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Economic and Health Effects of Increasing Coverage of Low Cost Water and Sanitation Interventions

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Economic and health effects of increasing coverage of low cost water and sanitation interventions

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Summary

The aim of this study is to estimate the health impacts and economic costs and benefits of improving water supply and sanitation services. Improvements were made using low cost options to achieve maximum coverage and achieve the MDG and universal coverage targets modelled in this study. Specifically, the two sets of targets modelled were (1) attaining the water and sanitation MDG targets to halve the proportion of the population without access, modelled separately and together, and (2) universal access to improved water and basic sanitation, modelled separately and together. The comparator for these targets was the predicted coverage in 2015, based on the trend line between coverage figures reported in 1990 and 2004, which predicts that at current trends the world is expected to fall short of meeting the water MDG by 354 million people and the sanitation MDG by 564 million people.

Results are presented for 6 non-OECD world regions and for 15 selected developing countries at greatest risk of not meeting the MDGs for water and sanitation. Predicted reductions in the incidence of diarrhoeal disease were calculated for each intervention based on the expected population receiving these interventions and the relative risk reductions of populations moving to different exposure scenarios. Deaths averted were estimated based on a region- and age-specific case fatality rate for diarrheal disease. The costs of the interventions included the full investment and annual running costs. The benefits of the interventions included time savings associated with better access to water and sanitation, gain in productive time due to less time spent ill, economic gains associated with saved lives, health sector and patient costs saved due to less health seeking.

The benefit-cost ratios, shown in the table, indicate that all water and sanitation improvements are cost-beneficial, and this conclusion applies to all world regions. In achieving the water and sanitation MDGs using low cost improvements, an estimated rate of return (benefit-cost ratio) of between US$ 5 and US$ 36 return on a US$ 1 investment is achieved in the six world regions, with a global average of US$ 8.1 return per US$ 1 investment for the combined water and sanitation MDGs. The benefit cost ratio of achieving the combined W&S MDG varies by world region, as shown in the table.

Cost-benefit ratio for achieving six water and sanitation coverage scenarios

World Region *	MDG			Universal		
	Water	Sanitation	W&S	Water	Sanitation	W&S
Sub-Saharan Africa	2.8	6.6	5.7	3.9	6.5	5.7
Arab States	6.1	5.3	5.4	5.9	12.7	11.3
East Asia & Pacific	6.9	12.5	10.1	6.6	13.8	12.2
South Asia	3.5	6.9	6.6	3.9	6.8	6.6
Latin America & Caribbean	8.1	37.8	35.9	17.2	39.2	36.3
Eastern Europe & CIS	8.3	27.8	18.9	8.9	29.9	27.4
Non-OECD	**4.4**	**9.1**	**8.1**	**5.8**	**11.2**	**10.3**

* Regional groupings reflect those used in the UNDP Human Development Report 2005

The results suggest that achieving the sanitation MDG is economically more favourable than the water MDG, with a global return of US$ 9.1 for sanitation compared to US$ 4.4 for water, per US$ 1 invested. This is due to the greater relative health impacts (and the related health cost savings and productivity benefits) of investing in sanitation (190 million annual diarrhea cases averted globally for the sanitation MDG versus 72 million for the water MDG) and the higher convenience time savings per person receiving the intervention (30 minutes per *person* per day for

sanitation compared with 30 minutes per *household* per day for water). However, balancing these effects is the higher cost of sanitation improvements per capita.

Economic benefits are estimated to total US$ 38 billion annually for meeting the combined water and sanitation MDGs. 92% of this value is accounted for the sanitation MDG. Sub-Saharan Africa accounts for 41% of the global economic benefit, followed by Latin America & Caribbean (22%), East Asia & Pacific (17%) and South Asia (15%). Economic benefits for achieving universal coverage are several times greater, at US$171 billion annually, a gain which is spread between East Asia & Pacific (39%), South Asia (20%), Latin America & Caribbean (17%), sub-Saharan Africa (14%), Eastern Europe & CIS (5%), and the Arab States (4%). These proportions are most heavily weighted by the results of universal coverage for sanitation. For universal coverage with water supply, the proportion is considerably higher for East Asia & Pacific (42%) and for the Arab States (11%), and lower for South Asia (5%) and Latin America & Caribbean (3%).

The contribution to economic benefits varies between water and sanitation. For the case of sub-Saharan Africa, in achieving the water MDG, 63% of the benefits are attributed to convenience time savings, 28% to productivity gains, and 9% to health care cost savings. Economic benefits of sanitation, on the other hand, are more heavily dominated by convenience time savings, at 90% of the total economic benefit, followed by 8% to productivity gains, and 2% to health care cost savings.

For the combined water and sanitation targets, considerable per capita gains are expected. For achieving the combined water and sanitation MDG target, sub-Saharan Africa benefits the most with an average of US$ 17.5 per capita per year, based on the entire population. The next region benefiting is Latin America & Caribbean, at US$ 13.5 per capita per year. Under universal coverage, all world regions benefit substantially under these improvements, with at least US$ 15 per capita per year for the entire population.

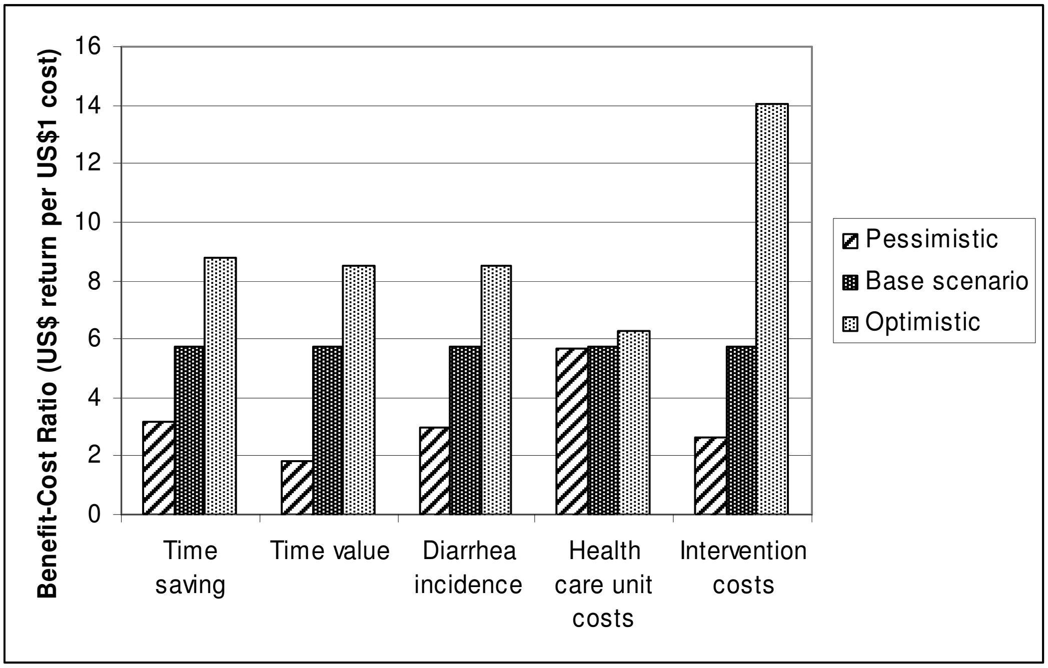
The annual cost of achieving the MDGs in non-OECD regions is US$ 858 million for water, and US$ 3.81 billion for sanitation, giving a total of US$4.67 billion for the two MDGs combined. Sub-Saharan Africa accounts for over 50% of these costs, at US$ 2,665 million, followed by South Asia (18%), and East Asia & Pacific (13%). These costs are an incremental cost over and above the current annual investments in W&S services.

These annual figures translate into an incremental cost of achieving the combined water and sanitation MDGs of US$46.7 billion, which would be spent over the period 2005 to 2015. However, this figure assumes MDG targets will be met immediately. If there is a gradual and linear scaling up of coverage, the actual cost could be as little as half this figure, at an additional US$23 billion.

In achieving universal coverage in water and sanitation, the global annual cost of US$ 16.6 billion is more equally divided between three world regions: sub-Saharan Africa (25%), East Asia & Pacific (33%), and South Asia (31.5%), with the remaining 11.5% going to the other three non-OECD regions. Achieving universal sanitation coverage account for 87.5% of the combined water and sanitation universal coverage.

An important caveat of a global study such as the one conducted here is the uncertainty in the results. One important element of uncertainty is the generalization of epidemiological, cost and economic benefit data from one region to another. Alternative upper and lower values for these data inputs were tested in a one-way sensitivity analysis. The figure below shows a summary of the findings for sub-Saharan Africa for five areas of uncertainty. Large ranges on the resulting benefit-cost ratios for four out of the five variables tested suggests that the cost-benefit results need to be interpreted with caution, especially in specific country contexts.

Range on the base case scenario benefit-cost ratio from using pessimistic and optimistic values for selected uncertain variables.



Hence, the findings of the sensitivity analysis indicate that the results presented for specific countries in section 4 are only indicative, and this present study needs to be followed up with more scientific and comprehensive studies at country level.

A second element of uncertainty is the model uncertainty, concerning the choices over diseases, costs and benefits that are taken into account in the cost-benefit model. In order to create a model of global relevance and not overly data demanding, some benefits were left out. The implication is that the benefit-cost ratios are likely to be underestimated, given that diarrhea was the only water and sanitation-related disease included, and the broader range of setting-specific benefits of water resources that would need to be included in future cost-benefit studies.

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Abbreviations

CBA	Cost-Benefit Analysis
CBR	Cost-Benefit Ratio
CER	Cost-Effectiveness Ratio
DALY	Disability-Adjusted Life-Year
GNP	Gross National Product
MDG	Millennium Development Goal
OECD	Organisation for Economic Cooperation and Development
UNDP	United Nation's Development Fund
UNICEF	United Nation's Children's Fund
US$	United States Dollar
VIP	Ventilated Improved Pit latrine
W&S	Water and sanitation
WHO	World Health Organization

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1. Introduction

Especially in the developing world, diseases associated with poor water and sanitation have considerable public health significance. In 2003, it was estimated that 4% (60.7 million DALYs) of the global burden of disease and 1.6 million deaths per year were attributable to unsafe water supply and sanitation, including lack of hygiene [1]. During the 1980s and 1990s there was considerable investment in the provision of water supply and sanitation in developing countries. By 2000, however, still a significant proportion of the world's population remained without access to improved water and sanitation (see Table 1). In Africa in the year 2000, roughly 40% of the population did not have access to improved water supply and sanitation, and in Asia 19% were without access to an improved water supply and 52% were without access to an improved sanitation [2]. Other regions of the world have higher rates of access, but even in Latin America and the Caribbean many millions remain without.

Table 1: Water and sanitation coverage by region

Region	Coverage (%)	
	Water supply	Sanitation
Africa	62	60
Asia	81	48
LA&C	85	78
Oceania	88	93
Europe	96	92
N America	100	100

Source: WHO/UNICEF/WSSCC 2000 [*2*]

In order to increase the rate at which access to improved water and sanitation is extended, further advocacy is needed at international and national levels to increase resource allocations to this process and to increase programme efficiency in achieving overall goals including poverty reduction and health improvement. In the current climate where poverty reduction strategies dominate the development agenda, the potential productivity and income effects of improved access is a significant argument to support further resource allocations to water and sanitation. Cost-effectiveness analysis is proving an increasingly important tool in the allocation of funds within the health sector, although cost-benefit analysis remains the form of economic evaluation most useful for cross-sectoral resource allocation to different government-financed activities. While there are many criteria for allocating resources to different ministries and government programmes, the relative economic costs and effects of different programmes and interventions remain critically important. These were among the reasons why WHO, in 2002, commissioned a cost-benefit analysis for selected water and sanitation interventions, which fed into the 2002 World Health Report, and was later published as a WHO document [3].

The issue of perspective continues to be a challenge for those working in the field of economic evaluation of development projects. This was recognised in the case of environmental health interventions by a WHO discussion document [4], and later for the case of water supply [5]. Presentation from a certain perspective is important not only from the point of view of financing, but knowing who benefits also helps in advocating interventions that target certain groups or entities, such as the poor, disadvantaged populations and populations likely to benefit disproportionately. In the case of improving access to water and sanitation, there are several considerations if the analysis is undertaken from the societal perspective:

- In terms of financing interventions, it is important to make a clear distinction between the public and private sectors or spheres. Should water and sanitation be provided at zero or subsidised cost by the government, or should the beneficiary pay the full cost? Are there other agencies that are able to bear some of the cost, such as non-governmental organisations or the private sector?

- In terms of who receives the benefit, a similar public-private distinction should be made with a further disaggregation by the sector or government ministry benefiting (health, agriculture, trade, infrastructure, finance, etc.) and other beneficiaries (industry, agriculture, households).

Therefore, economic evaluation including cost-benefit analysis should not only aim to provide information on economic efficiency, but also provide other policy-relevant information on who benefits and, therefore, who may be willing to contribute to the financing of interventions.

2. Methods

The present study methods and model are based on those used in the previous report on the global cost-benefit of improvements in water and sanitation interventions [3], with some key differences, however. In summary, the main differences are the following (described in more detail later in this section):

- The year and coverage levels which are used to compare the target coverage levels of the interventions, and for calculating the cost-benefit ratios, are the predictions for the year 2015.
- Some data inputs (diarrheal disease incidence rates) are updated from the year 2000 to the most recent year for which data are available. Health service unit cost data are sourced from a paper prepared for the Disease Control Priorities Project [6].
- The scenarios, or targets, under which the results are presented are different, to reflect water and sanitation targets separately, as well as together.

2.1 Interventions

The range of options available for improving access to water and sanitation is wide, especially in low-income settings where large proportions of the population have access to only the most basic facilities. For developing countries, WHO favours intervention options that are effective (in terms of healthy and social benefits), low cost, technically feasible, and those for which there is evidence for sustainability (which will in turn contribute to low annualized lifetime costs and high lifetime health benefits)

The analysis presented in this paper is based on changes in water and sanitation service levels. Table 2 categorises which types of service are ‘improved’ and which are considered to be ‘unimproved’. Note that services can be defined as unimproved not only if they are unsafe, but also if they are unnecessarily costly, such as bottled water or water provided by tanker truck. Whilst these generalisations are reasonable at global level, they should be verified and corrected as necessary in any country or local level application.

This study models the costs and benefits of basic and simply applied improvements to water and sanitation services:

- 'Improved' water supply, generally involving better access and protected water sources (e.g., stand post, borehole, protected spring or well, or collected rain water). Improvement does not necessarily mean that the water is safe, but that it is more accessible and some measures are taken to protect the water source from contamination. Whilst 'improved' water would normally include water piped into the living area of a household (plot, courtyard or house), in terms of projecting the costs and benefits in this study, we have assumed that all increments are through access to standpost/pipe, borehole, protected spring or well, or collected rain water
- 'Improved' sanitation involves better access and safer disposal of excreta (septic tank, pour-flush, simple pit latrine, small bore sewer, or ventilated improved pit-latrine). However, sewer connection is not modelled in this present study.

Table 2: Categories of 'improved' water supply and sanitation

Intervention	Improved	Unimproved *
Water supply	• House connection • Standpost/pipe • Borehole • Protected spring or well • Collected rain water • Water disinfected at the point-of-use	• Unprotected well • Unprotected spring • Vendor-provided water • Bottled water • Water provided by tanker truck
Sanitation	• Sewer connection • Septic tank • Pour-flush • Simple pit latrine • Ventilated Improved Pit-latrine	• Service or bucket latrines • Public latrines • Latrines with an open pit

* Due to being either unsafe, inconvenient, or costly Source: WHO/UNICEF/WSSCC [2]

The study models the achievement of the millennium targets for water and sanitation separately (halving the proportion of people who do not have access to improved water or basic sanitation by 2015), as well as the water and sanitation targets together. The study also presents results for the achievement of universal access to basic services, as a hypothetical policy goal. Therefore, six sets of results are presented for the costs and benefits of achieving:

I. Water MDG target alone.
II. Sanitation MDG target alone.
III. Water and sanitation MDG targets together.
IV. Universal access to improved water sources alone.
V. Universal access to basic sanitation alone.
VI. Universal access to improved water and basic sanitation together.

Table 3. Scenarios presented in this report

Coverage	Water alone	Sanitation alone	W&S together
MDG target	I	II	III
Universal access	IV	V	VI

The baseline, which provides the comparison for these interventions, is not the population coverage in 2000, as in the WHO study of 2004 [3]. Instead, the comparison group is the predicted population coverage in 2015, based on an assumption of a continuation of the average linear increase in coverage from 1990 through 2002 to 2015. Therefore, if a country is on course to meet the MDG targets for water, then the costs and benefits in scenario 1 would be zero. Annex 2 presents coverage gaps for countries predicted to miss the water and sanitation MDGs, using projected coverage in 2015[4]. By choosing the projected 2015 coverage levels as the baseline of the study gives greater emphasis to those countries that are at risk of not meeting the MDG targets. On the other hand, for the universal access interventions (IV to VI), most developing countries are included in this analysis, given that very few are predicted to attain universal access by the year 2015.

Populations are classified according to whether they have no improved access to either water supply or sanitation services (Level VI in Table 4), access to only improved water supply (Level Vb), access to only improved sanitation (Level Va), or already with improved access to both water supply and sanitation services (Level IV). The present study, unlike the WHO study from 2004, does not consider further improvements that make the water or sanitation services safer, or more convenient (e.g. water disinfection at the point of use) or high technology improvements such as regulated water supply through a household connection or household connection to the sewerage system. Therefore, Levels III, II, and I in Table 4 are not relevant for the present study. Hence, the cost estimations made in this present study will be an underestimation of the actual investments undertaken and recurrent costs incurred, given that piped water supply and sewer connection are not considered here.

Table 4: Selected exposure scenarios

Level	Description	Environmental faecal-oral pathogen load
VI	No improved water supply and no basic sanitation in a country which is not extensively covered by those services, and where water supply is not routinely controlled	Very high
Vb	Improved water supply and no basic sanitation in a country which is not extensively covered by those services, and where water supply is not routinely controlled	Very high
Va	Improved sanitation but no improved water supply in a country which is not extensively covered by those services, and where water supply is not routinely controlled	High
IV	Improved water supply and improved sanitation in a country which is not extensively covered by those services, and where water supply is not routinely controlled	High
III	Improved water supply and improved sanitation in a country which is not extensively covered by those services, and where water supply is not routinely controlled, plus household water treatment	High
II	Regulated water supply and full sanitation coverage, with partial treatment for sewage, corresponding to a situation typically occurring in developed countries	Medium to low
I	Ideal situation, corresponding to the absence of transmission of diarrhoeal disease through water, sanitation and hygiene	Low

Based on Prüss *et al.* 2002 [7]

[4] Countries not included in the Annex 2 are excluded from the MDG analysis. For some countries, this is because the MDG target is predicted to be met at current projections. For other countries, this is due to missing data to make a projection (either no base year, or no mid-point year such as 2002 or 2004).

2.2 Geographical focus

The analysis was conducted for each non-OECD country and the results aggregated (weighted by country population size) to give the regional averages (14 WHO sub-regions categorised according to epidemiological indicators) (see Annex Table A 1.1). For presentation of results in this present study, countries were reclassified according to the seven regions being used by UNDP for the Human Development Report. The OECD region was excluded from presentation, giving 6 regions presented in this report. Nevertheless, results from 15 selected countries are presented to illustrate variation existing at the country level. Countries are selected that are furthest from meeting the water and/or sanitation MDGs. However, the results presented from individual countries in isolation need to be interpreted with caution, and further adaptation of the methodology and use of country level data would improve accuracy. For this purpose, a guide developed by the World Health Organization on country-level application of cost-benefit and cost-effectiveness analysis is in the closing stages of preparation.

2.3 Cost measurement

An incremental cost analysis was carried out, with an estimate of the costs of extending access to water supply and sanitation services for those currently not having access. Incremental costs consist of all resources required to put in place and maintain the interventions, as well as other costs that result from an intervention. These are separated by investment and recurrent costs. Investment costs include: planning and supervision, hardware, construction, protection of water sources and education that accompanies an investment in hardware. Recurrent costs include operating materials to provide a service, maintenance of hardware and replacement of parts, emptying of septic tanks and latrines, ongoing protection and monitoring of water sources, and continuous education activities.

The main source of data inputs into the estimate of the initial investment costs of water and sanitation interventions was the Global Water Supply and Sanitation Assessment 2000 Report [2], which gave the investment cost per person covered in three major world regions (Africa, Latin America and the Caribbean, and Asia/Oceania), presented in Table 5. More recent cost estimates could not be used for this present study, as no further multi-country data have been produced in the intervening period that would give more reliable cost estimates for a global study.

Table 5: Initial investment cost per capita (US$)

Improvement	Initial investment cost per capita (US$ year 2000)		
	Africa	Asia	Latin America & Caribbean
Water improvement			
Standpost	31	64	41
Borehole	23	17	55
Dug well	21	22	48
Rainwater	49	34	36
Sanitation improvement			
Small bore sewer	52	60	112
Septic tank	115	104	160
Pour-flush	91	50	60
VIP	57	50	52
Simple pit latrine	39	26	60

Source: WHO/UNICEF/WSSCC [2]

Annualised costs of the investment costs were calculated based on an annuitization formula [8]:

$$E = \frac{K - (S/(1+r)n}{A\ (n,r)} \qquad (1)$$

Where E is the equivalent annual investment cost
K is the purchase price
S is the resale price (assumed to be 0)
n is the useful life of the equipment (see Table 6)
r is the discount rate (3%)
A (n,r) is the annuity factor (n years at r discount rate)

The estimation of recurrent costs was more problematic due to the lack of easily available data sources. Values from the literature were combined with assumptions for the various components of recurrent costs which are presented in Table 6. Cost assumptions were based on the likely recurrent cost as a percentage to the annual investment cost, using values from the literature (World Bank and other international projects). Data sources and explanations for selected values are provided in the original report [3].

Table 6. Assumptions used in estimating annualized and recurrent costs

Improvement	Length of life In years (+ range)	Operation, Maintenance, Surveillance as % annual cost (+ range)	Education as % annual cost (+ range)	Water source protection as % annual cost (+ range)
Water improvement				
Stand post	20 (10-30)	5 (0-10)	-	10 (5-15)
Borehole	20 (10-30)	5 (0-10)	-	5 (0-10)
Dug well	20 (10-30)	5 (0-10)	-	5 (0-10)
Rainwater	20 (10-30)	10 (5-15)	-	0
Sanitation improvement *				
Septic tank	30 (20-40)	10 (0-10)	5 (0-10)	-
VIP	20 (10-30)	5 (0-10)	5 (0-10)	-
Simple pit latrine	20 (10-30)	5 (0-10)	5 (0-10)	-

* To calculate sewerage costs, sewage disposal is assumed to cost US$2/person/year for VIP and simple pit latrine and US$3/person/year for septic tanks.

Total annual costs were then calculated by multiplying the equivalent annual investment cost (E in formula (1) above) by the various recurrent cost factors, as appropriate (see Table 6). Table 7 presents the annual costs of each improvement per person reached, based on the intervention costs and assumptions in Tables 5 and 6. It can be seen that the costs vary considerably between different types of improvement. For example, water improvement varies from US$1.55 per person per year in Africa for dug well, to US$3.62 for rain water collection, including both hardware and software components. For sanitation, costs vary in Africa from small pit latrine at US$4.88 to septic tank at US$9.75.

Table 7. Annual costs for improvements on a per-person-reached basis

INTERVENTION	Annual cost per person reached (US$ year 2000)		
	Africa	Asia	LA&C
Improved water supply			
Standpost	2.40	4.95	3.17
Borehole	1.70	1.26	4.07
Dug well	1.55	1.63	3.55
Rain water	3.62	2.51	2.66
Improved sanitation			
Septic tank	9.75	9.10	12.39
VIP	6.21	5.70	5.84
Small pit latrine	4.88	3.92	6.44

Data based on annual investment costs (Table 4) and recurrent cost assumptions (Tables 5 & 6)

2.4 Health benefits

Knowledge of the health benefits of W&S improvements is important not only for a cost-effectiveness analysis, but also for a cost-benefit analysis as some important economic benefits depend on estimates of health effects. Over recent decades, compelling evidence has been gathered that significant and beneficial health impacts are associated with improving population access to and use of water and sanitation facilities. The routes by which pathogens infect individuals and affect population health via water, sanitation and hygiene are many and diverse. They include:

- water-borne diseases (e.g. cholera, typhoid),
- water-washed diseases (e.g. trachoma),
- water-based diseases (e.g. schistosomiasis),
- water-related vector-borne diseases (e.g. malaria, filariasis and dengue), and
- water-dispersed infections (e.g. legionellosis).

While a full analysis of improved water and sanitation services would consider pathogens passed via all these routes, the present study focuses on faecal-oral disease transmission which dominates the burden of disease associated with the water borne and water washed routes. This is partly because, at the household level, it is the transmission of these diseases that is most closely associated with poor water supply, poor sanitation and poor hygiene. Moreover, water-borne and water-washed diseases are responsible for the greatest proportion of the direct-effect water and sanitation-related disease burden.

In terms of burden of disease, water-borne and water-washed diseases comprise mainly infectious diarrhoea. Infectious diarrhoea includes cholera, salmonellosis, shigellosis, amoebiasis, and other protozoal and viral intestinal infections. These are transmitted by water, person-to-person contact, animal-to-human contact, and food-borne, droplet and aerosol routes. As infectious diarrhoea causes the main burden resulting from poor access to water and sanitation, and as there are data for all regions on its incidence rates and deaths, in this analysis the impact of interventions is exclusively measured by the following two indicators:

- Reduction in incidence rates (number of cases reduced per year).
- Reduction in mortality rates (number of deaths avoided per year)

These were calculated by applying relative risks taken from a literature review [7] which were converted to risk reduction when moving between different exposure scenarios (based on the current water and sanitation situation). Relative risks are presented in Table 8 below. Diarrhoeal disease risk reductions are therefore in the order of 21% for moving from VI to Vb (improved water), 38% for moving from VI to Va (improved sanitation) or from VI to IV, and 21% for moving from Vb to IV.

Table 8: Relative risks with lower/upper uncertainty estimates for different scenarios (see Table 4)

Scenario	I	II	III	IV	Va	Vb	VI
Lower estimate	1	2.5	4.5	3.8	3.8	4.9	6.1
Best estimate	1	2.5	4.5	6.9	6.9	8.7	11.0
Upper estimate	1	2.5	4.5	10.0	10.0	12.6	16.0

Based on Prüss-Üstün *et al.* 2004 [9]

2.5 Economic benefits

There are many and diverse potential benefits associated with improved water and sanitation, ranging from the easily identifiable and quantifiable to the intangible and difficult to measure [5]. Benefits include both (a) reductions in costs and (b) additional benefits resulting from the interventions, over and above those that occur under current conditions [8]. Some of these benefits – the direct benefits related to the health intervention – are used for calculating the cost-effectiveness ratio (CER) in terms of cost per DALY avoided [10]. All these benefits, on the other hand, can be used in calculating the cost-benefit ratio (CBR), which is a broader measure of economic efficiency [11, 12].

The aim of this analysis is not to include all the benefits, but to capture the most tangible and measurable ones, and identify who the beneficiary groups are. This approach was adopted not only because of the difficulties of estimating some types of economic benefit due to environmental changes [13-15], but also because the selected benefits were those most likely to occur in all settings. This exclusion of context-specific economic impacts will therefore likely lead to an under-estimation of not only the economic benefits, but also perhaps negative consequences of the improvements modelled.

For ease of comprehension and interpretation of findings, the benefits of the water and sanitation improvements not captured in the DALY estimates were classified into three main types: (1) direct economic benefits of avoiding diarrhoeal disease; (2) indirect economic benefits related to health improvements; and (3) non-health benefits related to water and sanitation improvements. These benefits are described in Table 9, grouped by main beneficiary. As a general rule, these benefits were valued in monetary terms using conventional economic methods for valuation [14-16]. Details concerning the specific valuation approaches are described for each benefit below.

Table 9: Economic benefits arising from water and sanitation improvements *

BENEFICIARY	Direct economic benefits of avoiding diarrhoeal disease	Indirect economic benefits related to health improvement	Non-health benefits related to water and sanitation improvement
Health sector	▪ Less expenditure on treatment of diarrhoeal disease	▪ Value of less health workers falling sick with diarrhoea	▪ Convenience of water and sanitary facility availability
Person with avoided disease	▪ Less expenditure on treatment of diarrhoeal disease and less related costs ▪ Less expenditure on transport in seeking treatment ▪ Less time lost due to treatment seeking	▪ Value of avoided days lost at work or at school ▪ Value of avoided time lost of parent/ caretaker of sick children ▪ Value of economic contribution of a saved life	
Consumers affected by the non-health benefits of the interventions			▪ Time savings related to water collection or accessing sanitary facilities ▪ Labour-saving devices in household ▪ Switch away from more expensive water sources ▪ Property value rise ▪ Leisure activities and non-use value
Agricultural and industrial sectors	▪ Less expenditure on treatment of employees with diarrhoeal disease	▪ Less impact on productivity of ill-health of workers	▪ Benefits to agriculture and industry of improved water supply, more efficient management of water resources.

* Health benefits are only partially captured in the health care expenditure and value of work loss days avoided.

2.5.1 Health-seeking costs averted

'Direct' in the definition of Gold *et al*. includes "the value of all goods, services and other resources that are consumed in the provision of an intervention or in dealing with the side effects or other current and future consequences linked to it" [10]. In the case of preventive activities – including improvement of water and sanitation facilities – the main benefits (or costs avoided) relate to the health care and non-health care costs avoided due to fewer cases of diarrhoea and other water-associated diseases.

Cost savings in health care relate mainly to the reduced number of treatments of diarrhoeal cases [7, 17]. As shown in Table 9, costs saved may accrue to the health service (if there is no cost recovery), the patient (if there is cost recovery) and/or the employer of the patient (if the employee covers costs related to sickness). To whom the costs are incurred will depend on the status of the patient as well as on the nature of the payment mechanism in the country where the patient is seeking care. These mechanisms vary from one country to the other. In economic evaluation, what is most important is not who pays, but the overall use of resources, and their value. In the current analysis, therefore, the direct costs of outpatient visits and inpatient days incurred to the health services are assumed to equal the economic value of these services. Informal payments made by the patient to the health provider are excluded, as this is a transfer payment and not strictly a use of resources.

The source of health service unit cost data is the Disease Control Priorities Project working paper 'Unit costs of health care inputs in low and middle income countries' [6]. For outpatient care unit costs, figures were used which reflect health centres at 90% population coverage. For inpatient care unit costs, figures were used which reflect primary level inpatient facilities. The data are presented for the year 2001, which are deflated to the year 2000 prices for consistency purposes.

As shown in Table 10, the total cost avoided is calculated by multiplying the health service unit cost by the number of cases avoided, using assumptions about health service use per case. Due to a lack of studies presenting data on the number of outpatient visits per case, it was assumed that 30% of cases (range 0.2 – 1.0) would visit a health facility one time each (range 0.5 - 1.5 visits). If hospitalised, the average length of stay was assumed to equal 5 days (range 3 – 7 days). In the base case 8.2% of total cases were assumed to be hospitalised, based on data collected by WHO (range 5% - 10%). The unit costs included the full health care cost (consultation, medication, overheads, etc.).

Direct costs of a non-health care nature are mainly those incurred to the patient, and are usually related to treatment seeking, such as transport costs, other expenses associated with visiting a health facility (e.g. food and drinks) and opportunity costs (e.g. time that could have been spent more productively). The most tangible patient cost included in the analysis refers to transport, although there is a lack of data on average transport costs. In the base case it was assumed that 50% (range 0%-100%) of patients use some form of transport at US$0.50 per return journey, excluding other direct costs associated with the journey. This gives an average of US$0.25 (range US$0 to US$0.50) per patient visit. Other costs associated with a visit to the health facility were also assumed, such as the costs of food and drinks, and added to transport costs, giving US$0.50 per outpatient visit and US$2 per inpatient admission (range US$1-US$3). Time costs avoided as a result of treatment seeking are assumed to be included in the benefits related to health improvement, and are therefore not included here.

Table 10: Data sources and values for economic benefits

Benefit by sector	Variable	Data source	Data values (+ range)
1. Health sector			
Direct expenditures avoided, due to less illness from diarrhoeal disease	Unit cost per treatment	WHO regional unit cost data	US$4.46-US$21.92 (cost per visit) US$18.3-US$86.6 (cost per day) *Varying by WHO region*
	Number of cases	WHO burden of disease data	Variable by region
	Visits or days per case	Assumptions	0.3 outpatient visit per case (0.5-1.5) 5 days for hospitalised cases (3-7)
	Hospitalisation rate	WHO data	91.8% of cases ambulatory 8.2% of cases hospitalised
2. Patients			
Direct expenditures avoided, due to less illness from diarrhoeal disease	Transport cost/ visit	Assumptions	US$0.50 per visit
	% of patients who use transport	Assumptions	50% of patients use transport (0-100%)
	Non-health care patient costs	Assumptions	US$0.50 ambulatory (US$0.25-1.0) US$2.00 hospitalisation (US$1.0-3.0)
	Number of cases	WHO data	Variable by region
	Visits or days per case	Assumptions	0.3 outpatient visit per case (0.5-1.5) 5 days for hospitalised cases (3-7)
	Hospitalisation rate	WHO data	91.8% of cases ambulatory 8.2% of cases hospitalised
Income gained, due to days lost from work avoided	Days work loss/case	Assumptions	2 days (1-4)
	Number of people of working age	WHO 2002 population data	Variable by region
	Time cost	World Bank	GNP per capita, year 2000
Days of school absenteeism avoided	Absent days / case	Assumptions	3 (1-5)
	Number of school age children (5-14)	WHO 2002 population data	Variable by region
	Time cost	World Bank	GNP per capita, year 2000
Productive parent days lost avoided, due to less child illness	Days sick	Assumptions	5 (3-7)
	Number of babies (0-4)	WHO 2002 population data	Variable by region
	Opportunity cost of time	World Bank data	50% GNP per capita, year 2000
Loss-of-life avoided (life expectancy, discounting future years at 3%)	Discounted productive years lost: 0 – 4 years	Suarez & Bradford [18]	16.2 years (9.5 – 29.1)
	5 – 14 years	Suarez & Bradford [18]	21.9 years (15.2 – 33.8)
	15+ years	Suarez & Bradford [18]	19.0 years (16.3 – 22.7)
	Opportunity cost per year of life lost	World Bank data	GNP per capita, year 2000
3. Consumers			
'Convenience' – time savings	Water collection time saved per household per day (external access)	Reviews: Cairncross and Valdmanis [19], Dutta [20]	0.5 hours (0.25-1.0)
	Sanitation access time saved / person	Assumptions	0.5 hours (0.25-0.75)
	Average household size	WHO 2002 population data	6 people (4-8)
	Time cost	World Bank data	GNP per capita, year 2000

2.5.2 Productivity gains related to health improvement

A second type of benefit stated by Gold *et al*. is the productivity effect of improving health [10]. These are traditionally split into two main types: gains related to lower morbidity and benefits related to fewer deaths. In terms of the valuation of changes in time use for cost-benefit analysis, the convention is to value the time that would be spent ill at some rate that reflects its opportunity cost. It is argued that whatever is actually done with the time, whether spent in leisure, household production, or income-earning activities, the true opportunity cost is the amount in monetary units that the person would earn over the same period of time if he/she were working [16]. This is a relatively easy estimate to make for those of working age, where the GNP per capita can be taken as a minimum value for what their time is worth. Work days gained are valued using the assumed days off work per episode, and multiplying by the number of people of working age and the GNP per capita. Note, however, that this may overvalue the time gains in countries where a significant proportion of the population works in subsistence agriculture. Sensitivity analysis is used to explore the impact of alternative time values on the overall results.

Such a convention is, however, not acceptable for those not of working age, mainly children, or those unable to work. Assuming that children of school age should be at school, then the impact of illness is school absenteeism, which has an impact on their education. For this reason, time not spent at school by children of school age is also valued on the basis of the GNP per capita. For the youngest age category, children under five, the assumption is made that a parent or caretaker has to spend more time with sick child than a healthy one, or alternative child care arrangements are needed that impose a cost. Therefore, healthy infant days and healthy child days gained as a result of less diarrhoeal illness are valued at 50% of the GNP per capita rate, reflecting the opportunity cost of caring for a sick baby or infant, and the opportunity loost of spending a day in school of children 5 and above. These assumptions reflect those used in WHO's previous global study on water and sanitation interventions [3].

A literature search revealed very few studies providing data for the number of days of ill-health attributable to infectious diarrhoea - some studies reported illness rates and changes in illness rates due to changes in risk behaviour, but the actual length of illness is rarely reported. One study in Mexico reported that the average episode for breast-fed infants lasted 3.8 days (standard deviation 2.2) and for formula-fed infants 6.2 days (standard deviation 4.4) [21]. For the present analysis, an average of two working days lost were assumed per case (range: one to four days) for those of working age, while for those of school age three days of school attendance lost were assumed (range: one to five days). The duration of illness for babies and infants was assumed to be five days (range: three to seven days). While it is clear that the impact of a case of diarrhoea will vary from one individual to another (depending on the severity of infection, resistance of the individual and other determinants), in the absence of adequate data a sub-group analysis is not feasible. Therefore, all cases are valued according to a global average cost.

Table 9 also shows other possible economic benefits related to health improvement. An implication for the health system is that there will be less health workers ill from diarrhoea, thus reducing disruption of the health service caused by staff absence. Similarly, the reduction of productive days lost due to less ill-health in the workforce will be an important benefit to agriculture and companies/industry. However, in order to avoid double counting of these benefits (patient benefits of working days lost avoided and companies' benefits of productivity lost avoided) they are excluded from this part of the analysis.

In terms of diarrhoea associated deaths avoided following the introduction of improved water and sanitation, the expected number is predicted from the health impact model (number of cases avoided times case fatality rate, both of which vary by world region). An important question relates to the decision on determining the economic value associated with a saved life: should one attempt to value life or death itself as is often done in economic studies, or should one more simply attempt to value the economic consequences of the loss of life. A convention often used in traditional cost-benefit analysis is to value saved lives at the discounted income stream of the individual whose death is avoided, thus representing the net present value of their economic contribution to society. For saved lives of children, the discounted income stream is calculated from the age at which the person becomes productive.

Therefore, to estimate the economic contribution of saved lives, the number of productive years ahead of the individual who would have died needs to be estimated (depending on the age of the person whose life is saved) and the economic value per year of healthy life saved. Using assumptions from a previous cost-of-illness study, assumptions about length of productive life were: 40 years for the age group 0-4; 43 years for the age group 5-14; 25 years for the age group 15-59; and no years for the age group over 60 years [18]. Future benefits were discounted at 3% per year (range: 1% - 5%). The GNP per capita was used to reflect the annual opportunity cost of a productive member of society, with a lower value of 30% of GNP and an upper value of the minimum wage . For those not yet in the workforce (those in the 0-4 and 5-15 age brackets) the current value for the future income stream was further discounted to take account of the time period before they become income earners.

2.5.3 Non-health benefits related to water and sanitation improvement

Due to problems in measurement and quantification/valuation, and also because of substantial variability between settings, many non-health benefits of the interventions were not included in the present analysis [10]. For completeness sake, however, a brief overview of their nature is presented below.

Beyond any argument, one of the major benefits of water and sanitation improvements is the time saving associated with better access. Time savings occur due to, for example, the relocation of a well or borehole to a site closer to user communities, the installation of piped water supply to households, closer access to latrines and shorter waiting times at public latrines. These time savings translate into either increased production, improved education levels or more leisure time. The value of convenience time savings is estimated by assuming a daily time saving per individual for water and sanitation facilities separately, and multiplying these by the GNP per capita daily rate for each sub-region. Different time saving assumptions are made based on whether the source is in the house (household connection) or in the community. In this global analysis estimates of time savings per household could not take into account the different methods of delivery of interventions and the mix of rural/urban locations in different countries and regions, due to the dearth of data on time uses in the literature. Even within single settings, considerable variations in access have been found. The studies reported in two separate reviews are presented below [19, 20]:

- Barnes (2003) reports that in India the average time spent per household on water collection is 0.93 hours [22]. A separate study based on a national survey in India undertaken for UNICEF, found that women spend an average 2.2 hours per day collecting water from rural wells [23]. Saksena et al (1995) report average water collection times in a Himalayan region of Northern India, at 30 minutes for both men and women [24].

- Kumar and Hotchkiss (1988) report from Nepal daily water collection times for men (0.1 hour), women (1.15 hours) and children (0.23 hours).
- Mertens et al (1990) report that in Sri Lanka more than 10% of women had to travel more than 1 kilometre to their nearest water source [25].
- The World Bank (2001) reported that in Vietnam the average daily household water collection time to be 36 minutes [26].
- In a 3 country study, Nathan (1997) provides a breakdown for men and women separately for water haulage (hours per day), with the major burden falling on women (figures quoted for women only): Burkina Faso 0.63 hours; India 1.23 hours; and Nepal 0.67 hours [27].
- Results of UNICEF's Multi-Indicator Cluster Surveys in 23 African countries, reported in Cairncross and Valdmanis [19], shows that 44% of households required a journey of more than 30 minutes to collect water.
- In a World Bank study on women and rural transport, Malmberg-Calvo (1994) reports average water collection times per day for four rural sites: Ghana (3 hours/day); Makete, Tanzania (1.8 hours/day); Tanga, Tanzania (2.7 hours/day); and Zambia (0.5 hours/day) [28].
- Thompson et al (2001) reported from 334 study sites from East Africa (Kenya, Tanzania and Uganda) the mean distance from rural unpiped households to their water sources of 622 metres, compared with 204 metres for urban areas [29].
- Whittington et al (1990) reports from Kenya that journeys to a local well in a small town averaged between 10 and 30 minutes (median around 15 minutes); and journeys to a kiosk between 3 and 13 minutes (median around 10 minutes) [30]. However, to collect enough water for the entire household would require more than one visit, thus requiring closer to one hour or more per household per day.
- Biran (2004) reports average time per day for water collection for two rural masai communities – 54 minutes per day for women and 36 minutes per day for girls [31].
- Feachem et al (1978) found in 10 villages in Lesotho that the installation of a water supply had saved the average adult woman 30 minutes per day [32].
- Fieldwork and Zorse (1991) report water collection times per woman per day in Ghana in the dry season (1.2 hours in 1991) and wet season (1.2 hours per day in 1991).
- Sahel Consult (2000) report from Sampara, Mali, that 6% of a woman's 17 hour day (= 1.02 hours) is taken up with water collection in the dry season, and 7% of a woman's 15 hour day (1.05 hours) in the wet season (reported in Dutta 2005 [20].
- Whittington et al (1991) reports from Nigeria that in the dry seasons average journey time to the local springs was 4-7 hours for some rural communities, which does not include waiting time at the spring [33].

Given these wide variations quoted in the literature, as well as the expected enormous differences between settings in the developing world in water availability (current and future), this analysis made assumptions about time savings following water improvements based on a consolidated assessment of the evidence presented above. It was assumed that, on average, a household gaining access to improved water supply outside the home or plot will save 30 minutes per day (range: 15 to 60 minutes), giving 30.4 hours saved per individual per year, assuming six members per household. This reflects the same assumption as in the original WHO report of Hutton and Haller [3], as there was insufficient global evidence to change the assumption. Clearly, a 30 minute time saving assumption will underestimate likely time savings in some, especially rural water-scarce areas, whereas it would overestimate likely time savings in some urban or water abundant regions. However, it is likely that 30 minutes is a reasonably conservative assumption that would not lead to gross overestimates of time saving.

For improved sanitation, no data were found in the literature for an estimate of time saved per day due to less distant sanitation facilities and less waiting time. No references have even been made in the literature cited above to time use for going to the toilet, as use of toilet / personal hygiene are rarely if ever included in questionnaires about time use. Cairncross and Valdmanis (2005) report a study from Benin on the benefits of latrine ownership as perceived by 320 rural households, which ranks 'saving time' as 11th out of 20 reasons, with an importance rating of 3.53 out of 4 [34]. Given the need to make several visits per day to a private place outside the home (especially for women), an assumption was made of 30 minutes saved per person per day, from improvements along the above lines, giving 182.5 hours per person per year saved. Again, this reflects the same assumption as in the original WHO report [3].

Valuation of time savings due to better access to water and sanitation is recognised as a tricky issue [19]. In terms of the economic value of time gained, the advantage of a cost-benefit study over a purely financial analysis is that a proxy value of time can be used and applied irrespective of what individuals actually do with their time. In fact, whether the time gained is used in income earning, productive but non-income work, or leisure activities, there is evidence that people value their time at or close to their hourly wage [35] or at close to the minimum wage [36]. For example, studies by Whittington and others in Africa showed that households valued their time spent collecting water at around the average wage rate for unskilled labour [30]. Begoña et al find considerable variation between individuals in how they value their leisure time [37]. The importance of valuing leisure time is also supported by the fact that wage rates for overtime worked are generally higher than the average wage [38], and thus Isley argues that the market wage rate should be used as the lower bound for valuing leisure time [39]. In other words, people need to be paid more than their average wage to give up their leisure time to work. The OECD has also been reported to use GDP per capita as the basis for valuing leisure time[5].

From an equity perspective, it is appropriate to assign to all adults the same economic value of time, so that high income earners are not favoured over low or non-income earners, or men over women. Moreover, variations between different population groups would be difficult to capture in a global study.

Therefore, based on the above evidence and considerations, the Gross National Product (GNP) per capita (in US$) in the year 2005 is used as the average value of time in an economy, with average (weighted) GNP being calculated at the regional level, using a population-weighted average for each sub-region. The annual GNP value is transformed to an hourly value. In the sensitivity analysis, a lower bound of 30% of GNP per capita is used, and an upper bound of the minimum wage rate, using an average population-weighted minimum wage by world region.

The other benefits tabulated in the final column of Table 9 were not included in the cost-benefit analysis. These benefits relate mainly to improved water supply and they are described briefly below, with a justification for their exclusion from this analysis.

- Indirect effects on *vector-borne disease transmission* resulting from water and sanitation improvements depend on many local factors and are therefore globally not predictable. Their exclusion is likely to lead to an under-estimation of benefits

[5] http://www.economist.com/finance/PrinterFriendly.cfm?story_id=5504103

- Costs avoided due to *reduced reliance on expensive water sources /such as vendors) or on unsafe water purification methods*, due to increased availability of cheaper water and phasing out hazardous methods of water purification such as boiling. These gains are excluded for economic reasons. For example, from the societal point of view, water purchases from vendors are a transfer payment and do not represent an economic loss or gain compared to the use of other sources.

- In areas with improved water and sanitation, *property value* is likely to increase [13]. Such an increase is, however, indirect and difficult to evaluate without databases from different regions, and if entire areas receive the improvements the market may not be able to support price increases. Moreover, property value increases represent a transfer of resources and not a gain to society per se.

- There are also *leisure activities (e.g. boating, fishing), aesthetics and non-use values* associated with improvements in water and sanitation. Non-use is divided into option value (the possibility that the person may want to use it in the future), existence value (the person values the fact that the environmental good exists, irrespective of use), and bequest value (the person wants future generations to enjoy it). However, these are difficult to value, and there are very few data available on these benefits [14, 15, 40]. Their exclusion will lead to an under-estimation of benefits.

- Improved water supply also leads to economic benefits related to options for *labour-saving devices and increased water access*, due to changes in location of water sources and increases in water quantity available. These include benefits in home production and small business possibilities), as well as in agriculture or private industry; and within the home (e.g. time savings of buying a washing machine). Agricultural benefits may mean a change in land use (e.g. due to reclaimed land), loss of land (if a reservoir is created), or the option to chose different crops due to increased water availability. However, there are huge variations as well as uncertainties associated with these benefits and costs, especially in a global analysis, and therefore they are left out in this study.

2.6 Sensitivity analysis

Many of the data used in the model are uncertain or highly uncertain. In the sensitivity analysis. However, only a selected few variables were tested for their impact on the overall results, with variables selected based on their expected importance in determining the overall results and the level of uncertainty in the input value used in the base case analysis. These include:

- Time gains due to better access to water and sanitation. Given that the overall results were expected to be heavily determined by time savings, the time saving assumptions used in the sensitivity analysis for improved water access were the following: one quarter of an hour saved per household per day in an average household of 8 persons, giving 11.41 hours saved per person per year in the pessimistic scenario; and one hour saved per household per day in an average household of 4 persons, giving 91.25 hours saved per person per year in the in the optimistic scenario. For sanitation access, the base case value of 182.50 hours per person per year were halved (91.25 hours) and increased by 50% (273.75 hours).
- The value of time. A realistic variation should be reflected for the value of time, giver its key importance in this study as an economic benefit. An alternative lower bound value to the use of GNP per capita as the base case is proposed by WHO, based on an IMF study [41]. This study suggests that people, on average, adults value their time at roughly 30% of the GNP per capita. In this pessimistic

scenario, children and infants are given a zero opportunity cost of time. In the optimistic scenario, the minimum wage was applied. According to World Bank data, a minimum wage is not defined in all countries, but in general, in most countries where one exists, it exceeds the GNP per capita. For countries without a minimum wage value, the WHO sub-regional average is applied.

- Diarrheal incidence. Low and high values were based on halving and increasing by 50% the base case incidence rates, respectively.
- Health care costs. Low and high values are based on those presented in Mulligan et al (2005), for health centre outpatient visit cost and primary hospital inpatient care cost.
- Intervention costs. Low and high cost values were substituted in the model, based on the different sets of assumptions (ranges) shown in Table 6. Ranges are provided on four input variables to estimating annualized intervention cost: (1) length of life of hardware; (2) operation, Maintenance, Surveillance as % annual cost; (3) education as % annual cost; and (4) water source protection as % annual cost.

There is also uncertainty in the coverage predictions for 2015. However, changes in these estimates would not change considerably the cost-benefit ratios, and the coverage costs can be estimated easily by adjusting proportionally according to the difference in coverage expected.

2.7 Presentation of results

The model developed for this present study generated a huge quantity of data. Selected results are presented for the six interventions and for the six non-OECD world regions, and include (a) the cost-benefit ratios; (b) the intervention costs; (c) the total economic benefits; (d) the number of cases of diarrhoea and deaths prevented per year, and (e) the economic benefits broken down by major benefit categories. Cost-benefit ratios are presented for all costs and benefits together, followed by costs and selected benefits. All costs are presented in US$ in the year 2002. Costs and benefits are presented assuming that all the interventions are implemented within a one-year period, hence requiring the annuitization of investment costs described above [8]. All results are presented assuming constant population growth based on 2000 predictions (UN Statistics Division).

In summary, the calculation of the total societal economic benefit is the sum of:
(1) Health sector benefit due to avoided illness
(2) Patient expenses avoided due to avoided illness
(3) Deaths avoided
(4) Time savings due to access to water and sanitation
(5) Productive work days gained of those with avoided illness (at least 15 years old)
(6) Days of school attendance gained of those with avoided illness (5-15 years old)
(7) Baby days gained of those with avoided illness (0-4 years old).

3. Global and regional results

3.1 Cost-benefit ratios

Table 11 shows that in meeting the water and sanitation MDGs using low cost improvements, an estimated rate of return (benefit-cost ratio) of between US$ 5 and US$ 36 return on a US$ 1 investment is achieved in the six world regions, with a global average of US$ 8.1 return per US$ 1 investment for the combined water and sanitation MDGs. The benefit cost ratio of achieving the combined W&S MDG also vary by world region: the Arab States (BCR = 5.4), sub-Saharan Africa (BCR = 5.7), South Asia (BCR = 6.6), East Asia & Pacific (BCR = 10.1), Eastern Europe & CIS (BCR = 18.9), and Latin America and the Caribbean (BCR = 35.9). All these ratios reflect a highly favourable result for the interventions evaluated. Some further explanations and qualification are given in the presentation of the detailed results below, to allow a full and appropriate interpretation of these data.

The results suggest that achieving the sanitation MDG is economically more favourable than the water MDG, with a global return of US$ 9.1 for sanitation compared to US$ 4.4 for water, per US$ 1 invested. This is due to the greater relative health impacts (and the related health cost savings and productivity benefits) of investing in sanitation and the higher convenience time savings per person receiving the intervention. However, balancing these effects is the higher cost of sanitation improvements per capita (see Tables 5 and 7).

In achieving universal access, cost-benefit ratios are broadly similar as in meeting the MDGs. This is because the unit cost per person reached and the health and economic benefits are assumed to be the same at whatever level of coverage is achieved, given the lack of information to indicate the shape of the cost curve as coverage increases (e.g. whether economies of scale are present, and whether diminishing returns are likely at high levels of coverage). However, there are some differences in the benefit-cost ratios between MDG coverage and universal coverage, such as for universal coverage of sanitation in the Arab States, where differences become evident due to the different range of countries included in the universal coverage analysis.

Table 11. Cost-benefit ratio for achieving six water and sanitation coverage scenarios, by world region

World Region *	MDG			Universal		
	Water	Sanitation	W&S	Water	Sanitation	W&S
Sub-Saharan Africa	2.8	6.6	5.7	3.9	6.5	5.7
Arab States	6.1	5.3	5.4	5.9	12.7	11.3
East Asia & Pacific	6.9	12.5	10.1	6.6	13.8	12.2
South Asia	3.5	6.9	6.6	3.9	6.8	6.6
Latin America & Caribbean	8.1	37.8	35.9	17.2	39.2	36.3
Eastern Europe & CIS	8.3	27.8	18.9	8.9	29.9	27.4
Non-OECD	**4.4**	**9.1**	**8.1**	**5.8**	**11.2**	**10.3**

* Regional groupings reflect those used in the UNDP Human Development Report 2005

3.2 Intervention total costs

Table 12 shows that the estimated total annual costs of achieving the MDGs in non-OECD regions is US$ 858 million for water, and US$ 3,813 million for sanitation, giving a total of US$4,671 million for the two MDGs combined. Sub-Saharan Africa accounts for over 50% of these costs, at US$ 2,665 million, followed by South Asia

(18%), and East Asia & Pacific (13%). These costs are an incremental cost over and above the current annual investments in W&S services.

In achieving universal coverage in water and sanitation, the global annual cost of US$ 16,581 million is more equally divided between three world regions: sub-Saharan Africa (25%), East Asia & Pacific (33%), and South Asia (31.5%), with the remaining 11.5% going to the other three non-OECD regions. Achieving universal sanitation coverage account for 87.5% of the combined water and sanitation universal coverage.

The considerably higher cost of sanitation is due to the fact that, globally, sanitation coverage is behind water coverage to meet MDGs and thereby to 'halve the unserved proportion' implies serving a greater number of households and persons. Furthermore, improved sanitation also costs more per person reached than water (see Table 7).

In addition, there is considerable uncertainty in the cost figures, especially for some world regions. This study used cost data available from the Global Water Supply and Sanitation Assessment Report in the year 2000, where data were summarized for three major world regions (Africa, Asia, and Latin America) [2]. Therefore, the cost figures only represent crude cost estimates for these three world regions, thus losing specificity when applied to six different non-OECD world regions in the UNDP regional classification. The implication is that the cost estimates in Table 12, and those used in estimating the cost-benefit ratio, are most likely to be understated for higher income countries (where costs are correspondingly higher) and countries with water scarcity or with low population densities. Therefore, it is most likely that costs will be understated for the regions of the Arab States and countries such as Chad and the Sudan (for reasons of water scarcity and low population density), and for countries such as South Africa (who have significantly higher costs than the regional average for sub-Saharan Africa).

Table 12. Annual cost estimates (US$ millions) for achieving six water and sanitation coverage scenarios, by world region

World Region	MDG			Universal		
	Water	Sanitation	W&S	Water	Sanitation	W&S
Sub-Saharan Africa	479	2,185	2,665	777	3,379	4,156
Arab States	66	188	254	96	492	589
East Asia & Pacific	229	399	628	891	4,576	5,468
South Asia	53	802	856	189	5,033	5,222
Latin America & Caribbean	14	219	233	87	734	821
Eastern Europe & CIS	16	19	35	34	292	326
Non-OECD	**858**	**3,813**	**4,671**	**2,075**	**14,507**	**16,581**

Using the annual figures in Table 12, it is possible to estimate an upper bound for the total incremental cost of achieving the MDGs. Assuming the MDGs are met immediately, the total incremental cost from 2006 to 2015 is US$46.71 billion. However, if there is a gradual and linear scaling up of water and sanitation coverage, the actual cost could be as little as half this figure, at an additional US$23 billion.

3.3 Intervention total economic benefits

Table 13 shows that economic benefits total US$ 38 billion annually for meeting the combined water and sanitation MDGs, 92% of which is accounted for the sanitation MDG. Sub-Saharan Africa accounts for 41% of the global economic benefit, followed by Latin America & Caribbean (22%), East Asia & Pacific (17%) and South Asia (15%). In achieving the water MDG alone, the contribution of East Asia & Pacific to the US$ 3,762 million is more significant at US$ 1,593 (42%) followed by sub-Saharan Africa at US$ 1,336 million (35.5%).

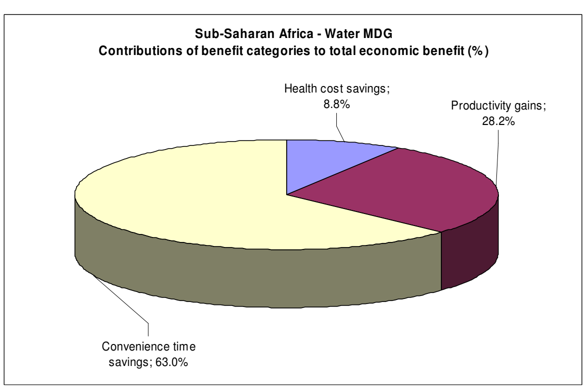
Economic benefits for achieving universal coverage are several times greater, at US$171 billion annually, a gain which is spread between East Asia & Pacific (39%), South Asia (20%), Latin America & Caribbean (17%), sub-Saharan Africa (14%), Eastern Europe & CIS (5%), and the Arab States (4%). These proportions are most heavily weighted by the results of universal coverage for sanitation. For universal coverage with water supply, the proportion is considerably higher for East Asia & Pacific (42%) and for the Arab States (11%), and lower for South Asia (5%) and Latin America & Caribbean (3%).

Table 13. Total economic benefit (US$ millions) estimates for achieving six water and sanitation coverage scenarios, by world region

World Region	MDG			Universal		
	Water	Sanitation	W&S	Water	Sanitation	W&S
Sub-Saharan Africa	1,336	14,359	15,292	3,006	21,963	23,566
Arab States	403	1,005	1,375	572	6,230	6,680
East Asia & Pacific	1,593	5,003	6,364	5,883	63,093	66,825
South Asia	186	5,507	5,635	733	34,305	34,706
Latin America & Caribbean	110	8,287	8,352	1,498	28,787	29,801
Eastern Europe & CIS	133	542	671	307	8,711	8,930
Non-OECD	**3,762**	**34,703**	**37,689**	**11,999**	**163,088**	**170,508**

The contribution to economic benefits varies between water and sanitation, as shown in Figure 1 for the case of sub-Saharan Africa. In achieving the water MDG, 63% of the benefits are attributed to convenience time savings, 28% to productivity gains, and 9% to health care cost savings. Economic benefits of sanitation, on the other hand, are more heavily dominated by convenience time savings, at 90% of the total economic benefit, followed by 8% to productivity gains, and 2% to health care cost savings.

Figure 1. Contribution of major benefit categories to total economic benefit in sub-Saharan Africa for meeting water (left) and sanitation (right) MDGs



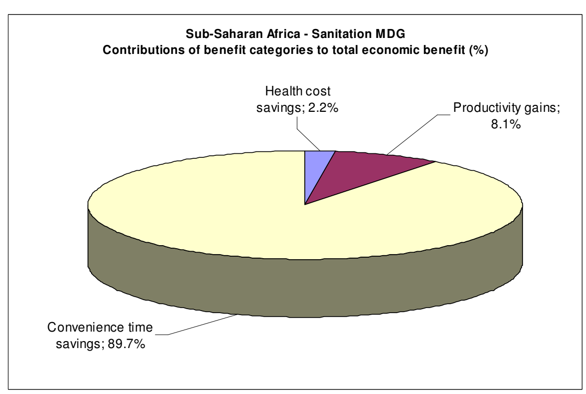
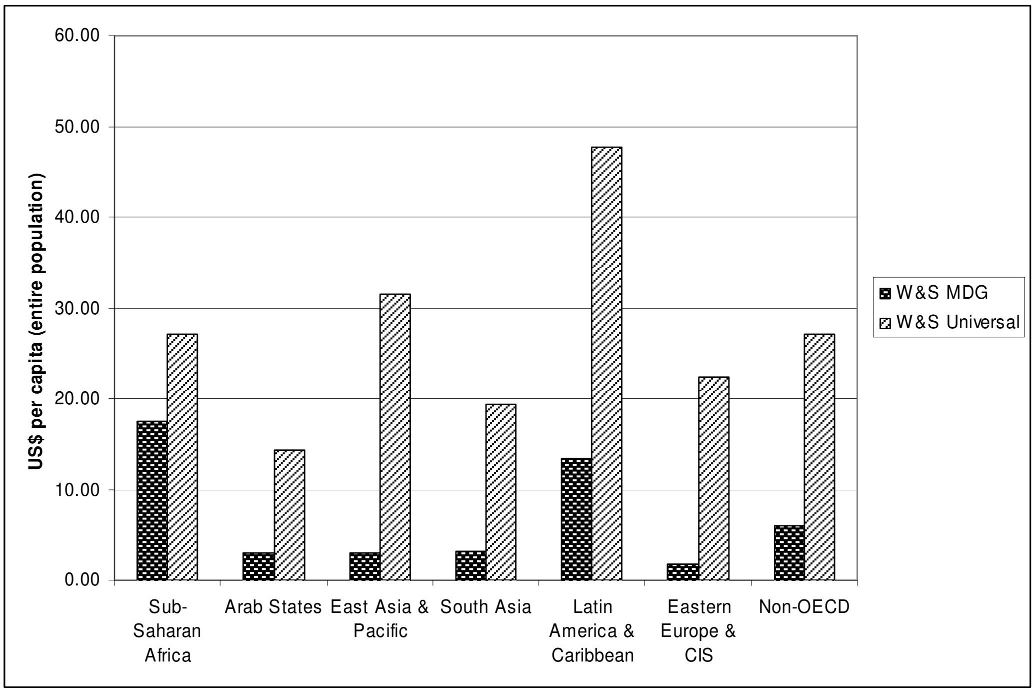


Figure 2 shows the per capita annual economic benefit of combined water and sanitation interventions, for the two targets MDG and universal coverage. For achieving the combined water and sanitation MDG target, sub-Saharan Africa benefits the most with an average of US$ 17.5 per capita per year, based on the entire population, and not just the population receiving the intervention. The next region benefiting is Latin America & Caribbean, at US$ 13.5 per capita per year. Under universal coverage, all world regions benefit substantially under these improvements, with at least US$ 15 per capita per year for the entire population. Under universal coverage, Latin America & Caribbean has the highest per capita gain at US$48.

Figure 2. Per capita annual economic benefit of combined water and sanitation interventions (MDG and universal coverage)



In order to interpret the economic benefits related to improved water supply, it is important to note that these relate solely to community supply of water, and not household supply. In previous cost-benefit analyses, household supply was included as one of several interventions to improve water coverage [3]. This analysis excludes household improvements in order to focus on the lowest cost interventions. Therefore, other economic benefits related to household supply such as the greater opportunity for household treatment (which gives more health benefits) and the closer proximity of water sources (thus giving further time savings) are excluded from this present analysis.

3.4 Number of people getting improvement

Table 14 presents the population sizes targeted under the six different coverage scenarios. Globally, a total population of 354 million who will not to have access to water in 2015 (at the current trend rate of coverage change from 1990 to 2004) will benefit from having access in achieving the water MDG. Of this figure, 207 million population (58%) is from countries in sub-Saharan Africa, and 25% from East Asia & Pacific.

Table 14. Total populations (millions) receiving interventions for achieving six water and sanitation coverage scenarios, by world region

World Region	MDG			Universal		
	Water	Sanitation	W&S	Water	Sanitation	W&S
Sub-Saharan Africa	207	315	364	335	486	490
Arab States	28	28	42	40	73	80
East Asia & Pacific	89	64	114	345	733	740
South Asia	21	129	134	73	807	809
Latin America & Caribbean	4	27	28	26	89	89
Eastern Europe & CIS	6	2	8	12	37	39
Non-OECD	**354**	**564**	**690**	**831**	**2,226**	**2,248**

For sanitation, a total population of 564 million who will not have sanitation coverage in 2015 (at the current trend rate of coverage change from 1990 to 2004) will benefit from having access in achieving the sanitation MDG. 315 million population (56%) is from countries in sub-Saharan Africa, and 23% from South Asia. For the combined water and sanitation MDG targets, a total population of 690 million is expected to benefit from either water supply, sanitation coverage, or both. Over half (53%) of this population is from sub-Saharan Africa.

However, uncertainties in these MDG target figures are high, given that projections for coverage are based on an assumption of linear progress in coverage from 1990 to 2004, and beyond to 2015. These uncertainties therefore impact on the cost and benefit figures presented above. However, the cost-benefit ratios presented above are unlikely to be sensitive to these uncertainties.

The population to be covered under the universal water coverage scenario is roughly three times the population size than for the MDG, at 831 million population to be covered, in addition to the current projected growth in coverage until 2015. For sanitation, the population to be covered under the universal coverage scenario is roughly five times the population size than for the MDG, at 2.23 billion population to be covered. These figures show clearly that, globally, target coverage is further from being achieved for the two sanitation targets (MDG targets and universal coverage) than for the water targets.

3.5 Impact on population health

Table 15 presents the number of predicted diarrhea cases averted under the six coverage scenarios. In achieving the MDGs, the investment to close the gap between the predicted coverage and the MDG target coverage, would bring 72 million fewer cases of diarrhea from water coverage and 190 million fewer cases for sanitation coverage. Roughly 60% of these are averted in sub-Saharan Africa. This considerable proportion is this region is to be expected due to the large proportion of the population receiving the interventions coming from sub-Saharan Africa (Table 14, and Annex 2). When combining the W&S MDG targets, the number of cases averted increases to 218 million (note that the combined MDG is not the sum of the two MDGs separately, as some of the targeted population receive both water and sanitation, and not just one). The incremental health impact of meeting the water MDG after meeting the sanitation MDG is 28 million cases of diarrhea averted (218 minus 190 million); whereas the incremental health impact of the meeting the sanitation MDG after meeting the water MDG is 146 million cases of diarrhea averted (218 minus 72 million).

Table 15. Predicted diarrheal cases (millions) averted from achieving six water and sanitation coverage scenarios, by world region

World Region	MDG			Universal		
	Water	Sanitation	W&S	Water	Sanitation	W&S
Sub-Saharan Africa	42.6	113.0	123.3	112.5	247.4	247.4
Arab States	4.5	10.1	11.8	9.4	25.6	25.6
East Asia & Pacific	18.3	24.0	37.7	70.2	194.7	194.7
South Asia	4.3	32.6	34.0	16.8	175.1	175.1
Latin America & Caribbean	0.8	9.0	9.4	6.9	26.2	26.2
Eastern Europe & CIS	1.2	0.7	1.9	1.4	4.1	4.1
Non-OECD	**71.7**	**189.5**	**218.1**	**217.3**	**673.1**	**673.1**

Universal coverage of improved water supply results in 217 million averted cases of diarrhea, while for universal coverage of improved sanitation results in 673 million averted cases of diarrhea. The combined W&S universal coverage bring the same health benefit as sanitation alone, as the relative risk reductions used assumes that moving from scenario VI (neither improved water or sanitation) to Va (improved sanitation) is the same as moving from VI to IV (improved water and sanitation).

Figures 3 and 4 show a summary breakdown of diarrhea cases averted by age group and by world region from meeting the water and sanitation MDGs, respectively. In sub-Saharan Africa, the population benefiting most from achieving the water MDG and the sanitation MDG is the 1-4 year old group, followed by the 0-1 age group. The pattern is similar in other world regions except in East Asia & Pacific, where the population most benefiting is the 15-59 age group. This result is explained by the fact that a large proportion of the population (65%) is in the 15-59 age group in its most populous nation, China. Annex 2 Tables 1 to 6 present figures by region for the six coverage scenarios.

Figure 3. Diarrheal cases averted by age group, from meeting the water MDG

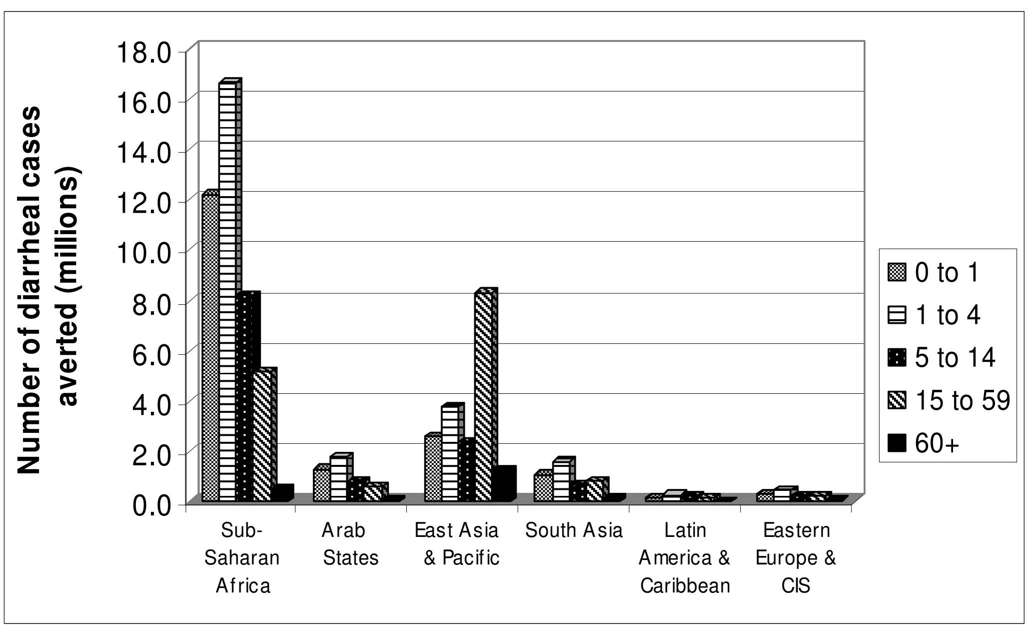
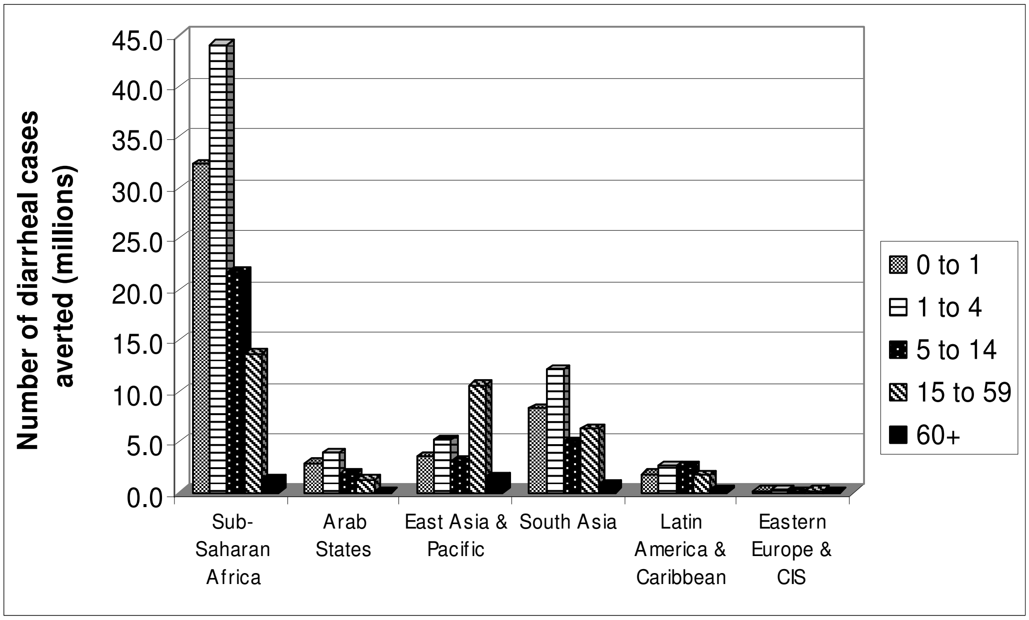


Figure 4. Diarrheal cases averted by age group, from meeting the sanitation MDG



The predicted number of deaths averted is shown in Table 16. From meeting the water MDG, almost 66,000 deaths are averted annually, while for meeting the sanitation MDG it is 180,000 deaths annually. This gives an average global case fatality rate of roughly 1 death per 1,000 cases of diarrhea. Universal water coverage results in 190,000 averted deaths annually, while universal sanitation coverage results in 592,000 averted deaths annually. In estimating the global avertable burden of disease from water and sanitation-related diseases, it should be noted that further deaths would be averted from achieving complete coverage in some OECD countries where universal access to water supply and sanitation coverage has not yet been reached. Additionally, it should be noted that the estimates of deaths averted due to diarrheal disease does not account for the feedback 'loop' from malnutrition which would lead to an extra fraction of disease reduction.

Table 16. Predicted deaths averted due to diarrhea from achieving six water and sanitation coverage scenarios, by world region

World Region	MDG			Universal		
	Water	Sanitation	W&S	Water	Sanitation	W&S
Sub-Saharan Africa	42,958	113,865	124,240	113,334	249,213	249,213
Arab States	4,539	10,197	11,972	9,573	25,891	25,891
East Asia & Pacific	12,475	16,757	25,290	44,650	124,063	124,063
South Asia	4,064	31,157	32,539	16,093	167,471	167,471
Latin America & Caribbean	697	7,582	7,855	5,811	21,970	21,970
Eastern Europe & CIS	1,135	624	1,741	1,353	3,732	3,732
Non-OECD	**65,870**	**180,182**	**203,637**	**190,814**	**592,339**	**592,339**

Figures 5 and 6 show a summary breakdown of deaths averted due to diarrhea by age group from meeting the water and sanitation MDGs, respectively. In all regions, the population benefiting most from achieving the water and sanitation MDGs is the

0-4 year old group, due to a combination of the high number of diarrhea cases and the higher case fatality rate in that age group. Annex 2 Tables 7 to 12 the present figures by region for the six coverage scenarios.

Figure 5. Deaths averted due to diarrhea by age group, from meeting the water MDG

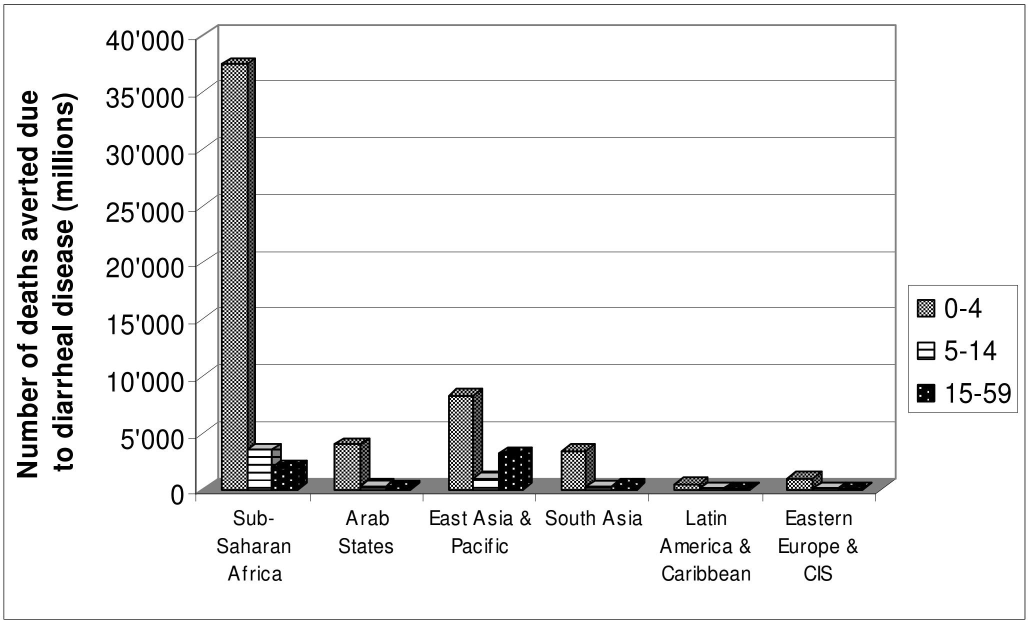
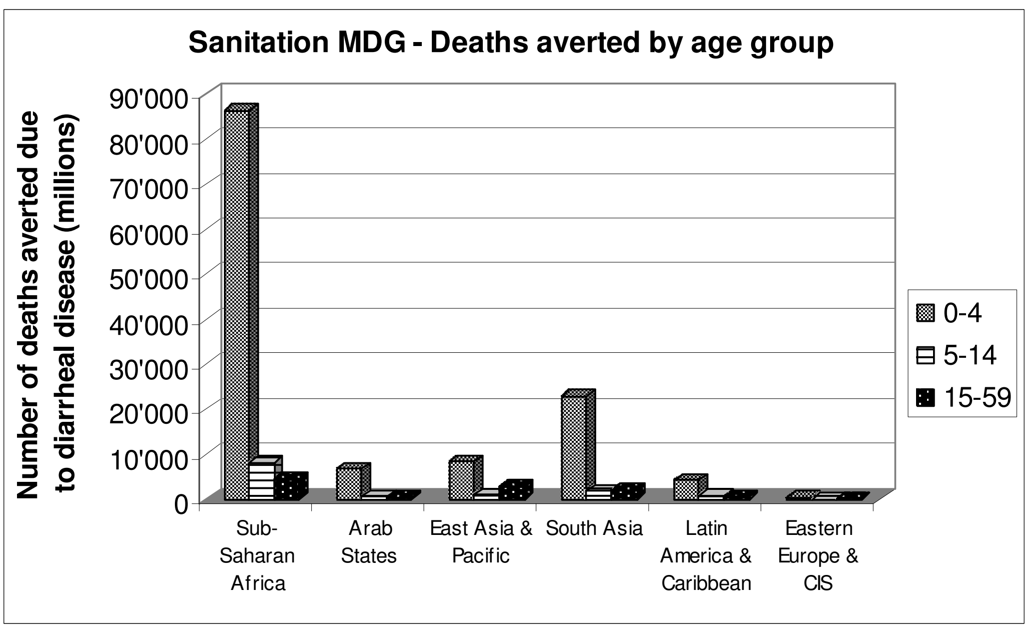


Figure 6. Deaths averted due to diarrhea by age group, from meeting the sanitation MDG



3.6 Treatment costs saved due to less cases of infectious diarrhoea

Table 17 presents the estimated health system costs saved for the six coverage scenarios. By meeting the MDG, US$ 205 million (water MDG) and US$ 552 million (sanitation MDG) are estimated to be saved annually, in terms of economic costs. For the combined water and sanitation MDGs, the expected economic savings are US$ 641 million annually. Roughly half of these savings are in sub-Saharan Africa. These costs includes both marginal costs (such as drugs and supplies) and fixed costs (staff, equipment, buildings), and therefore represents economic opportunity cost and not expected financial savings. Under a scenario of universal coverage, between 2 and 3 times these savings are expected.

Table 17. Estimated health system costs saved (US$ millions) for achieving six water and sanitation coverage scenarios, by world region

World Region	MDG			Universal		
	Water	Sanitation	W&S	Water	Sanitation	W&S
Sub-Saharan Africa	105	279	304	277	610	610
Arab States	21	35	44	23	63	63
East Asia & Pacific	54	71	112	173	480	480
South Asia	11	85	88	41	432	432
Latin America & Caribbean	7	79	82	17	65	65
Eastern Europe & CIS	6	4	10	4	10	10
Non-OECD	**205**	**552**	**641**	**536**	**1,659**	**1,659**

Table 18 presents the estimated non-medical patient costs saved for the six coverage scenarios. By meeting the MDG, US$ 22 million (water MDG) and US$ 57 million (sanitation MDG) are estimated to be saved annually. These costs reflect transport and food costs, and therefore reflect an expected financial cost saving to households. In countries where patients are charged fee-for-service, households will also be saved these fees when health seeking is averted. These costs are not reflected in Table 18 due to the fact that medical costs are already included in Table 17. However, given the variation by country in the proportion of the cost paid by the patient (both directly under fee-for-service and indirectly via health insurance), it is not possible in this global study to estimate the total health care user fees likely to be saved by patients. Under a scenario of universal coverage, roughly 3 to 4 times these savings are expected.

Table 18. Estimated patient non-medical health-seeking costs saved (US$ millions) for achieving six water and sanitation coverage scenarios, by world region

World Region	MDG			Universal		
	Water	Sanitation	W&S	Water	Sanitation	W&S
Sub-Saharan Africa	13	34	37	34	75	75
Arab States	1	3	4	3	8	8
East Asia & Pacific	6	7	11	21	59	59
South Asia	1	10	10	5	53	53
Latin America & Caribbean	0	3	3	2	8	8
Eastern Europe & CIS	0	0	1	0	1	1
Non-OECD	**22**	**57**	**66**	**66**	**203**	**203**

3.7 Value of work loss days gained from less illness and death

Table 19 presents the economic value of work loss days avoided for the six coverage scenarios. In achieving the MDGs, an annual economic value of US$ 293 million (water MDG) and US$ 1,056 (sanitation MDG) are expected to be gained by households due to less time spent ill. For the water MDG, sub-Saharan Africa and East Asia & Pacific account for 77% of these benefits, while for the sanitation MDG the benefits are more evenly spread among four of the six regions. Under universal coverage, the major share of benefits shift from sub-Saharan Africa (US$451 out of US$ 1,087 million) to ast Asia & Pacific (US$ 1,058 out of US$ 3,470 million).

These figures reflect not only the expected immediate work productivity of adults (15-59) and adults caring for small children (0-4 years), but also the hypothetical and implicit value of children being able to attend school regularly, and without taking time off school due to illness. Thus, these figures should not be interpreted as being immediate and direct economic gains to a country or region, as would be reflected in statistics of economic activity. Under universal coverage, the economic gains are estimated to be roughly 3 to 4 times those of achieving the MDGs.

Table 19. Economic value of work loss days avoided (US$ millions) for achieving six water and sanitation coverage scenarios, by world region

World Region	MDG			Universal		
	Water	Sanitation	W&S	Water	Sanitation	W&S
Sub-Saharan Africa	110	452	451	332	897	851
Arab States	25	34	48	49	162	152
East Asia & Pacific	126	153	192	349	1,396	1,058
South Asia	15	131	124	58	709	646
Latin America & Caribbean	9	272	253	161	784	712
Eastern Europe & CIS	8	14	19	12	61	53
Non-OECD	**293**	**1,056**	**1,087**	**961**	**4,010**	**3,470**

Table 20 presents the economic contribution of saved lives deaths for the six coverage scenarios. In achieving the MDGs, an annual economic value of US$ 739 million (water MDG) and US$ 1,718 (sanitation MDG) are expected to be gained by households due to less premature death. Sub-Saharan Africa account for over one-third of these benefits, while East Asia & Pacific accounts for almost one half of the benefits for the water MDG and just under one-third for the sanitation MDG. Under universal coverage, the economic gains are estimated to be roughly 3 to 4 times those of achieving the MDGs, with around half of the economic benefits going to East Asia & Pacific (US$ 3,533 out of US$ 7,294 million).

Table 20. Economic contribution due to saving lives (US$ millions) for achieving six water and sanitation coverage scenarios, by world region

World Region	MDG			Universal		
	Water	Sanitation	W&S	Water	Sanitation	W&S
Sub-Saharan Africa	267	715	778	712	1,623	1,623
Arab States	20	32	44	38	97	97
East Asia & Pacific	343	518	731	1,269	3,533	3,533
South Asia	41	188	202	165	1,073	1,073
Latin America & Caribbean	18	226	231	231	775	775
Eastern Europe & CIS	50	39	89	64	193	193
Non-OECD	**739**	**1,718**	**2,073**	**2,479**	**7,294**	**7,294**

In interpreting these figures, it is important to bear in kind that they reflect the immediate loss of economic contribution by adults who die prematurely, as measured by the discounted future average income earnings. They also reflect the future loss of earnings of children and infants who die, further discounted by the delay between the event of their death and them entering the productive workforce, assumed at age 15. Given that an individual consumes him- or herself a large proportion of their income, these figures do not reflect net economic gains from saving lives, but instead their total (estimated) economic contribution to society.

The economic value of saving lives (Table 20) is higher than the value of work loss days due to morbidity (Table 19), because although death is a significantly less common event, the estimated productivity cost per death is significantly greater than a morbidity episode.

3.8 Value of convenience time savings

Table 21 presents the economic value of convenience time savings for the six coverage scenarios. In achieving the MDGs, an annual economic value of US$2,503 million (water MDG) and US$31,320 (sanitation MDG) are expected to be gained by households due to savings in time due to water haulage and travel to (or waiting time at) sanitation facilities. Roughly 40% of these economic benefits are in sub-Saharan Africa, followed by Latin America & Caribbean (23%), and East Asia & Pacific and South Asia (16% each).

Under universal coverage, the economic gains are estimated to be roughly 3 times (water) to 5 times (sanitation) compared to the gains of achieving the MDGs. The doistribution between world regions is different than the MDG target, with East Asia & Pacific taking the largest share (39%), followed by South Asia (21%), Latin America & Caribbean (18%), and sub-Saharan Africa (13%). The economic value of meeting the combined water and sanitation coverage targets is exactly the sum of the two targets separately, as the convenience time savings of each intervention are independent.

Table 21. Economic value of convenience time savings (US$ millions) for achieving six water and sanitation coverage scenarios, by world region

World Region	MDG			Universal		
	Water	Sanitation	W&S	Water	Sanitation	W&S
Sub-Saharan Africa	841	12,880	13,722	1,651	18,758	20,409
Arab States	335	900	1,236	460	5,900	6,360
East Asia & Pacific	1,064	4,254	5,318	4,070	57,626	61,697
South Asia	118	5,093	5,211	464	32,038	32,502
Latin America & Caribbean	76	7,707	7,783	1,086	27,155	28,242
Eastern Europe & CIS	68	485	553	227	8,445	8,673
Non-OECD	**2,503**	**31,320**	**33,823**	**7,958**	**149,923**	**157,882**

3.9 Sensitivity analysis

In the initial sensitivity analysis, alternative values were entered for five selected areas of data uncertainty than represented the largest areas of uncertainty or the most important determinants of the benefit-cost ratios.

1. Time savings assumption

Given the high level of uncertainty in the base scenario time saving assumptions, a wide range was employed to reflect possible high and low values on time savings (see methods section 2.6). Figure 7 shows the cost-benefit ratio is sensitive to these alternative assumptions, ranging from 1.5 to 6.1 for sub-Saharan Africa for achieving the water MDG, and from 3.7 to 9.6 for achieving the sanitation MDG. Despite the sensitivity of the results, the conclusion holds that the interventions are cost-beneficial.

Figure 7. Cost-benefit ratios under alternative time saving assumptions for achieving the six water and sanitation targets, for sub-Saharan Africa

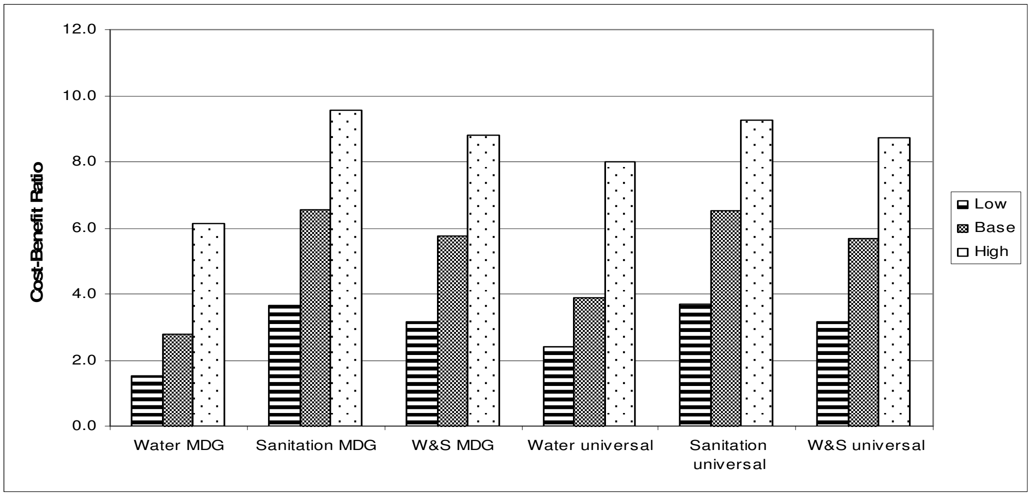
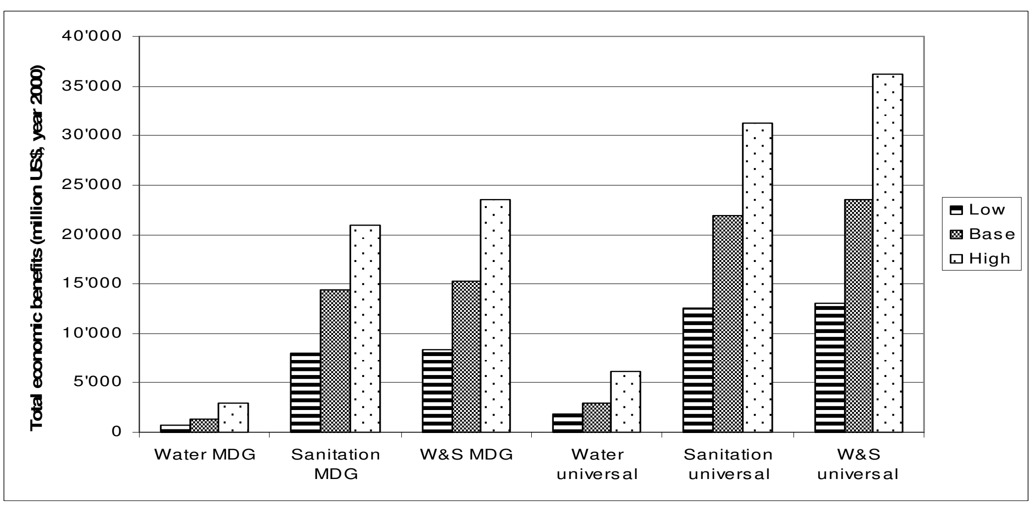


Figure 8 shows the sensitivity of the economic benefits to time saving assumptions, showing wide variation around the base case results.

Figure 8. Total annual economic benefits under alternative time saving assumptions for achieving the six water and sanitation targets, for sub-Saharan Africa



2. Time value

Given the high level of uncertainty in the base scenario time value assumptions, alternative values were employed to reflect possible high and low values on the value of people's time (see methods sections 2.5.3 and 2.6). Figure 9 shows the benefit-cost ratio is highly sensitive to these alternative assumptions, ranging from 1.1 to 5.3 for sub-Saharan Africa for achieving the water MDG, and from 2.1 to 9.5 for achieving the sanitation MDG. Hence, at the lower time value assumptions (30% of GNP for adults, and zero for infants and children), the water intervention alone is only marginally cost-beneficial.

Figure 9. Cost-benefit ratios under alternative time value assumptions for achieving the six water and sanitation targets, for sub-Saharan Africa

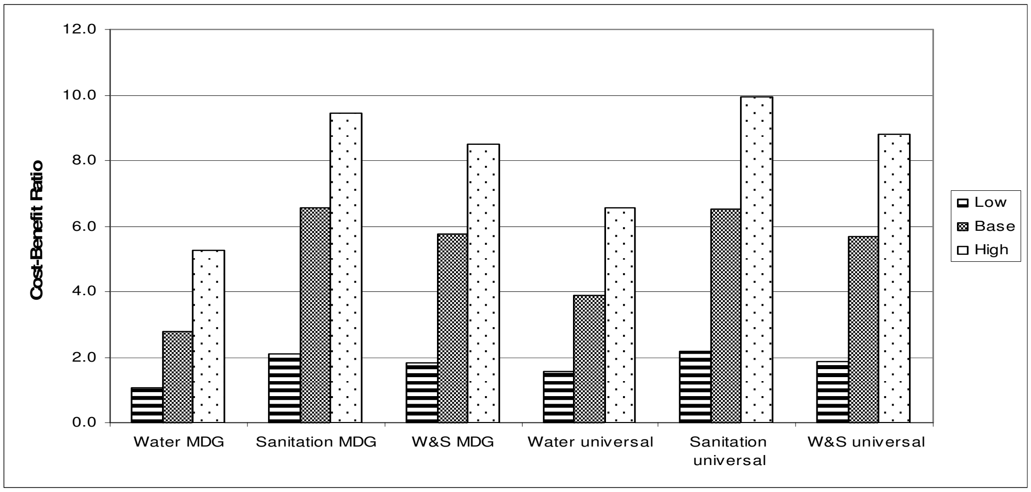
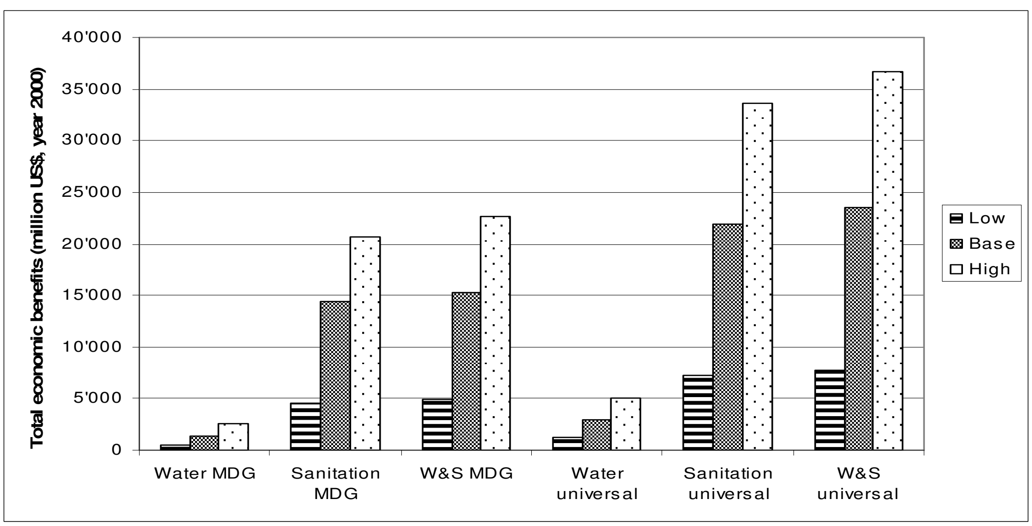


Figure 10 shows the sensitivity of the economic benefits to time value assumptions, showing wide variation around the base case results.

Figure 10. Total annual economic benefits under alternative time value assumptions for achieving the six water and sanitation targets, for sub-Saharan Africa



3. Incidence

Under the assumption of different diarrheal disease incidence rates, Figure 11 also shows wide variation in the cost-benefit ratios.

Figure 11. Cost-benefit ratios under alternative diarrheal disease incidence assumptions for achieving the six water and sanitation targets, for sub-Saharan Africa

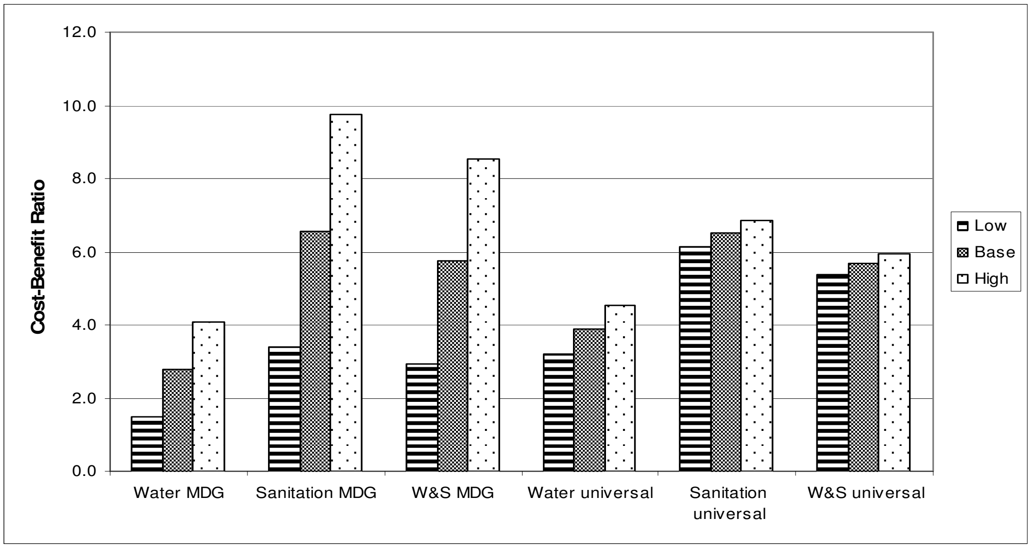
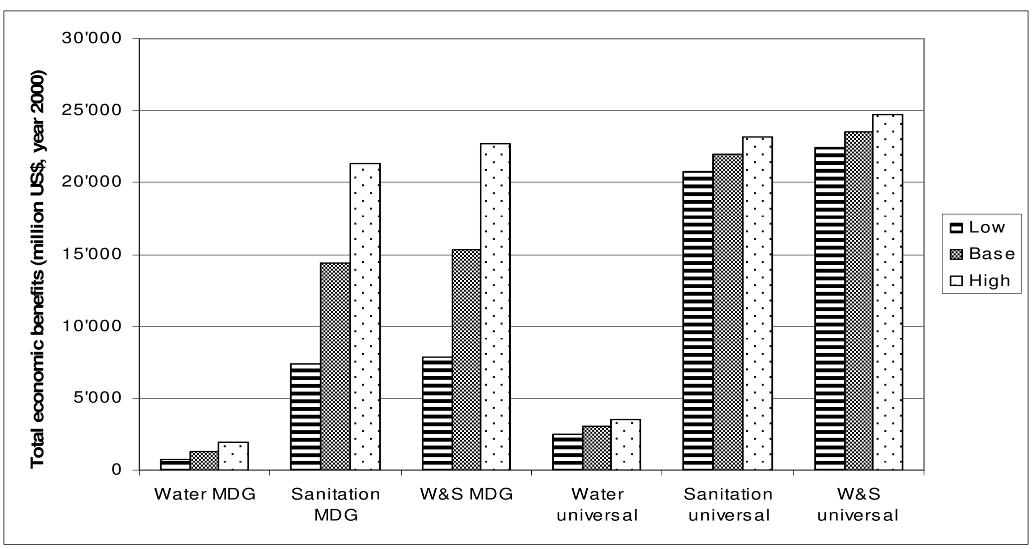


Figure 12 shows the sensitivity of the economic benefits to diarrheal disease incidence assumptions, showing wide variation around the base case results for the MDG targets, but a less important variation for the universal coverage target.

Figure 12. Total annual economic benefits under alternative diarrheal disease incidence assumptions for achieving the six water and sanitation targets, for sub-Saharan Africa



4. Health care costs

Under the assumption of different health care unit cost assumptions, Figure 13 shows insignificant variation in the cost-benefit ratios. In fact, as there appears to have been greater uncertainty for the upper value for health care unit costs, the range on the benefit-cost ratio is correspondingly larger on the upper end.

Figure 13. Cost-benefit ratios under alternative health care unit cost assumptions for achieving the six water and sanitation targets, for sub-Saharan Africa

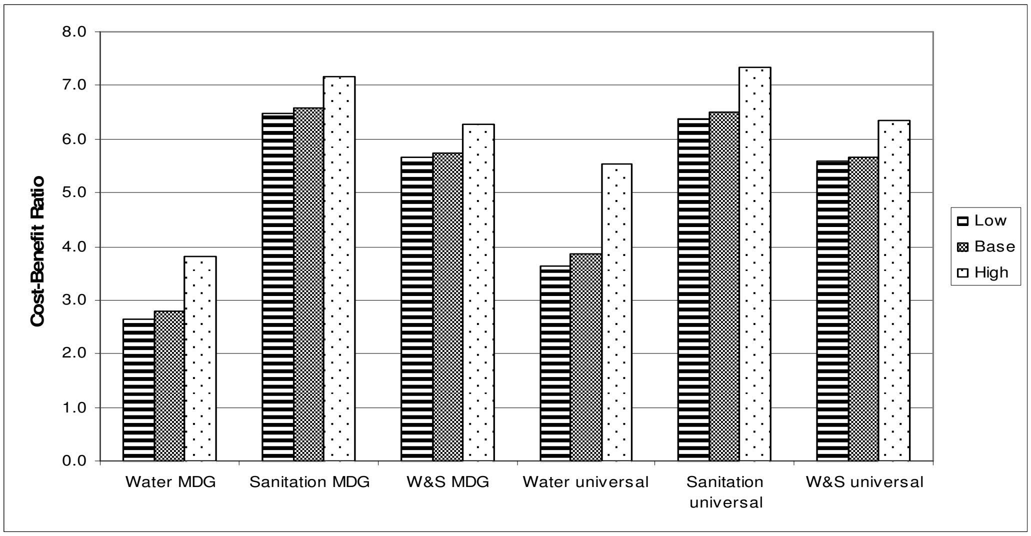
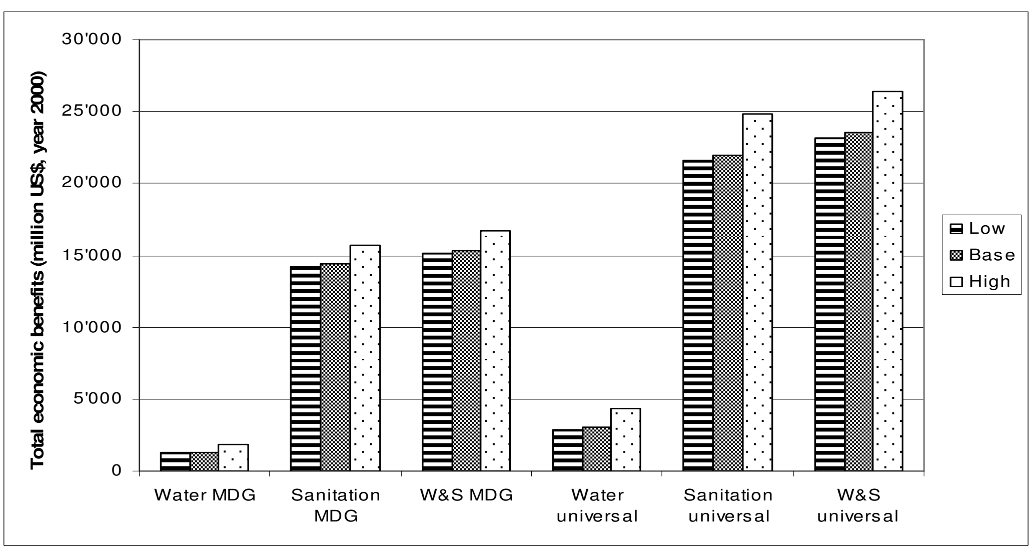


Figure 14 shows the sensitivity of the economic benefits to health care unit cost assumptions, showing only limited variation around the base case results. The impact is limited because health care costs contribute only a small proportion (under 10%) of total economic benefits.

Figure 14. Total annual economic benefits under alternative health care unit cost assumptions for achieving the six water and sanitation targets, for sub-Saharan Africa



5. Costs of improved water and sanitation coverage

Under the assumption of different intervention cost assumptions, Figure 15 shows significant variation in the cost-benefit ratios.

Figure 15. Cost-benefit ratios under alternative intervention cost assumptions for achieving the six water and sanitation targets, for sub-Saharan Africa

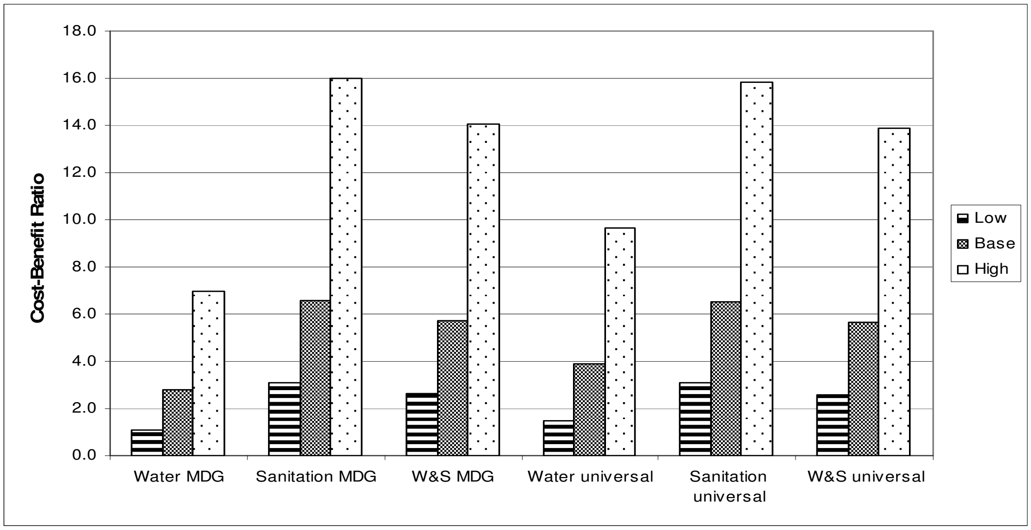


Figure 16 shows the sensitivity of the total economic costs of the interventions to the cost assumptions, showing wide variation around the base case results.

Figure 16. Total annual economic costs under alternative intervention cost assumptions for achieving the six water and sanitation targets, for sub-Saharan Africa

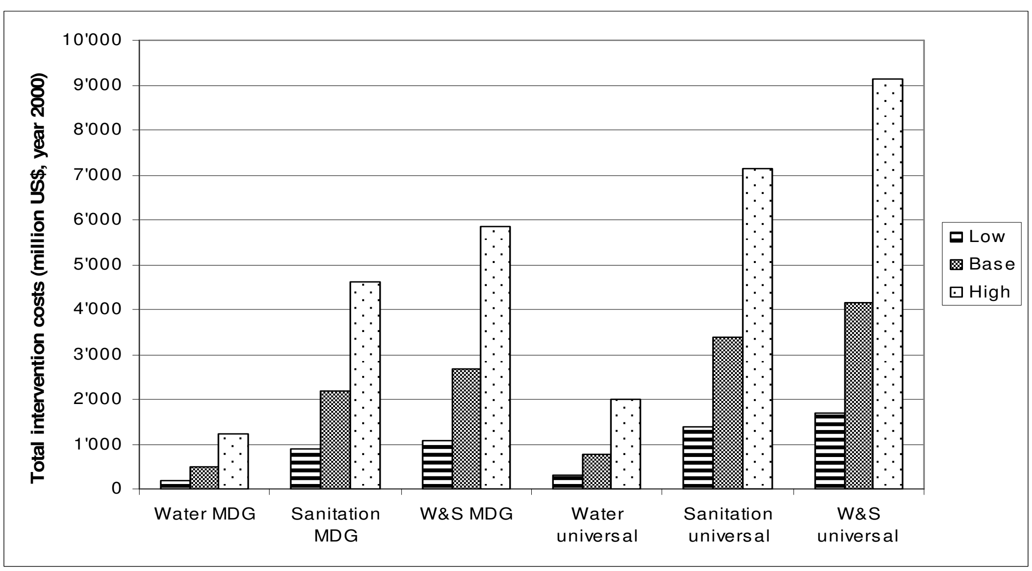


Table 22 shows the low, base and high annual intervention costs for three selected regions and globally for the six intervention scenarios. Base case values of unit cost per person reached (Table 7) were recalculated under alternative assumptions, based on using ranges for four variables used in estimating annualized intervention cost: (1) length of life of hardware; (2) operation, maintenance, surveillance as % annual cost; (3) education as % annual cost; and (4) water source protection as % annual cost.

Table 22. Total annual economic costs under alternative intervention cost assumptions for achieving the six water and sanitation targets, for three selected regions

World region and cost assumption	Water MDG	Sanitation MDG	W&S MDG	Water universal	Sanitation universal	W&S universal
Sub-Saharan Africa						
Low	192	896	1,088	312	1,386	1,697
Base	479	2,185	2,665	777	3,379	4,156
High	1,238	4,620	5,857	2,006	7,144	9,150
East Asia & Pacific						
Low	91	164	256	355	1,883	2,238
Base	229	399	628	891	4,576	5,468
High	595	827	1,423	2,314	9,485	11,799
South Asia						
Low	21	330	351	75	2,071	2,146
Base	53	802	856	189	5,033	5,222
High	138	1,663	1,801	490	10,433	10,922
WORLD (NON-OECD)						
Low	343	1,565	1,908	829	5,961	6,790
Base	858	3,813	4,671	2,075	14,507	16,581
High	2,220	8,017	10,236	5,375	30,289	35,665

4. Country results

4.1 Cost-benefit ratios

Table 23 presents the benefit-cost results for 15 selected countries which are at risk of not achieving the MDG targets for water, sanitation, or both, by 2015. The results show some similarities as well as differences between countries. There appears to be no systematic differences between world regions.

Table 23. Cost-benefit ratio for achieving six water and sanitation coverage scenarios, by selected country

Regional code	World Region	MDG			Universal		
		Water	Sanitation	W&S	Water	Sanitation	W&S
1	Benin	3.7	5.7	7.3	4.4	6.0	5.4
1	DRC	5.2	8.3	11.6	6.2	8.7	7.6
1	Ethiopia	1.1	1.6	2.2	1.4	1.8	1.5
1	Guinea	4.7	7.4	11.2	5.5	7.6	6.9
1	Kenya	3.5	5.5	8.6	4.2	5.6	5.1
1	Mozambique	2.6	3.6	5.1	3.4	4.0	3.4
1	Nigeria	2.9	4.2	5.8	3.6	4.7	3.9
1	Togo	3.1	4.7	7.0	3.7	5.0	4.4
2	Sudan	2.9	4.8	7.4	3.4	4.9	4.5
2	Yemen	3.4	6.3	5.6	3.1	6.0	5.0
3	China	6.7	13.1	7.6	6.5	12.6	11.3
3	Indonesia	7.0	11.4	8.8	6.6	10.7	9.3
4	Bangladesh	3.5	6.4	5.4	3.7	6.3	5.6
5	Haiti	4.6	7.0	8.0	5.0	7.0	5.9
6	Uzbekistan	8.4	N/A	N/A	7.5	13.7	10.4

4.2 Intervention total costs

Table 24 presents the cost estimates for the selected countries.

Table 24. Total cost estimates (US$ millions) for achieving six water and sanitation coverage scenarios, by selected country

Regional code	World Region	MDG			Universal		
		Water	Sanitation	W&S	Water	Sanitation	W&S
1	Benin	4	5	6	7	32	39
1	DRC	70	175	147	99	350	450
1	Ethiopia	133	298	262	162	487	649
1	Guinea	7	46	32	12	61	73
1	Kenya	7	117	76	30	156	185
1	Mozambique	21	54	45	30	98	128
1	Nigeria	189	420	367	211	609	820
1	Togo	5	25	18	7	30	37
2	Sudan	18	151	104	29	192	220
2	Yemen	24	34	49	33	99	132
3	China	161	265	583	693	3'608	4'301
3	Indonesia	41	133	190	136	562	698
4	Bangladesh	53	113	161	114	549	662
5	Haiti	8	24	23	15	50	64
6	Uzbekistan	16	0	0	19	36	55

4.3 Intervention total economic benefits

Table 25 presents the total economic benefits for selected countries.

Table 25. Total economic benefit (US$ millions) estimates for achieving six water and sanitation coverage scenarios, by selected country

Regional code	World Region	MDG			Universal		
		Water	Sanitation	W&S	Water	Sanitation	W&S
1	Benin	15	29	42	29	192	208
1	DRC	366	1'445	1'715	611	3'057	3'412
1	Ethiopia	153	484	587	235	880	986
1	Guinea	33	337	360	64	465	501
1	Kenya	24	638	653	124	875	944
1	Mozambique	54	196	229	101	396	439
1	Nigeria	555	1'760	2'140	765	2'841	3'198
1	Togo	16	119	129	26	148	162
2	Sudan	52	729	767	96	938	998
2	Yemen	79	212	274	102	595	663
3	China	1'077	3'471	4'460	4'523	45'574	48'482
3	Indonesia	284	1'525	1'667	901	6'000	6'473
4	Bangladesh	185	725	862	415	3'447	3'689
5	Haiti	35	170	186	74	347	378
6	Uzbekistan	131	0	131	141	496	577

4.4 Number of people getting improvement

Table 26 presents the populations receiving improvements for the six interventions for selected countries.

Table 26. Total populations (millions) receiving interventions for achieving six water and sanitation coverage scenarios, by selected country

Regional code	World Region	MDG			Universal		
		Water	Sanitation	W&S	Water	Sanitation	W&S
1	Benin	1.7	0.7	1.8	2.8	4.6	4.6
1	DRC	30.3	25.2	30.3	42.9	50.4	50.4
1	Ethiopia	57.6	42.9	57.6	70.0	70.0	70.0
1	Guinea	3.0	6.6	6.6	5.0	8.8	8.8
1	Kenya	3.0	16.8	16.8	12.8	22.4	22.4
1	Mozambique	8.9	7.8	8.9	12.9	14.1	14.1
1	Nigeria	81.6	60.5	81.2	90.9	87.6	90.9
1	Togo	2.3	3.6	3.6	3.0	4.3	4.3
2	Sudan	7.7	21.8	21.8	12.3	27.6	27.6
2	Yemen	9.1	5.4	9.1	12.6	15.9	15.9
3	China	62.4	42.5	82.2	267.9	578.2	578.2
3	Indonesia	15.8	21.4	21.4	52.5	90.0	90.0
4	Bangladesh	20.5	18.0	22.9	44.0	87.9	87.9
5	Haiti	2.3	2.9	2.9	4.4	6.0	6.0
6	Uzbekistan	6.1	0.0	6.1	7.3	5.8	7.3

4.5 Impact on population health

Table 27 and 28 present the predicted cases of diarrhea and lives saved, respectively, for the selected countries.

Table 27. Predicted diarrhea cases (millions) averted for achieving six water and sanitation coverage scenarios, by selected country

Regional code	World Region	MDG			Universal		
		Water	Sanitation	W&S	Water	Sanitation	W&S
1	Benin	0.4	0.3	0.5	1.0	2.3	2.3
1	DRC	6.3	9.5	10.3	14.5	28.4	28.4
1	Ethiopia	11.9	16.1	19.0	23.6	43.0	43.0
1	Guinea	0.6	2.5	2.5	1.7	4.2	4.2
1	Kenya	0.6	6.3	6.3	4.3	10.5	10.5
1	Mozambique	1.8	2.9	3.1	4.4	8.3	8.3
1	Nigeria	16.8	22.7	26.9	29.8	54.3	54.3
1	Togo	0.5	1.4	1.4	1.0	2.2	2.2
2	Sudan	1.6	7.9	7.9	4.2	11.9	11.9
2	Yemen	1.9	2.0	2.8	3.0	6.2	6.2
3	China	12.9	15.9	27.5	57.0	157.7	157.7
3	Indonesia	3.3	8.0	8.0	9.9	23.9	23.9
4	Bangladesh	4.2	6.8	8.2	10.5	27.8	27.8
5	Haiti	0.5	1.1	1.1	1.2	2.7	2.7
6	Uzbekistan	1.2	0.0	1.2	1.2	2.1	2.1

Table 28. Predicted deaths averted for achieving six water and sanitation coverage scenarios, by selected country

Regional code	World Region	MDG			Universal		
		Water	Sanitation	W&S	Water	Sanitation	W&S
1	Benin	362	278	504	972	2'272	2'272
1	DRC	6'304	9'524	10'425	14'586	28'626	28'626
1	Ethiopia	11'965	16'222	19'149	23'826	43'320	43'320
1	Guinea	626	2'489	2'489	1'705	4'179	4'179
1	Kenya	617	6'363	6'363	4'356	10'593	10'593
1	Mozambique	1'847	2'934	3'145	4'403	8'333	8'333
1	Nigeria	16'947	22'830	27'072	30'053	54'641	54'641
1	Togo	468	1'364	1'364	1'038	2'237	2'237
2	Sudan	1'604	7'989	7'989	4'221	11'961	11'961
2	Yemen	1'919	2'083	2'858	3'112	6'328	6'328
3	China	7'149	8'864	15'272	31'685	87'625	87'625
3	Indonesia	3'201	7'879	7'879	9'768	23'468	23'468
4	Bangladesh	4'040	6'470	7'828	10'083	26'583	26'583
5	Haiti	409	960	960	1'088	2'310	2'310
6	Uzbekistan	1'117	0	1'117	1'117	2'031	2'031

4.6 Economic benefits by benefit type

Figures 17 and 18 summarise the economic benefits for the selected countries. It is clear from the figures that the convenience time savings account for the major share of total economic benefits, followed by the associated economic gains of saved lives. The figures also show the dominance of the larger countries with projected coverage rates that fall far short of the MDG targets, such as DRC, Nigeria, Indonesia and China, and to a lesser extent Bangladesh, Kenya, Sudan and Ethiopia. Full results for the selected countries are presented in Annex 4 Tables 1 to 5.

Figure 17. Summary of economic benefits for selected sub-Saharan African countries for achieving the combined water and sanitation MDGs

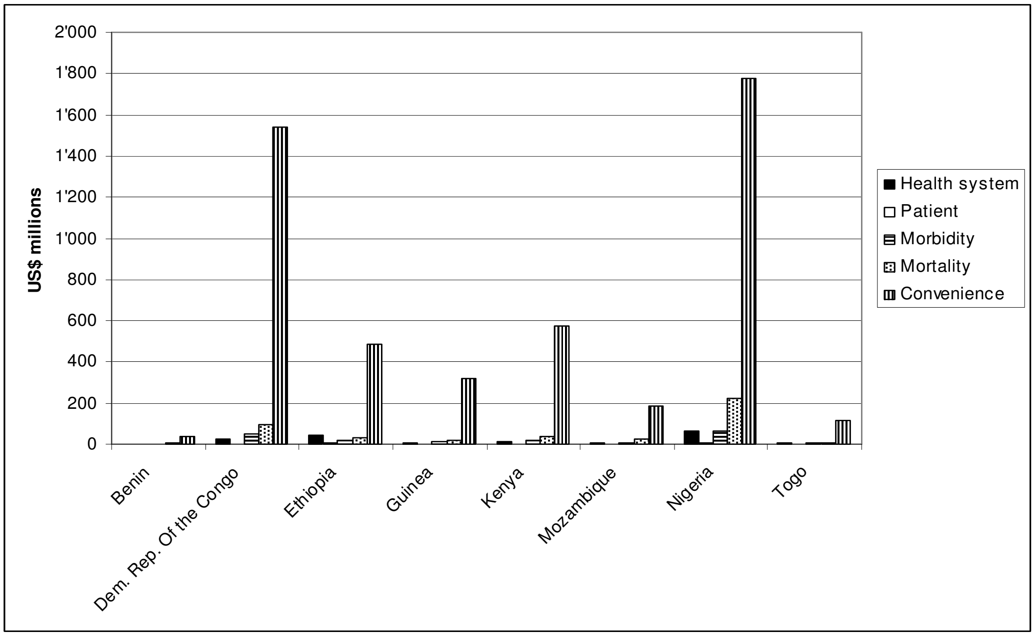
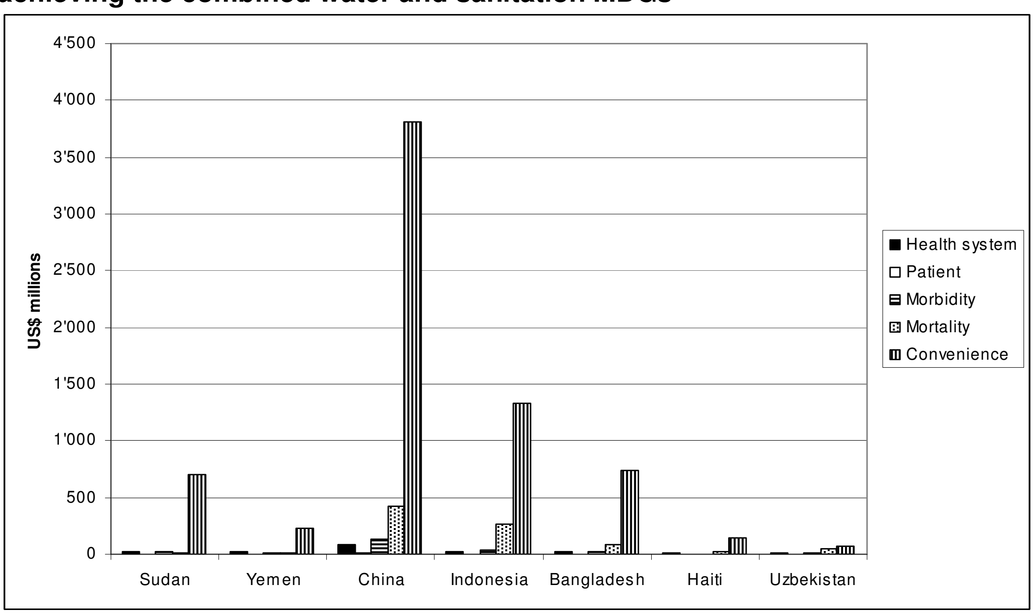


Figure 18. Summary of economic benefits for selected other countries for achieving the combined water and sanitation MDGs



5. Discussion

5.1 Study focus

This study has presented water and sanitation coverage improvements under two main scenarios: the scenario of meeting the MDG targets for water and sanitation, and the scenario of universal coverage. The first of these, the MDG target scenario, compared the MDG target with a baseline of the projected coverage levels in 2015 at the current ‘rate’ of coverage improvement. Hence, these results focussed on regions and countries that are at greatest risk of not achieving the water and sanitation MDG targets. This focus has been further emphasised by the presentation in section 4of cost-benefit results from 15 of these countries at risk of not achieving the water and sanitation MDG targets. Such an analysis should be considered a useful addition to previous global cost or cost-benefit analyses which did not take into account the rate of progress over the first period (1990 to 2003). The usefulness of this analysis lies in the fact that both international and national fund holders and policy makers need to be alerted to the additional efforts and costs required to meet the MDGs, as well as the implications of not making renewed efforts to meet the MDGs (i.e. benefits foregone). In other words, if countries, donor governments and international organisations continue with “business as usual” between now and the year 2015, what are the major missed opportunities for improving the lives of those living without improved water supply and sanitation services? This study comes at a time when the international community is asking itself what it has to do to achieve the MDG targets, especially in countries that appear to be making only limited (if any) progress towards them.

5.2 Interpretation of main findings

The cost-benefit analysis results of the selected water and sanitation coverage scenarios are highly favourable, standing at between US$3 and US$21 economic benefit per US$1 invested for all developing world regions. These results give to water and sanitation advocates a powerful basis for arguing for increased water and sanitation investments.

The cost-benefit ratio remains above US$1 even under less optimistic assumptions for some of the key variables in the analysis. However, a more comprehensive and multi-way probabilistic sensitivity analysis was not conducted as part of this study, and therefore the study cannot conclude how different sources of uncertainty may interact with each other, thus tempering interpretation of the cost-benefit results.

Offsetting this uncertainty and a cautious approach to interpreting the results is the fact that intervention benefits are likely to be underestimated. While some of the intervention benefits included such as time savings have considerable uncertainty and variability between settings, other benefits have been left out altogether, such as non-time and non-health related benefits of latrines (e.g. see Jenkins et al 1999 [34], presented in Cairncross and Valdmanis 2006 [19]), aesthetic and non-use value of improved water resources, and so on. Omitted benefits were left out for a variety of reasons, including the lack of research evidence presenting the likely range of benefits per project or per person; problems in valuing benefits in economic terms; and the fact that some benefits were likely to be small in relation to others.

The main contributor to the cost of the low technology interventions selected was found to be the investment cost for the interventions. The main contributor to the overall economic benefits was the time saving associated with more convenient access to water supply and sanitation, while health-related productivity gains and health care cost savings were also important.

In interpreting the impressive cost-benefit ratios presented in this study, an important caveat needs to be taken into account. On the cost side, the costs are very tangible, requiring financial and time input upfront for the interventions to be put in place. On the benefit side, however, the majority of the benefits are not highly tangible, in that the benefits do not bring immediate money 'in the hand'. The benefits involve possible money savings from less health service use, accruing to both the health sector and the patient. The reduced number of days spent ill can lead to direct economic benefits, such as more time spent on income earning activities, or to other benefits such as more leisure time or more time spent at school, which do not have immediate economic implications. On the other hand, the benefits related to time savings due to less time spent collecting water or accessing sanitation services can also be argued to be valuable to household members, as it increases their time spent in productive activities.

Therefore, while this analysis attempted to make realistic assumptions about the economic value of these potential savings, it is recognised that the real economic benefits accruing to the population may not be financial in nature, nor will they be immediate. Also, the real benefits depend on a number of factors related to the individual or household, such as what activities are done instead when time is saved or illness avoided, and what health seeking behaviour does he/she engage in. Furthermore, the assumptions about the value of time may overestimate the actual economic value, due to the presence of unemployment, underemployment or seasonal labour, which together determine the income earned when more time is available for work. In some cases the changes in time uses will lead to income gains, but data from micro-economic studies to support the assumptions used in this study are limited. On the other hand, potential economic benefits omitted from the analysis offsets this uncertainty, and may eventually produce even more favourable cost-benefit ratios.

5.3 Financing considerations

While cost-benefit analysis can be carried out to identify clearly all the beneficiaries and the (potential) financers of development projects, the analysis does not provide answers to the question of who should pay. This represents a particular challenge to economic evaluation when health care interventions have non-health sector costs and benefits, as the objective of the health ministry – "to maximise health with a given budget" – may come into conflict with other societal objectives, including the maximisation of non-health related welfare. For this reason, the societal perspective is very rarely represented in a comprehensive way in the economic evaluation of health care programmes.

If all costs and benefits are included in a cost-benefit analysis, then a full analysis can be made of financing options. While this study did not include all the benefits, the most widespread benefits were included, which were generally the benefits where country and regional averages could be estimated. For example, benefits accruing to agriculture and industry are very setting-specific, and even estimating economic gains by country would be a challenging task. One of the problems associated with identifying beneficiaries in order to identify those willing to pay for the costs is that the main beneficiaries (patients and consumers) do not always understand the full benefits until well after the investment. Also, most costs are incurred in the first year of the intervention, while benefits accrue over time. These factors together lead to a type of market failure, and implies that many private consumers cannot be expected to finance the initial investment costs up-front. On the other hand, water supply improvements may in fact involve a lower annual cost than the current options, if water trucks, water vendors or bottled water are presently used. This means that certain groups could be convinced that a household water connection could be cheaper in the short and long-term, and therefore persuade them to finance water supply improvements privately.

With respect to the question whether the health sector would be interested in financing the interventions, it is clear from this analysis that in most regions and for most interventions there is little incentive for the health sector to make significant contributions to the costs, as the real savings to the sector are small in comparison to the annual intervention costs. Compared to the potential cost savings reported in this study, it is unlikely that the health sector will ever be able to recover these costs, as only a small proportion are marginal costs directly related to the treatment cost of the diarrhoeal episode. Most costs, such as personnel and infrastructure, are fixed costs that do not change with patient throughput in the short-term. On the other hand, the reduced burden to the health system due to less patients presenting with diarrhoea will free up capacity in the health system to treat other patients.

The implication of these arguments is that there should exist a variety of financing mechanisms for meeting the costs of water and sanitation improvements, depending on the income and asset base of the target populations, the availability of credit, the economic benefits perceived by the various stakeholders, the budget freedom of government ministries, and the presence of NGOs to promote and finance water and sanitation improvements. One finding is clear though: the health sector, with the meagre budget it has at its disposal in most developing countries, cannot and should not be expected to fund water and sanitation improvements. On the other hand, it can play a key role in providing the 'software' (education for behaviour change) alongside 'hardware' interventions, involving both technical and limited financial contributions, and it can provide a strengthened knowledge base to repeat at the national level the type of analysis presented in this publication from a global perspective.

5.4 Other issues

The definition of access in meeting the MDGs is more on a development (i.e. physical access) rather than a public health (i.e. water quality) perspective. This study purposefully did not consider disinfection at the point-of-use, but the potential cost-benefit (as presented in Hutton and Haller) could be raised here.

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Annex 1. WHO world sub-regions

Table 1. Countries included in World Health Organization epidemiological sub-regions

Region*	Mortality stratum**	Countries
AFR	**D**	Algeria, Angola, Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Comoros, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Niger, Nigeria, Sao Tome And Principe, Senegal, Seychelles, Sierra Leone, Togo
AFR	**E**	Botswana, Burundi, Central African Republic, Congo, Côte d'Ivoire, Democratic Republic Of The Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Uganda, United Republic of Tanzania, Zambia, Zimbabwe
AMR	**B**	Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, El Salvador, Grenada, Guyana, Honduras, Jamaica, Mexico, Panama, Paraguay, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela
AMR	**D**	Bolivia, Ecuador, Guatemala, Haiti, Nicaragua, Peru
EMR	**B**	Bahrain, Cyprus, Iran (Islamic Republic Of), Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates
EMR	**D**	Afghanistan, Djibouti, Egypt, Iraq, Morocco, Pakistan, Somalia, Sudan, Yemen
EUR	**B**	Albania, Armenia, Azerbaijan, Bosnia And Herzegovina, Bulgaria, Georgia, Kyrgyzstan, Poland, Romania, Slovakia, Tajikistan, The Former Yugoslav Republic Of Macedonia, Turkey, Turkmenistan, Uzbekistan, Yugoslavia
EUR	**C**	Belarus, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, Republic of Moldova, Russian Federation, Ukraine
SEAR	**B**	Indonesia, Sri Lanka, Thailand
SEAR	**D**	Bangladesh, Bhutan, Democratic People's Republic Of Korea, India, Maldives, Myanmar, Nepal
WPR	**B**	Cambodia, China, Lao People's Democratic Republic, Malaysia, Mongolia, Philippines, Republic Of Korea, Viet Nam
		Cook Islands, Fiji, Kiribati, Marshall Islands, Micronesia (Federated States Of), Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu

* AFR = Africa Region; AMR = Region of the Americas; EMR = Eastern Mediterranean Region; EUR = European Region; SEAR = South East Asian Region; WPR = Western Pacific Region

** B = low adult, low child mortality; C = high adult, low child mortality; D = high adult, high child mortality; E = very high adult, high child mortality

Annex 2. Countries included in MDG analysis

Table 1. Remaining % population by country to be served to reach MDG target compared to the 2015 forecast

Country	Remaining % population to be served to reach MDG target compared to the 2015 forecast	
	Water MDG target	Sanitation MDG target
World Region 1: Sub-Saharan Africa		
Angola	1	33
Benin	11	5
Botswana	0	26
Burkina Faso	0	36
Burundi	0	41
Cameroon	0	22
Central African Republic	0	29
Chad	0	43
Comoros	16	35
Cote d'Ivoire	0	12
Dem. Rep. Of the Congo	22	18
Eritrea	0	44
Ethiopia	39	29
Ghana	0	36
Guinea	16	35
Kenya	5	26
Liberia***	14	50
Madagascar	18	10
Malawi	0	3
Mali	2	15
Mauritania	0	26
Mozambique	23	20
Namibia	0	38
Niger	16	35
Nigeria	30	22
Rwanda	0	20
South Africa	0	23
Togo	21	33
Uganda	0	28
United Republic of Tanzania	1	26
Zambia	7	9
Zimbabwe	4	21
World Region 2: Arab States		
Algeria	20	0
Djibouti	12	6
Jordan	0	5
Morocco	4	0
Sudan	11	32
Yemen	23	14
World Region 3: East Asia & Pacific		
China	4	3
Cook Islands	0	0
Dem. People's Republic of Korea	0	0

Country	Remaining % population to be served to reach MDG target compared to the 2015 forecast	
	Water MDG target	Sanitation MDG target
Fiji	0	10
Indonesia	7	9
Kiribati	0	5
Marshall Islands	18	0
Micronesia, (Fed. States of)	0	35
Palau	4	0
Philippines	12	0
Samoa	11	0
Vanuatu	20	0
World Region 4: South Asia		
Bangladesh	10	8
India	0	9
Maldives	23	0
Nepal	0	2
World Region 5: Latin America & Caribbean		
Bolivia	0	10
Brazil	0	7
Colombia	2	0
El Salvador	0	7
Haiti	16	21
Jamaica	1	3
Nicaragua	1	26
Peru	0	5
Trinidad and Tobago	6	0
World Region 6: Eastern Europe & CIS		
Azerbaijan	1	0
Georgia	6	4
Russian Federation	0	6
Slovakia	0	0
Uzbekistan	21	0

Countries not included in the table are excluded from the MDG analysis. For some countries, this is because the MDG target is predicted to be met at current projections. For other countries, this is due to missing data to make a projection (either no base year, or no mid-point year such as 2002 or 2004).

Annex 3. Health impact by age group

Table 1. Diarrheal cases averted by age group from achieving intervention 1 (water MDG)

World Region	*0 to 1*	*1 to 4*	*5 to 14*	*15 to 59*	*60 plus*	*Total*
Sub-Saharan Africa	12.2	16.6	8.2	5.2	0.5	42.6
Arab States	1.3	1.8	0.8	0.6	0.1	4.5
East Asia & Pacific	2.6	3.8	2.3	8.3	1.3	18.3
South Asia	1.1	1.6	0.7	0.8	0.1	4.3
Latin America & Caribb.	0.2	0.2	0.2	0.2	0.0	0.8
Eastern Europe & CIS	0.3	0.5	0.2	0.2	0.0	1.2
Non-OECD	**17.6**	**24.5**	**12.4**	**15.2**	**2.0**	**71.7**

Table 2. Diarrheal cases averted by age group from achieving intervention 2 (sanitation MDG)

World Region	*0 to 1*	*1 to 4*	*5 to 14*	*15 to 59*	*60 plus*	*Total*
Sub-Saharan Africa	32.4	44.1	21.7	13.6	1.3	113.0
Arab States	2.9	4.0	1.8	1.3	0.1	10.1
East Asia & Pacific	3.6	5.2	3.1	10.5	1.6	24.0
South Asia	8.3	12.2	5.0	6.3	0.8	32.6
Latin America & Caribb.	1.8	2.7	2.6	1.8	0.2	9.0
Eastern Europe & CIS	0.2	0.2	0.0	0.2	0.1	0.7
Non-OECD	**49.1**	**68.3**	**34.2**	**33.8**	**4.1**	**189.5**

Table 3. Diarrheal cases averted by age group from achieving intervention 3 (water and sanitation MDG)

World Region	*0 to 1*	*1 to 4*	*5 to 14*	*15 to 59*	*60 plus*	*Total*
Sub-Saharan Africa	35.3	48.1	23.6	14.9	1.4	123.3
Arab States	3.4	4.7	2.1	1.5	0.1	11.8
East Asia & Pacific	5.2	7.5	4.8	17.5	2.7	37.7
South Asia	8.7	12.7	5.2	6.6	0.8	34.0
Latin America & Caribb.	1.9	2.8	2.7	1.8	0.2	9.4
Eastern Europe & CIS	0.4	0.7	0.3	0.4	0.1	1.9
Non-OECD	**54.9**	**76.4**	**38.8**	**42.8**	**5.3**	**218.1**

Table 4. Diarrheal cases averted by age group from achieving intervention 4 (water universal coverage)

World Region	*0 to 1*	*1 to 4*	*5 to 14*	*15 to 59*	*60 plus*	*Total*
Sub-Saharan Africa	32.2	43.9	21.6	13.6	1.3	112.5
Arab States	2.7	3.7	1.6	1.2	0.1	9.4
East Asia & Pacific	8.7	12.5	9.0	34.7	5.3	70.2
South Asia	4.3	6.3	2.6	3.3	0.4	16.8
Latin America & Caribb.	1.4	2.0	2.0	1.3	0.2	6.9
Eastern Europe & CIS	0.3	0.5	0.2	0.3	0.1	1.4
Non-OECD	**49.6**	**68.9**	**36.9**	**54.5**	**7.4**	**217.3**

Table 5. Diarrheal cases averted by age group from achieving intervention 5 (sanitation universal coverage)

World Region	*0 to 1*	*1 to 4*	*5 to 14*	*15 to 59*	*60 plus*	*Total*
Sub-Saharan Africa	70.8	96.5	47.4	29.9	2.8	247.4
Arab States	7.4	10.1	4.4	3.4	0.3	25.6
East Asia & Pacific	24.1	34.7	24.9	96.2	14.8	194.7
South Asia	44.6	65.4	27.0	34.1	4.2	175.1
Latin America & Caribb.	5.2	7.7	7.5	5.2	0.7	26.2
Eastern Europe & CIS	1.0	1.5	0.5	0.9	0.2	4.1
Non-OECD	**153.1**	**215.9**	**111.7**	**169.6**	**22.9**	**673.1**

Table 6. Diarrheal cases averted by age group from achieving intervention 6 (water and sanitation universal coverage)

World Region	*0 to 1*	*1 to 4*	*5 to 14*	*15 to 59*	*60 plus*	*Total*
Sub-Saharan Africa	70.8	96.5	47.4	29.9	2.8	247.4
Arab States	7.4	10.1	4.4	3.4	0.3	25.6
East Asia & Pacific	24.1	34.7	24.9	96.2	14.8	194.7
South Asia	44.6	65.4	27.0	34.1	4.2	175.1
Latin America & Caribb.	5.2	7.7	7.5	5.2	0.7	26.2
Eastern Europe & CIS	1.0	1.5	0.5	0.9	0.2	4.1
Non-OECD	**153.1**	**215.9**	**111.7**	**169.6**	**22.9**	**673.1**

Table 7. Deaths averted due to diarrhea by age group from achieving intervention 1 (water MDG)

World Region	*0 to 4*	*5 to 14*	*15 to 59*	*Total*
Sub-Saharan Africa	37'464	3'519	1'976	42'958
Arab States	3'984	331	224	4'539
East Asia & Pacific	8'282	1'008	3'185	12'475
South Asia	3'465	282	317	4'064
Latin America & Caribb.	538	101	58	697
Eastern Europe & CIS	963	92	80	1'135
Non-OECD	**54'696**	**5'333**	**5'840**	**65'870**

Table 8. Deaths averted due to diarrhea by age group from achieving intervention 2 (sanitation MDG)

World Region	*0 to 4*	*5 to 14*	*15 to 59*	*Total*
Sub-Saharan Africa	99'300	9'331	5'234	113'865
Arab States	8'916	795	486	10'197
East Asia & Pacific	11'390	1'322	4'045	16'757
South Asia	26'565	2'162	2'430	31'157
Latin America & Caribb.	5'792	1'109	682	7'582
Eastern Europe & CIS	525	20	79	624
Non-OECD	**152'488**	**14'739**	**12'956**	**180'182**

Table 9. Deaths averted due to diarrhea by age group from achieving intervention 3 (water and sanitation MDG)

World Region	*0 to 4*	*5 to 14*	*15 to 59*	*Total*
Sub-Saharan Africa	108'349	10'180	5'711	124'240
Arab States	10'476	920	575	11'972
East Asia & Pacific	16'511	2'076	6'703	25'290
South Asia	27'743	2'258	2'538	32'539
Latin America & Caribb.	5'997	1'149	709	7'855
Eastern Europe & CIS	1'472	112	157	1'741
Non-OECD	**170'548**	**16'696**	**16'393**	**203'637**

Table 10. Deaths averted due to diarrhea by age group from achieving intervention 4 (water universal coverage)

World Region	*0 to 4*	*5 to 14*	*15 to 59*	*Total*
Sub-Saharan Africa	98'837	9'287	5'210	113'334
Arab States	8'401	701	472	9'573
East Asia & Pacific	27'460	3'868	13'322	44'650
South Asia	13'721	1'117	1'255	16'093
Latin America & Caribb.	4'450	848	513	5'811
Eastern Europe & CIS	1'146	99	108	1'353
Non-OECD	**154'014**	**15'919**	**20'880**	**190'814**

Table 11. Deaths averted due to diarrhea by age group from achieving intervention 5 (sanitation universal coverage)

World Region	*0 to 4*	*5 to 14*	*15 to 59*	*Total*
Sub-Saharan Africa	217'336	20'423	11'455	249'213
Arab States	22'714	1'883	1'294	25'891
East Asia & Pacific	76'449	10'743	36'871	124'063
South Asia	142'786	11'622	13'063	167'471
Latin America & Caribb.	16'763	3'216	1'991	21'970
Eastern Europe & CIS	3'162	220	350	3'732
Non-OECD	**479'210**	**48'107**	**65'022**	**592'339**

Table 12. Deaths averted due to diarrhea cases averted by age group from achieving intervention 6 (water and sanitation universal coverage)

World Region	*0 to 4*	*5 to 14*	*15 to 59*	*Total*
Sub-Saharan Africa	217'336	20'423	11'455	249'213
Arab States	22'714	1'883	1'294	25'891
East Asia & Pacific	76'449	10'743	36'871	124'063
South Asia	142'786	11'622	13'063	167'471
Latin America & Caribb.	16'763	3'216	1'991	21'970
Eastern Europe & CIS	3'162	220	350	3'732
Non-OECD	**479'210**	**48'107**	**65'022**	**592'339**

Annex 4. Economic benefits by type for selected countries

Table 1. Estimated health system costs saved (US$ millions) for achieving six water and sanitation coverage scenarios, by selected country

Regional code	World Region	MDG			Universal		
		Water	Sanitation	W&S	Water	Sanitation	W&S
1	Benin	1	1	1	2	6	6
1	DRC	15	23	25	36	70	70
1	Ethiopia	29	40	47	58	106	106
1	Guinea	2	6	6	4	10	10
1	Kenya	2	16	16	11	26	26
1	Mozambique	5	7	8	11	20	20
1	Nigeria	41	56	66	74	134	134
1	Togo	1	3	3	3	5	5
2	Sudan	4	20	20	10	29	29
2	Yemen	13	15	20	8	15	15
3	China	40	50	86	140	389	389
3	Indonesia	8	21	21	24	59	59
4	Bangladesh	11	18	21	26	69	69
5	Haiti	4	10	10	3	7	7
6	Uzbekistan	6	0	6	3	5	5

Table 2. Estimated patient costs saved (US$ millions) for achieving six water and sanitation coverage scenarios, by selected country

Regional code	World Region	MDG			Universal		
		Water	Sanitation	W&S	Water	Sanitation	W&S
1	Benin	0.1	0.1	0.2	0.3	0.7	0.7
1	DRC	1.9	2.9	3.1	4.4	8.6	8.6
1	Ethiopia	3.6	4.9	5.7	7.1	13.0	13.0
1	Guinea	0.2	0.7	0.7	0.5	1.3	1.3
1	Kenya	0.2	1.9	1.9	1.3	3.2	3.2
1	Mozambique	0.6	0.9	0.9	1.3	2.5	2.5
1	Nigeria	5.1	6.8	8.1	9.0	16.4	16.4
1	Togo	0.1	0.4	0.4	0.3	0.7	0.7
2	Sudan	0.5	2.4	2.4	1.3	3.6	3.6
2	Yemen	0.6	0.6	0.8	0.9	1.9	1.9
3	China	3.9	4.8	8.3	17.2	47.6	47.6
3	Indonesia	1.0	2.4	2.4	3.0	7.2	7.2
4	Bangladesh	1.3	2.0	2.5	3.2	8.4	8.4
5	Haiti	0.1	0.3	0.3	0.4	0.8	0.8
6	Uzbekistan	0.4	0.0	0.4	0.4	0.6	0.6

Table 3. Economic value of work loss days avoided (US$ millions) for achieving six water and sanitation coverage scenarios, by selected country

Regional code	World Region	MDG			Universal		
		Water	Sanitation	W&S	Water	Sanitation	W&S
1	Benin	1	1	2	3	8	8
1	DRC	33	51	52	73	152	144
1	Ethiopia	12	16	18	22	42	40
1	Guinea	3	12	11	8	20	19
1	Kenya	2	22	21	14	37	35
1	Mozambique	4	6	6	9	18	17
1	Nigeria	43	57	64	71	137	130
1	Togo	1	4	4	3	7	6
2	Sudan	5	25	24	13	38	36
2	Yemen	7	7	9	10	21	20
3	China	86	107	130	271	1'057	748
3	Indonesia	18	45	41	51	135	124
4	Bangladesh	15	24	26	34	98	89
5	Haiti	2	5	5	5	12	11
6	Uzbekistan	8	0	7	7	15	14

Table 4. Economic contribution due to saving lives (US$ millions) for achieving six water and sanitation coverage scenarios, by selected country

Regional code	World Region	MDG			Universal		
		Water	Sanitation	W&S	Water	Sanitation	W&S
1	Benin	2	2	3	6	15	15
1	DRC	58	88	96	135	265	265
1	Ethiopia	20	27	32	40	73	73
1	Guinea	5	21	21	14	34	34
1	Kenya	4	39	39	26	64	64
1	Mozambique	15	24	26	36	69	69
1	Nigeria	140	188	223	248	450	450
1	Togo	3	8	8	6	12	12
2	Sudan	4	17	17	9	26	26
2	Yemen	8	9	12	14	28	28
3	China	198	246	423	878	2'428	2'428
3	Indonesia	110	272	272	337	810	810
4	Bangladesh	41	65	79	102	268	268
5	Haiti	13	30	30	34	72	72
6	Uzbekistan	49	0	49	49	90	90

Table 5. Economic value of convenience time savings (US$ millions) for achieving six water and sanitation coverage scenarios, by selected country

Regional code	World Region	MDG			Universal		
		Water	Sanitation	W&S	Water	Sanitation	W&S
1	Benin	10	26	36	17	162	179
1	DRC	257	1'280	1'537	363	2'562	2'924
1	Ethiopia	89	397	485	108	647	754
1	Guinea	23	298	321	38	399	436
1	Kenya	16	560	576	71	745	816
1	Mozambique	30	158	188	44	287	331
1	Nigeria	327	1'452	1'778	364	2'104	2'468
1	Togo	11	103	114	14	122	137
2	Sudan	39	664	703	63	841	903
2	Yemen	51	181	231	70	529	598
3	China	749	3'064	3'813	3'217	41'652	44'869
3	Indonesia	146	1'185	1'331	485	4'989	5'474
4	Bangladesh	117	617	733	250	3'004	3'255
5	Haiti	16	125	141	31	256	287
6	Uzbekistan	67	0	67	81	386	467