.5%
Water-based	6%	18%	5%	12%
W-r insect vector	0.3%	0.2%	0%	0% .
Totals	100%	100%	100%	100%

Sources: White GF *et al*. (1972). DALYs from Rosen S, Vincent JR (2001)

Epidemiological questions, and epidemiological problems

The predominant contribution of the feco-oral diseases to the burden of disease attributable to water supply raises an important question, because this group can be transmitted by both water-borne 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, in other words, whether the feco-oral infections endemic in poor communities are mainly water-borne, 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 them. 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 very 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; there is no placebo for a standpipe. Where quasi-experimental studies have been used, opportunistically exploiting an intervention allocated by political or technical means, it has frequently been found that there has been significant confounding. Confounding is a particularly serious problem when the relative risk is of the order of 2 or less, as is common in studies of the impact of water supply and sanitation on diarrhea (Briscoe *et al* 1985).

Confounding has been especially intractable in studies where the allocation of facilities has been on a household basis, so that the exposure groups are self-selected; for instance, where individual households which have chosen to install a private tap are compared with others which have chosen not to do so. Such households are likely to be wealthier, better educated and more conscious of hygiene than their neighbors, so it would not be surprising if they are also more likely do many other things which 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 this does not guarantee that the confounding is eliminated (Coronary Drug Project Research Group 1980, Cairncross1990).

Where the allocation of the water supply intervention is by village or neighborhood, rather than by individual household, the problem of self-selection is of lesser importance. Researchers have generally relied upon, and sometimes sought to defend the assumption that the process of allocation is largely determined by technical and political criteria (ease of access, favorable geology, party allegiance, etc.) which have little to do with disease rates, and can therefore be considered as random from the epidemiological point of view. However, a further difficulty arises with such studies, because 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. And yet a number of important studies in the literature compare a single intervention area with only one control area.

There are other epidemiological weaknesses in the data. Blum and Feachem (1983) reviewed studies of the health impact of water supply and sanitation projects, and noted the following eight common methodological flaws among them.

1. Lack of an adequate control group
2. Comparison of only one served and one unserved community
3. Inadequate control for confounding variables
4. Excessive health indicator recall period
5. Inadequate health indicator definition
6. Failure to analyze by age
7. Failure to record usage of the facilities
8. No control for the seasonality of outcome variables.

In fact, every one of the 50 studies they reviewed contained one or more of these basic errors of methodology.

A further weakness in the evidence for the impact of water supply on diarrheal disease burden is that most of it relates to diarrheal disease morbidity, and significant assumptions are needed to extrapolate such evidence to an impact on diarrheal mortality.

Impact on diarrheal disease

Esrey *et al*. (1985a, 1991) reviewed the same literature from a different perspective. Though conscious of the methodological shortcomings of most studies in the literature, they sought to assess the overall reductions in diarrheal disease which 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 7.

Table 7 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
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 *et al*. (1991).

For more than a decade, this review has remained, *faute de mieux*, the most authoritative on the subject. However, the small reductions in disease which it reports for water supply conceal an important heterogeneity. Though these overall results are frequently quoted, the following remark by Esrey *et al*. (1991) 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."

The studies in the two reviews by Esrey *et al*. in which the water supply was provided in the home are listed in Table 8. Note that by the currently accepted rules of meta-analysis, a study with more than one independent outcome measure can be considered as several independent studies. The median reduction in diarrheal disease due to house connections can be seen to be 49% (from 12 studies), and that from the two better studies is 63%. These reductions are several times greater than the overall median impacts in Table 7. The 63% figure will be used in the burden of disease calculations below. Note that in the two better studies, the comparison group were not using 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.

Table 8: Studies of the impact of house connections on diarrheal morbidity or mortality

Reference	Country	Age group (months)	Water supply exposure	Outcome	% change	
*Freij & Wall (1977)	Ethiopia	0-24	private vs. community (>10 l.c.d.)	diarrhea days/year	-67%	19*
Shiffman *et al*. (1978)	Guatemala	All ages	piped vs. unpiped	diarrhea prevalence	-1%	20
Beck *et al*. (1957)	Guatemala	0-120	private vs. community	Shigella prevalence	-33%	22
Rajaskeran *et al* (1977)	India	0-60	standpipes vs. taps in homes	diarrhea incidence	-36%	25
				Shigella incidence	-61%	
van Zijl (1966)	Iran	0-84	piped vs. unpiped	diarrhea prevalence	-26%	28
				Shigella prevalence	-40%	
Henry (1981)	St. Lucia	6-26	public vs. household	diarrhea prevalence	-24%	35
Rubenstein *et al* (1969)	USA	0-12	indoor plumbing	diarrhea clinic visits	-58%	38
*Schliessman (1959)	USA	0-60	water outside vs. in premises	Shigella prevalence	-59%	40*
Hollister *et al* (1955)	USA	0-120	water outside vs. in homes (matched)	Shigella prevalence	-80%	43
Victora *et al* (1988)	Brazil	0-12	private tap vs. off-plot	diarrhea mortality	-80%	.

* Classed as a study of better epidemiological quality.

Source: Esrey *et al*. (1985a, 1990)

Some subsequent studies have confirmed this pattern. For example, Gorter *et al* (1991) found in Nicaragua that children in households with a yard tap or private well had 34% less diarrhea than those whose water source was over 500m from the house; Bukenya and Nwokolo (1991) showed in New Guinea that use of a household tap was associated with 56% less diarrhea than use of public standpipes providing water of good quality.

Conditions for health impact

It appears that provision of a public water point has little impact on health, even where the water provided is of good quality and it replaces a traditional source which 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 water-borne. While water-borne 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:

1. **Negative health impact studies.** As mentioned above, Esrey *et al*. (1985a, 1991) cite a number of studies of the health impact of water supplies, where water quality improvements have failed to produce a significant impact on diarrheal disease incidence.
2. **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 them to be far more heavily contaminated with fecal bacteria than their drinking water (Lanata 2003), even when the water has been stored in open pots.
3. **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 (Rowland 1986). This suggests that the bacterial pathogens show environmental re-growth 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.
4. **Fly control studies.** Trials in rural Asia and Africa have shown that fly control can reduce diarrheal disease incidence by 23% (Chavasse *et al*. 1999, Emerson *et al*. 1999).
5. **Hand washing studies.** A recent systematic review of the impact of hand washing with soap has shown that this simple measure is associated with a reduction of 43% in diarrheal disease, and 48% in diarrheas with the more life-threatening etiologies (Curtis and Cairncross, 2003).

These 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 influences 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 impact on water consumption unless the old source was more than 1 kilometre (30 minutes' round trip journey) away from the user's dwelling. This is illustrated by Figures 4(a) and (b), which show the relationship between distance and water usage in Eastern and Southern Africa respectively.

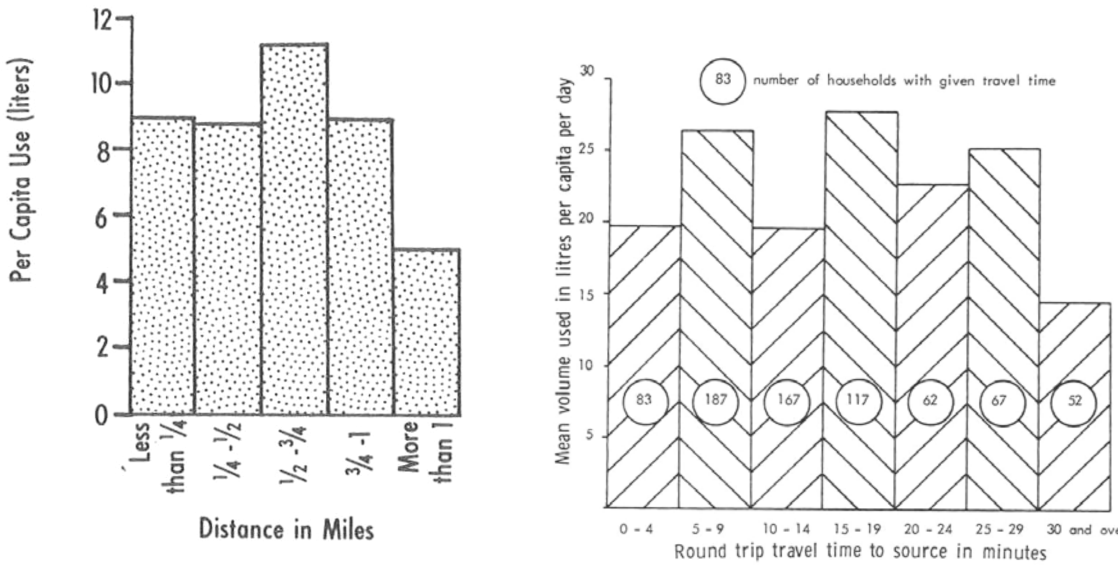

Figure 4 Relationship between distance to water and water consumption in (a) Eastern and (b) Southern Africa.
Sources: (a) White *et al*. (1972) and (b) Feachem *et al*. (1978).

On the other hand, water consumption doubles or trebles when house connections are provided (White *et al*. 1972), and there is reason to believe that much of the additional consumption is used for hygiene purposes. For example, Curtis *et al*. (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.

To conclude, water supplies are likely to have an impact on diarrheal disease when they lead to hygiene behavior change; that is, when the old source of water was more than 30 minutes' round trip 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 where 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, the collection of revenue from households with private connections is far simpler than from public taps because the sanction of disconnection can be used against households which default on payment of the tariff.

In order to calculate the burden of disease associated with inadequate water supply, we need a figure for the reduction associated with the levels of service for which coverage statistics are available. The burden of disease calculations below are based on a reduction of 17% from an "improved" public water supply (Table 7), and of a further 63% from house connections.

There are several reasons why the impact of water supply improvements (and of hygiene practices such as handwashing) on diarrhea mortality can be expected to be at least as great, and probably greater, than their impact on morbidity. A theoretical argument for this is given by Esrey *et al*. (1985b), in terms of infectious doses. Esrey *et al*. (1991) also reported a median reduction of 65% in diarrhea mortality attributable to water supply and/or sanitation in 3 studies, compared with 22% from 49 studies of morbidity. The impact of handwashing on life-threatening diarrheas (Shigellosis, typhoid, cholera and hospitalized cases) is greater than on diarrhea morbidity as a whole (Curtis and Cairncross 2003). Finally, the two known direct studies in the literature of the impact of house connections on diarrhea mortality (Serviço Especial da Saúde Pública, unpublished study in Palmares, Pernambuco, Brazil, cited by Wagner & Lanoix 1959, Victora *et al*. 1988) found reductions of 65% (relative to a public standpipe) and 80% (relative to various communal sources, some polluted) respectively.

Recent reviews, and point-of-use treatment

However coherent the preceding arguments might seem, they have been cast into controversy by two recent systematic reviews of the literature. The more complete of these (Fewtrell *et al.* 2004) reaches conclusions broadly similar to Esrey's review in all respects except one, although following a more systematic search strategy, limited to developing countries, and deriving random effects pooled estimates of the reductions in diarrhea incidence. The exception is the reduction due to household-based water treatment methods, calculated from eight 'good' studies as 40% (95% CI 19% - 54%). The other review (Gundry *et al.* 2004) focusses specifically on household interventions to improve drinking water quality, and arrives at a pooled estimate for the reduction of 65% (95% CI 44% - 79%).

Esrey's figure of a 20% reduction from water quality improvements lies within the confidence interval of the former review, but the two reviews together, and the studies they include, suggest that the relative importance of water-borne transmission, and hence of water quality improvements, may have been underestimated by the preceding discussion. Closer examination of the studies raises several questions.

First, a number of the point-of-use treatment studies relate specifically to cholera, which as the only enteric pathogen with an aquatic reservoir (Islam *et al.* 1993) has a particularly high propensity to waterborne transmission.

Second, many of them involved a hygiene education intervention as well as water treatment. This is true for three of the five 'good' studies reviewed by Fewtrell *et al.* where point-of-use treatment produced a significant reduction in diarrhea incidence. Given the effectiveness of hygiene promotion in preventing diarrhea, it is not at all certain that the reductions observed were entirely attributable to the water treatment.

Third, few of these studies were blinded, or even accompanied by a placebo intervention for the control group. Only two of the eight studies of household chlorination in both reviews involved a placebo (Kirchhoff 1985, Austin 1994); neither found a statistically significant reduction in diarrhea. The possibility that disease reporting may have been biased by participants' awareness of their intervention status is supported by the failure by Gundry *et al.* (2004) to find a clear relationship between diarrhea and microbiological water quality and by Fewtrell *et al.* (2004) to find a significant overall impact from water treatment administered at the source. Consumers are less likely to be aware of these two factors than of water treatment administered in their homes.

Many of the point-of-use treatment studies were far too small to detect a reduction in diarrhea incidence of the order of those in Table 7, which were widely considered as the most authoritative prior estimate. This gives reason to suspect publication bias, and indeed Fewtrell *et al*. found evidence of it using Begg's test. The two reviews are also incomplete; limiting consideration to the point-of-use treatment studies (13 in Fewtrell *et al.*, 12 in Gundry *et al.*), only 6 studies are common to both. Considering the two studies as a mark-release-recapture experiment, this suggests a universe of 28 studies which could be detected using an improved search strategy.

There is certainly a case for a more thorough search and rigorous review of the existing literature on point-of-use water treatment methods, and such a review has been registered with the Cochrane Collaboration (Clasen *et al.* 2003).

Meanwhile, there are two strong reasons why the promotion of such point-of-use treatment cannot be considered as an alternative to conventional water supply. First, there is an almost complete lack of information on the longevity of health impacts and behavior changes after the initial implementation period. Second, where water supplies exist but provide water of poor quality, it is far more cost-effective to ensure correct operation of the central water treatment works than to distribute the means of treatment to every household in the community and depend on every household taking appropriate action to operate it.

Impact on other disease categories

As mentioned above, water supplies have a beneficial impact on a number of other disease groups besides diarrhea, although the corresponding burden of disease is far less. The median reductions in morbidity from other water-related conditions, reported by Esrey *et al*. (1990), are shown in Table 9 below.

Table 9 Median reductions in morbidity associated with improved water supply and sanitation; conditions other than diarrhea, related most closely to water supply.

Disease	All studies		Better studies		
	No. of studies	Median reduction	No. of studies	Median reduction	Range
Dracunculiasis	7	76%	2	78%	75-81%
Schistosomiasis	4	73%	3	77%	59-87%
Trachoma	13	50%	7	27%	0-79%

Source: Esrey *et al*. (1990)

Reductions in schistosomiasis are more likely to be attributable to water supply improvements than to sanitation, because occasional open defecation by only a few members of a community is enough to maintain transmission, thanks to the multiplication of the parasites in their snail host. 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 can be achieved without house connections.

There is evidence that water availability and hygiene can produce substantial reductions in trachoma (Emerson *et al*. 2000) although more recent evidence suggests that improved excreta disposal may also help (Emerson 2002). Since 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 only by water supply and not sanitation, and the simplest "improved" water supply is adequate to prevent transmission.

There is conflicting evidence as to 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% reduction in the ascariasis among children under three over a 2-year period. On the other hand, Han and Hlaing (1989) showed in Burma that an intervention to promote hand washing with soap was successful in reducing the incidence of diarrheal disease. It can be concluded that their intervention was also successful at improving hand washing practice. At the beginning of their study, they had also treated their study groups with anthelminthics, to observe their rates of reinfection with Ascaris over the study follow-up period. At the end of the study, no difference in either prevalence or intensity of infection could be found between the intervention and control groups (Han *et al* 1988).

However, as mentioned above, the potential contribution of water supply to reducing the burden of disease through its impact on these other infections is relatively minor, when compared with its impact on diarrheal disease.

EXCRETA DISPOSAL

Levels of service, technologies and their costs

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 Assessment Report (WHO/Unicef 2000), it took a major effort 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 they are not connected to a functioning wastewater treatment plant.

A wide range of technologies is used, particularly for settings where low-cost solutions are required, and this has led some to enquire 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 was one of the questions it was asked to investigate, using field studies (Feachem *et al*. 1983a) and a very thorough literature review (Feachem *et al*. 1983b). The conclusion was that all types of system <u>can</u> 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."

It was therefore judged 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 was the definition followed in the Global Assessment (see Table 10). The effect of technology type on health benefit is further discussed below.

Table 10. Definitions of "improved" and "not improved" sanitation used for Global Water Supply and Sanitation Assessment 2000 Report (WHO/Unicef 2000).

"Improved"	**"Not improved"**
Sewerage Septic tank and soakaway Pour-flush latrine Ventilated improved pit (VIP) latrine Simple pit latrine	Service or bucket latrines (where excreta are manually removed) Public latrines Latrines with an open pit

No distinction is made here between on-site sanitation systems and conventional sewerage with a household connection. The World Bank study found no evidence that flush toilets with waterborne sewerage provide greater health benefits than the low-cost on-site alternatives. The matter is further discussed under "Direct health benefits" below.

On the other hand, public latrines 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 or disabled or, if there is an entry charge, by young children. This means that some promiscuous defecation continues to be practiced, particularly by children, in communities where they are the only level of service available.

Figure 5 shows the regional median construction costs per capita of the various sanitation technologies, found by the WHO/Unicef (2000) Global Assessment. While 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 that the mean cost of conventional sewerage to be ten times that for on-site systems such as improved pit latrines and pour-flush toilets (Kalbermatten *et al*. 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 Assessment.

For the purposes of calculating cost-effectiveness, a construction cost of $60 per capita seems adequate for basic sanitation facilities (a household pit latrine, VIP latrine or a pour-flush toilet) in any region of the developing world. Taking a relatively short lifetime of 5 years for a latrine and straight line amortization gives an annual cost of $12 per capita per annum. In such a short lifetime, very little maintenance is normally required, besides 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" (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.

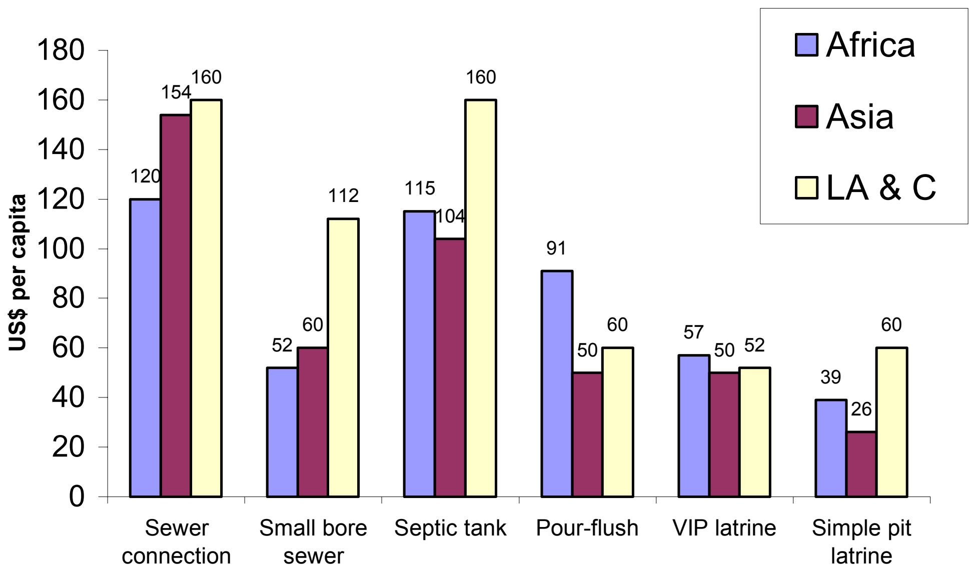

Figure 5 Median construction cost of sanitation technologies in Africa, in Asia and in Latin America and the Caribbean
Source: WHO/Unicef (2000)

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 is illustrated by the responses summarized in Table 11, when a sample of householders in rural Benin were asked to rate the importance they ascribed to the various benefits of latrines on a scale of 1 to 4. Health-related benefits (shown bold in Table 11) were rarely mentioned spontaneously, and generally rated among the less important benefits.

Table 11 Benefits of latrine ownership as perceived by 320 households in rural Benin (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/seeing feces in bush	3.78
Protect my feces from enemies	3.71
Have more privacy to defecate	3.67
Keep my house/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 due to age/sickness	2.62
Be able to increase my tenants' rent	1.17
For health (spontaneous mention)	**1.27**

Source: Jenkins MW (1999)

With sanitation as with water supply, there are strong gender differences 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, while 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, becoming effectively prisoners of daylight. Though no systematic study has been made of the health implications, these are likely to include an increased prevalence of urinary tract infections. The emancipation which a latrine bestows on such women cannot lightly be dismissed.

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. This means that the 2.6 billion people in Africa, Asia and Latin America who ***do*** have adequate sanitation, 53% 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 (Whittington *et al*. 1993, Altaf 1994, Altaf & Hughes 1994). With regard to the rural poor, the success of well-conceived sanitation promotion programs in achieving coverage close to 100%, without a substantial subsidy, in some of the poorest rural communities in the world (e.g. Kurup 1996, Allan 2003) shows that people are willing to pay for sanitation if a suitable product is offered to them on suitable terms.

Why then, one might ask, do 2.4 billion people still lack sanitation? There are several constraints to the expression of the existing demand.

The constraint most frequently mentioned by unserved householders is cost, but this 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 on offer because the 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 which 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 him to do so. This has a similar effect to the common misunderstanding whereby citizens believe, often encouraged by politicians, that the local government is responsible for sanitation and will eventually come to their aid: the outcome, though it may be obvious that the government is unequal to the task, is inaction.

Other constraints include lack of ready access to necessary techniques and skills, or to specific building materials and components, such as termite-proof wood for a latrine floor, or cheap pour-flush toilet pans. Where the skills exist locally, residents may lack confidence in the quality of work and value for money offered by the local artisans, or may not know how to contact the right ones. In many urban areas, local building regulations make low-cost sanitation technologies illegal.

None of these constraints is an insoluble problem, but they are compounded by the fragmentation of governmental responsibility for sanitation. Often it is devolved to local governments with little capacity to implement sanitation improvements, least of all those aimed at the population currently unserved, for whom a marketing effort is required. At national level one ministry may be responsible for sewerage and another for low-cost technologies; one 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 is probably more important in epidemiological terms, as discussed below. If households are not fully aware of the health benefit, or if much of it accrues to others, then there is a case for public intervention to increase coverage, since these externalities exist.

This public intervention need not necessarily 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 which are built to the size of the subsidy budget; it encourages the design and marketing of unaffordable sanitation systems; and 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 which can be used to increase sanitation coverage without significantly increasing costs or public expenditure. For example, more than 90% of households in the town of Bobo Dioulasso, Burkina Faso have their own latrine (Traoré *et al*. 1994). This is a direct result of the local administration's practice of withdrawing rights of land tenure from owners who do 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 can be done in a number of ways which the existing producers, mainly artisan builders and small component manufacturing workshops, are unable to do individually. These would aim principally at overcoming the constraints to the expression of effective demand for sanitation. They could include:

- 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, and
- provision of pit emptying and desludging services.

Promotion of improved hygiene practices, including appropriate use and maintenance of the sanitation facilities, is another avenue for possible intervention by the public sector. All of these measures will help to increase sanitation coverage and health benefit, 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 necessarily 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 (Philippines) per latrine, respectively (Cairncross 1992). Since these are largely fixed costs, 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 NGOs have documented slightly lower unit costs for promotion. For example, The Zimbabwe NGO AHEAD, 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 $13.43 per unit, equivalent to $2.24 per household member served (Waterkeyn 2003). In Bangladesh, WaterAid and its partner, a local NGO named VERC, have developed an approach which has successfully achieved 100% sanitation coverage, and the elimination of open defecation in more than 100 villages in six districts, at a cost of US$ 8 per household, or $1.50 per capita (Allan 2003). Both of these programs also promoted domestic hygiene practices in addition to the construction and use of latrines. Lower promotion costs of $3 to $6 per unit have been reported by Kurup (1996) from Kerala State, India; but in this program the effectiveness of the promotion is not fully proven as it was supported by a 75% government subsidy for each latrine. In Bangladesh all (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 programs. The promotion cost is taken as $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

Diarrheal disease

The impact of sanitation on diarrhea morbidity has already been mentioned. Table 7 showed the results of Esrey *et al*'s (1991) review, attributing a median reduction in incidence of 36% to sanitation. Although this figure is the median of the 5 "better" studies of the impact of sanitation alone, it must be interpreted with great care because almost all the known studies of the health impact of sanitation are observational studies. Most of them compare households which were found to have installed a latrine with households which had none. These studies therefore use self-selected exposure groups, and are particularly susceptible to confounding, even if multivariate analysis has been used to allow for it.

For example, it is not easy to control for confounding by socio-economic status – for one thing, socio-economic status is difficult to measure precisely – but confounding by a sense of hygiene is far harder to take into account. And yet it is likely to be a significant problem in any study of sanitation and health. From Brazil to Bangladesh, the owners of latrines have been observed to behave more hygienically than their neighbors, in practices such as handwashing which are not affected by the presence of a latrine (Hoque *et al*. 1995, see Table 12; Strina *et al*. 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.

Table 12 Factors associated with handwashing behavior by 90 women in Bangladesh

Associated factor	Handwashing behavior observed after defecation		Ratio of prevalences of good practice (95% CI)
	Good	Poor	
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 *et al*. (1995)

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

For example, Moraes *et al*. (2003), working in urban *favelas* in Northeast Brazil, found that diarrhea incidence among children in households with a toilet was half that in households which did not have one. This comparison is likely to be affected by confounding, as the households with toilets were a self-selected group. Comparison between communities is less likely to be affected by confounding, but Moraes *et al*. 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 which, for technical, administrative and technical reasons, did not have sanitary drainage.

Thus, while the quality of the studies reviewed by Esrey *et al.* was in general very poor and the range of reductions very wide, there is little doubt that excreta disposal <u>can</u> be associated with significant reductions in diarrhea morbidity. Studies showing that proximity to open or overflowing sewers (Moraes *et al*. 2003; Almeida *et al*. 2001), failure to dispose hygienically of children's stools (Mertens *et al*. 1992, Traoré *et al*. 1994) or the presence of excreta on the ground in the household compound (Clemens & Stanton 1987, Bukenya & Nwokolo 1991) are risk factors for fecal-oral infections provide supporting evidence for the likely impact of sanitation infrastructure, particularly in urban settings, on diarrheal disease transmission.

Such risk factor studies have a further implication for the health impact of sanitation hardware. Many of them have shown that household latrines, even when available, are not always used, particularly by children. Since young children suffer far more often than adults from diarrheal pathogens, their feces are more likely to be infectious. If children's feces are not disposed of hygienically, the provision of sanitation facilities is not itself likely to have an effect on health. Differing rates of usage of latrines, especially by children, in the different study environments may explain some of the heterogeneity found in Esrey *et al*'s review.

To conclude, there are some reasons, such as the likelihood of confounding, to believe that Esrey *et al*'s median reduction is an overestimate; but there are also reasons to believe that the reductions measured were not as great as they might have been if the provision of sanitation had been accompanied by hygiene promotion, to ensure that the facilities were fully and appropriately used and maintained. A systematic review of the impact of sanitation on diarrheal disease is urgently required. Meanwhile, and on balance, Esrey *et al*'s median reduction of 36% in diarrhea incidence is the most authoritative estimate available.

Interaction with water supply

The results of Esrey *et al*'s review (Table 7) suggest that the impact of water supply and sanitation combined is no greater than that of either on its own, and this was accepted in the assumptions made by Prüss *et al*. (2002). However, this is based on only two studies, and there is a wide range in the percentage reductions found in the individual studies of each type of intervention. Reflection upon how in practice each of the two interventions interrupts the transmission of fecal-oral pathogens would suggest that their effects would be largely independent; while water supply helps to prevent contamination of drinking-water, hands and food, excreta disposal helps to prevent contamination of the household yard and surroundings including children's play areas. Esrey *et al*. (1990) reported three other studies in which sanitation and water supply had a greater impact together than individually, but where reductions in diarrhea incidence 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. This has the advantage of simplicity.

Does level of service matter?

Esrey *et al.* (1991) found three studies which implied that the health benefit of sanitation depended on the level of service. Significantly, all three were studies of total child mortality, rather than diarrhea morbidity. Flush toilets were associated with less mortality than pit latrines, which in turn were associated with lower mortality when compared with no sanitation facilities. Such studies are even more likely to show confounding because there are two additional links in the causal chain between exposure (absent or inadequate sanitation) and outcome. Even if sanitation had no impact on diarrhea morbidity, it would suffice to have confounding in the relationship between morbidity and death, or between diarrhea deaths and overall mortality, to produce an apparent association of the kind found in these three studies.

Subsequently, Esrey (1996) analyzed the results of cross-sectional surveys in eight countries, and found an apparent reduction of diarrhea incidence associated with flush toilets. Here again there are strong reasons to believe that this result, which is only marginally significant statistically, is attributable to confounding (Cairncross & Kolsky 1997). In the analysis below, therefore, all sanitation technologies and levels of service are treated as equivalent from the point of view of their impact on health.

Impact on other disease categories
The first evidence for the health benefits of excreta disposal did not relate to its impact on diarrheal disease, but on intestinal helminths.

A prolonged series of in-depth studies from 1920 to 1930 by researchers of the Rockefeller Foundation (Cort *et al*. 1929, 1930, 1931) established beyond doubt that promiscuous defecation, especially in the household surroundings and particularly by children, played a major role in the transmission of ascaris, trichuris and the hookworms in a range of settings from Panama to China and the Southeastern USA. 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 *et al*. (1991), reviewing this literature, found that water supply and sanitation reduced the prevalence of ascariasis by a median of 28% (range 0-83%) and hookworm infection by 4% (0-100%). As noted above, It is likely that these reductions are due to the sanitation rather than the water supply improvements. Indeed, 3 of the 9 positive studies of ascariasis and 3 of the 5 positive studies of hookworm involved sanitation alone. It is also likely that the impact of excreta disposal on Trichuris infection is similar to that on ascariasis (Henry 1981; Moraes *et al*. 2004).

There is reason to believe that the public health impact of sanitation, where intestinal helminths are concerned, is greater than its effect on the prevalence of infection. For example, Arfaa *et al*. (1977) found that sanitation reduced the prevalence of hookworm and ascaris infection by 4% and 28% respectively, but the respective egg counts in stool by 26% and 60%. The combined effect of these two reductions is to reduce by a still greater margin the prevalence of intense infections – which cause most of the serious public health effects of intestinal worms.

Much emphasis has been placed in recent years on chemotherapy as a control intervention for intestinal helminths, particularly the chemotherapy of schoolchildren (Partnership for Child Development 1997). However this is not always a sustainable option, as the children are quickly reinfected by the eggs and larvae which remain in the environment. Sanitation, particularly school sanitation, has been adopted by the major international donor agencies as an integral component of the FRESH framework to ensure its sustainability.

A recent study in Bangladesh (Mascie-Taylor *et al*. 1999) suggested that chemotherapy was more cost-effective (though less effective) as a helminth control intervention than a health education program which 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 1600 Taka (US$ 30) per household, compared with 330 Taka (US$ 6) per annum for chemotherapy. This compares with the total cost of $8 per family for WaterAid's successful "100% sanitation" approach in rural Bangladesh, mentioned above (Allan 2003). Whereas the promotion of sanitation is a one-off 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 *et al*., sanitation promotion is more cost-effective against helminths in Bangladesh than chemotherapy. If the cost were apportioned between its effect on diarrheal disease and on helminths, it would be ***far*** more cost-effective than chemotherapy.

Other health benefits of sanitation are less well-known, such as its impact on trachoma. More than 70% 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 2002).

HYGIENE PROMOTION

The shortage of evidence

To a greater degree than with water supply and sanitation, there is lamentably little reliable evidence 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.

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:

1. A description of the intervention in sufficient detail to allow its replication.

2. An objective outcome measure, based either on health status or behavior change.

3. A control group, and a sample size greater than two clusters, or 60 individuals.

4. A description of the target population (in terms of their level of education, etc.) adequate to permit a judgment of the relevance of the study to other contexts.

Only three studies were found to me*et al*l four criteria. One of these (Stanton & Clemens 1987) dealt with environmental hygiene promotion, and some doubts arise about the reliability of its findings; 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 more recent studies (Cave & Curtis 1999) found five more studies which could be considered methodologically sound, but none showed a clear impact on behavior. Out of a further eleven studies of "reasonable" rigor, only two showed a major impact on behavior.

With regard to costs there are also major shortcomings in the data. Many costings are based on budget forecasts, and not on real expenditures. Even when actual expenditures are used, there are major difficulties in apportioning the overhead costs which 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 to agree 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 these 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 (Table 13).

Table 13 Differing unit costs of weaning education (1982 US$ per child), derived from actual expenditures on the same four programmes

Source: Country	Ashworth & Feachem (1985)	Phillips, Feachem & Mills ('87)
Morocco	4.20	1.00
Burkina Faso	2.40, 2.70	0.35
Philippines	9.60	9.44
Indonesia	2.00	5.25

An additional problem is that costs and effectiveness have so rarely been assessed reliably that they have hardly ever been so assessed for the same intervention, a requirement for an evidence-based assessment of cost-effectiveness.

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? Very little evidence is available to answer this question, but it is fundamental to the calculation of cost-effectiveness.

What we know

Sustainability

Taking the last question first, Wilson & Chandler (1993) returned after two years to a population where a four-month intervention to promote handwashing with soap had included provision of free soap. They found that 79% 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 Shordt and Cairncross (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 assessed and compared. In four of the six countries, indicators for populations where the intervention had ended relatively recently were compared with those in areas where the last intervention had ended several years previously. These 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, it was attributable to the deteriorating condition of the latrines due to wear and tear, rather than a decline in compliance.

There have even been some cases where 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. For example, Allen (2003) notes that open defecation was less common in Bangladeshi villages where the sanitation campaign had concluded several years ago, as more children had been taught to use the latrines by their parents and peers.

To conclude, 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 that calculations of cost-effectiveness should take into account not only the morbidity and mortality averted during the implementation of the intervention, but for a number of years – say five – thereafter.

Costs

As mentioned above, there are very few cases where the costs as well as the effectiveness of hygiene promotion programs have been documented objectively. In the absence of suitable data, Varley *et al*. (1998) calculated a costing for a typical program from first principles, arriving at a cost of $3 (range $2 - $3) per household per year, or $ 0.60 per head of population.

One of the few cases where data exist is a program in urban Burkina Faso, described by Borghi *et al*. (2002). Their data show that the total cost to the provider of the three-year intervention was US$ 0.65 per head of population covered or £4.54 per 7-person household, after deducting the cost of the international research component. The significant proportion represented by overheads is illustrated by the fact that 63% of this total 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 theatre presentations.

Additional costs were incurred by the 18.5% of households which complied, practicing improved hygiene as a result of the program, amounting to $8 per household per annum. More than 90% of this was the cost of soap for hand washing.

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

An example from rural Zimbabwe is provided by Waterkeyn (2003). 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% and 37% respectively, and reducing the prevalence of open defecation by 29% and 98% respectively. The marginal cost of the intervention, using existing health staff, was US$ 4.00 per club member, or an average of $0.67 per member of an affected household. Including the salaries of these staff would roughly double the figure to about $1.40 per capita.

These figures can be compared with an estimate of $5.00 per mother (in 1982 dollars) by Phillips *et al*. (1987) based on a review of several programs. Assuming that roughly one in ten members of the population are mothers of young children, this is equivalent to about $ 0.50 per capita. For cost-effectiveness analysis, a nominal cost of $1.00 per capita is therefore taken, as this is roughly the mid-point of the range of recent estimates.

Impact on diarrhea

Esrey *et al.* (1991) found only 6 studies of the effect of hygiene promotion interventions on diarrhea morbidity, with a median reduction of 33%. A subsequent review by Huttly *et al*. (1997) arrived at a similar result; a median reduction of 35%.

The interventions promoting the single hygiene practice of washing one's hands with soap tended to achieve greater reductions in disease than those which promoted several different behaviors. This 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%, and life-threatening diarrhea by 48%. Since the impact of diarrhea prevention in DALYs is mainly due to the prevention of diarrhea deaths, the higher of these two figures is more appropriate for calculating the impact of hygiene promotion on the burden of disease.

It is not surprising that interventions advocating more behavior changes should have less impact, because numerous messages dilute one another in the minds of the target audience (Curtis *et al*. 1997). Since some of the interventions in the systematic review were planned without an adequate prior program of formative research (Curtis et al. 1997), it is possible that they could have had a still greater impact if they were better-conceived.

Impact on respiratory infections

There are reasons 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 (ARI). The intervention is plausible *a priori,* given what is known about the transmission routes of ARI, and there is also epidemiological evidence, in that all six published studies of the impact of handwashing on ARI show a significant reduction (Cairncross 2003b). In Hong Kong, where handwashing was a key component of the SARS containment strategy and widespread compliance in the population continued for long after the epidemic, there was a noticeable reduction in the incidence of diarrhea, but also in respiratory infections (M. Ryan, personal communication).

However, all the published data are from industrialized countries. It is not yet clear whether handwashing is as effective among poor young children in developing countries as it is among the well-nourished citizens of rich countries. A randomized controlled trial is currently under way in Karachi, Pakistan, and preliminary results suggest a reduction of over 40%.

These two disease groups are the most important causes of child mortality worldwide, and the respiratory infections are also causes of 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 handwashing 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. Varley *et al*. (1998) developed a cost-effectiveness model based on the assumption that hygiene promotion would reduce diarrhea by 10% in the absence of water supply and sanitation hardware, but 20% where it was provided.

The former argument has only limited validity where sanitation is concerned; an important role for any hygiene promotion, when implemented in a setting without full sanitation coverage, is to promote sanitation itself. With regard to water, there is some evidence that constrained access to water limits the impact of hygiene promotion on health. Three of the 17 handwashing studies reviewed by Curtis & Cairncross (2003) were in settings where water availability was severely limited. These were:

1. Lima, Peru where vendors charge high prices for it
2. Burundi, where mean daily water usage was reportedly less than 5 liters/capita
3. a refugee camp in Malawi.

All three of these studies reported a reduction in diarrhea by less than 43%, but in only one of them was it ***significantly*** less.

It could equally be argued that water supply and sanitation bestow health benefits by making hygiene easier to practice; this would imply a smaller effect from hygiene promotion among those who already have access. However, the reductions in disease achieved by handwashing 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 impacts of water supply, sanitation and hygiene promotion on diarrhea are independent and additive to one another.

IMPACT ON BURDEN OF DISEASE

Assumptions: reductions in diarrheal disease

To summarise the discussion of health impacts 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 13 below. These reductions are considered to be independent of one another, so that the relative risks for several interventions can be multiplied together.

Table 13 Assumed reductions in diarrhea due to water supply, sanitation and hygiene promotion

Intervention	Reduction in diarrhea (%)	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

These can be compared as follows with the assumptions underlying a previous calculation of the global burden of disease from water, sanitation and hygiene (Prüss *et al*. 2002; WHO 2002). For that calculation, 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 IV and 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 the developed countries. Leaving out scenarios I and III, which apply only to a very small proportion of the population, these can be seen as broadly equivalent to the categories considered earlier in this chapter, as follows:

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

The relative risks associated with transition from scenarios Va and Vb to VI are taken by Prüss *et al*. as 1.26 and 1.60 respectively, comparable with the figures of 1.20 and 1.56 in Table 13. However, they 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% from hygiene promotion found by Huttly *et al*. (1997). Scenario III is essentially a theoretical construct, and between this and scenario II a further relative risk of 1.8 is assumed (in what Prüss *et al*. term their 'realistic' approach), based on 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 generalised and effective implementation of a well-conceived hygiene promotion intervention. Since 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 *et al*.) and 1.92 (Table 13) are of a similar order of magnitude.

The similarity of the two sets of assumptions, based on rather different premises, is illustrated in Figure 6.

To allow for the uncertainty in their assumptions, Prüss *et al*. calculated the burden of disease due to water supply, sanitation and hygiene using two approaches. The 'realistic' approach used the assumptions described above and shown in Figure 6. 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 which already benefits from high levels of water supply and sanitation provision, we consider the model on the right of Figure 6 as 'optimistic, and prefer to take for our more 'realistic' approach the less ambitious baseline of house connections and full sanitation, which approximates to the current position in most of Western Europe and North America. This responds to recent calls for "baselines and counterfactuals which should include alternative, operationalizable policy/program options (including the status quo)" (Ezzati 2003, Greenland 2002). It also has the advantage of providing an estimate of burden of disease to which the industrialized countries contribute only a negligible amount.

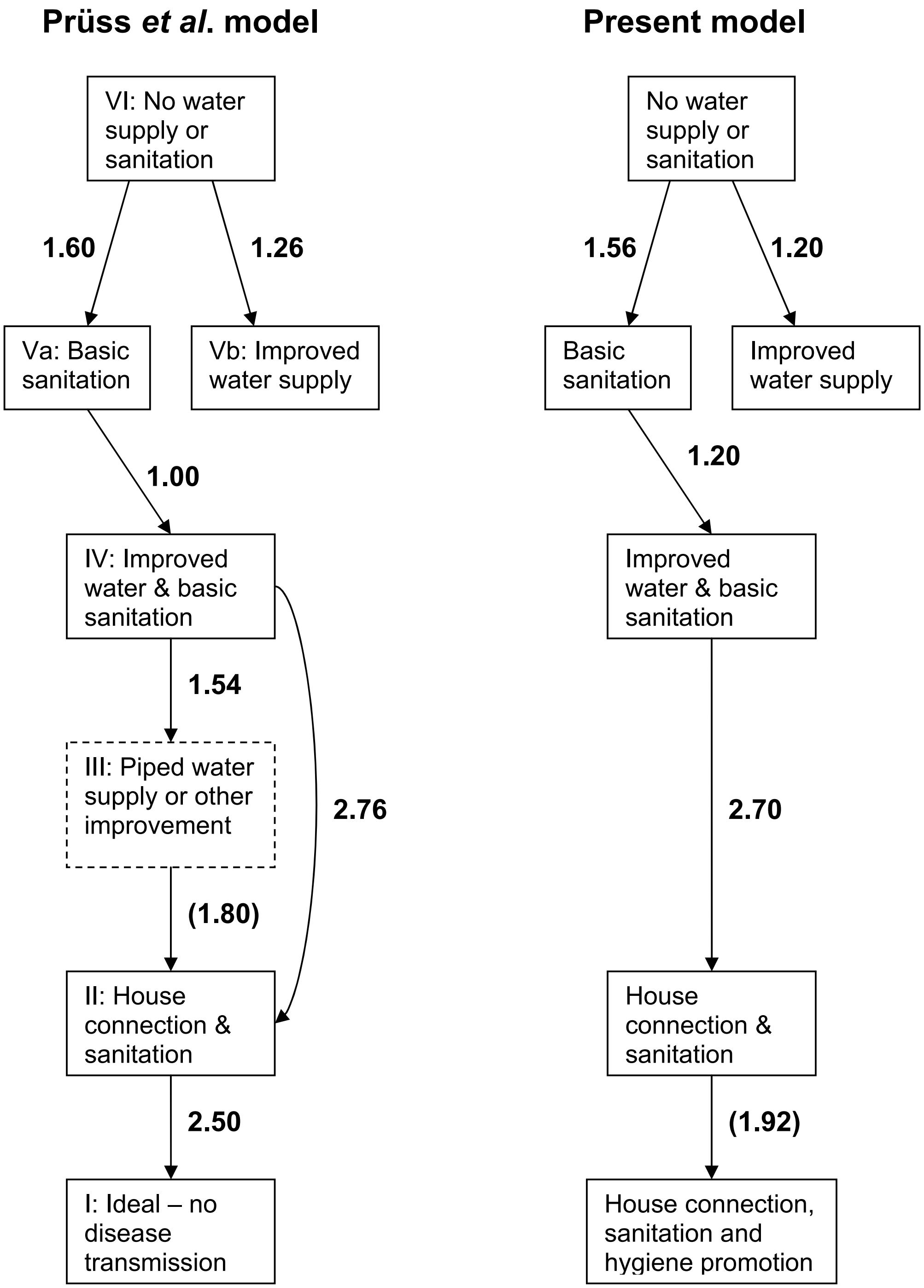

Figure 6 **Comparison of assumptions made by Prüss *et al.* (2002) and in this Chapter; the numbers show relative risk of diarrhea in higher relative to lower boxes. Relative risks in brackets are set to 1.0 for the 'minimal' version of the Prüss model, and for the 'realistic' version of the present model.**

Calculation of Burden of Disease

Prüss *et al*. (2002) worked with water and sanitation coverage data for individual countries (WHO/Unicef 2000) to derive distributions of the population in each region between five of the seven scenarios, as shown in Table 14. They then combined these with the relative risks in Figure 6 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. These are shown, for their 'realistic' and 'minimal' models, in the first two columns of Table 15. The 'realistic' estimates are those presented in the 2002 World Health Report (WHO 2002, p 225).

Table 14 .Distribution (%) of the population between scenarios of water supply and sanitation provision (from Prüss *et al*. 2002)

Region	**Scenario**				
(mortality in children and adults)	**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					
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	4

Using the same spreadsheets, but the relative risks on the right of Figure 6, we derive the results in the third and fourth columns of Table 15, 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 developed 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 developed (i.e. low mortality) countries of North America, Europe 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 does not mean that no diarrheal disease in those countries can be attributed to deficient water supply, sanitation or hygiene;

rather, that the baseline there is the status quo, because no realistic policy option is available to reduce the burden of such disease in the immediate future.

Table 16 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 Mediterranean region, reaching six to seven 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 four to five percent of the total. Globally, improvements in water supply, sanitation and hygiene could eliminate three to four percent of the global burden of disease.

Table 15 Distribution of DALYs due to diarrhea attributable to 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	6916	6198	6747	5727
Child high, adult very high	11720	10473	11402	9678
American				
Child very low, adult very low	61	61	49	1
Child low, adult low	1290	1143	1232	1009
Child high, adult high	756	673	725	613
Eastern Mediterranean				
Child low, adult low	629	548	599	482
Child high, adult high	8303	7318	7983	6653
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	1241	1096	1195	982
Child high, adult high	18487	16595	17856	15545
Western Pacific				
Child very low, adult very low	27	27	21	0
Child low, adult low	3991	3574	3619	3303
Total, developed countries	825	742	765	518
Total, developing countries	53333	47618	51358	43992
Global total	54158	48360	52123	44510

Table 16 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		
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, developed countries	0.4	0.2
Total, developing countries	4.3	3.5
Global total	3.7	3.0

Cost-effectiveness

Assumptions

The assumptions regarding impact on diarrheal disease are summarized in Table 13 above. Since the impact on diarrheal disease accounts for the vast majority of the impact, 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 17.

Table 17 Costs assumed for cost-effectiveness calculations, (US$ *per capita*)

Intervention	Construction cost	Amortization lifetime (years)	Amortized annual cost	Operation & maintenance cost
Water supply				
- house connections	150	20	7.50	10.00
- handpump or standpipe	40	20	1.00	1.00
Water regulation & advocacy	2¢ - 10¢ per head of population per annum			
Sanitation	≤ 60	5	≤ 12	-
Sanitation promotion	2.50	5	0.50	-
Hygiene promotion	1.00	5	0.20	-

The annual costs used for water supply included both the amortized construction cost and operation and maintenance costs. Bearing in mind 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 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, besides those set out above, are as described by Varley *et al*. (1998). The key parameters are as follows, with their ranges for sensitivity analysis in brackets:

Proportion of population < 5 years	17%
Diarrhea incidence	5 cases per child <5 years per year (3, 10)
Median age at onset of disease	1 year
Average duration	8 days
Case fatality rate (CFR)	0.5% (0.3%, 0.7%)
Coverage by oral rehydration (ORT)	30%
ORT reduction in CFR	50%

On this basis, the following cost-effectiveness values were arrived at, in US$/DALY:

Water supply

- handpump or standpost **$94**
- house connections **$223**

Water sector regulation & advocacy **$47**

Basic sanitation

- construction & promotion **≤ $270**
- promotion only **$11.15**

Hygiene promotion **$3.35**

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

- The impacts 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 very substantial if handwashing proves to affect acute respiratory infections;
- Impacts on diarrhea mortality, which accounts for 98% of the DALYs, are likely to be greater than the reductions in morbidity shown in Table 13;
- 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 there is a convenient aquifer or reliable rainfall;
- There are potential economies 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 handwashing, 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 $150/DALY cutoff value proposed by the World Bank (1993) as a criterion of cost-effectiveness. Allowing only for the cost component which should fall to the health sector puts them all well within this ceiling. For comparison, the cost-effectivness of promoting oral rehydration therapy, the principal other measure available to prevent diarrhea mortality, has been estimated at $23/DALY. The cost-effectiveness of promoting sanitation and hygiene as derived above ($11.15 and $3.35 respectively per DALY) compares very favorably with that figure.

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