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Water, sanitation and hygiene

Quantifying the health impact at national and local levels in countries with incomplete water supply and sanitation coverage

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A Microsoft Excel spreadsheet for calculating the estimates described in this document can be obtained from WHO/PHE. E-mail contact: EBDassessment@who.int

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Table of contents

List of tables

List of Figures

List of Annexes

Preface

In the formulation of rational risk management policies, policy-makers increasingly rely on estimates of the disease burden attributable to certain risk factors. Decision-makers consider such estimates and the distribution of the burden within populations to create frameworks for effective interventions.

Obtaining objective, reliable and accurate measurements of such attributable fractions of disease burdens is therefore of growing importance. Yet, the complexities of the links between environmental risk factors and their health effects continue to hamper the quantification of attributable fractions. This quantification itself and the opportunities it creates for potential health gains from implementing targeted interventions will not only support rational policy making. It will also facilitate, through raising awareness of the environmental risk dimensions of the disease burden, intersectoral collaboration needed to carry out environmental health interventions to the maximum of their potential impact. In the context of the present publication, the environmental focus is on water (access to safe water and integrated water resources management), sanitation and hygiene

The World Health Organization (WHO) carried out an assessment of the global disease burden from unsafe water, sanitation and hygiene, as part of a larger initiative to assess the impact of 25 risk factors in a standardized manner (WHO, 2002; Prüss et al., 2002; Murray and Lopez, 1996a). It also commissioned systematic literature reviews of the fraction of the estimated burden of four water-associated vector-borne diseases that can be attributed to water resources development (irrigation schemes and dams) (Keiser et al., 2005a; Erlanger et al., 2005; Keiser et al., 2005b; Steinmann et al., 2006). This guide builds on these, by providing a tool for public health professionals to carry out more-detailed estimates of the disease burden associated with water, sanitation and hygiene at both national and sub-national levels. It is complemented by an introductory volume on methods for assessing the environmental burden of disease (Prüss-Üstün et al., 2003). It is part of a series providing guidance on quantifying disease from various environmental risks.

Work on estimating the health impacts of interventions to tackle water sanitation and hygiene related disease is one component of the activities of WHO in the subject area. It complements and builds on other activities including:

- monitoring status and trends on use of basic water supply and sanitation and building national capacities for national and local monitoring (with UNICEF through the WHO/UNICEF 'Joint Monitoring Programme';
- normative 'Guidelines' analogous to international standards on drinking water quality, safe use of wastewater and excreta in agriculture, aquaculture and urban areas; safe recreational water environments;
- guidance on 'good practice' based on lessons learned in effectively managing water sanitation and hygiene hazards;
- supporting networks for practitioners in areas such as safe household water, small community water supply and safety, sanitation, and drinking-water regulators;

- information and publications in these and other areas are downloadable from the WHO website at www.who.int/water_sanitation_health/.

Affiliations and acknowledgements

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In preparing this document, we drew on methods developed for estimating the global burden of disease caused by exposure to unsafe water, sanitation and hygiene and the systematic literature review of the association between water resources development and vector-borne diseases. We therefore thank David Kay of the University of Wales, Aberystwyth, contributor to the global analysis, and Jürg Utzinger, Jennifer Keiser and their team at the Swiss Tropical Institute, Basel for the adaptation and application of the systematic review approach.

Abbreviations

DALY Disability-adjusted life years

WSH Water, sanitation and hygiene

Summary

This guide aims to assist in the development of a quantitative estimate of health impacts attributable to water, sanitation and hygiene (WSH) related risks at country or local level. Most of data available for the methods used cover developing countries, and this guide is therefore mainly relevant to developing countries. Eleven diseases or injuries are reviewed. For diarrhoea, a calculation method based on access levels to safe water and adequate sanitation service levels is used. The disease burden from malnutrition is linked to WSH risks because of repeated diarrhoea and intestinal nematode infections especially affecting children. Several infectious diseases such as intestinal nematode infections, schistosomiasis, trachoma or dengue in certain regions are almost entirely attributable to WSH-related risks. The fraction of the other diseases, including malaria, lymphatic filariasis, onchocerciasis, Japanese encephalitis and drowning that is attributable to WSH should be estimated based on the basis of expert judgement and, where possible, a systematic review of the literature. Methods for pooling of expert judgement and for systematic literature reviews are outlined in this guide.

The fractions of disease attributable to WSH obtained by the methods outlined in this guide should be combined with national disease statistics for those diseases (deaths, prevalence/incidence or DALYs). Where such national disease statistics are unavailable or of poor quality, approximate estimates may also be obtained from WHO[1].

The quantification of health impacts and development of understanding of the potential benefits of interventions provide an opportunity to highlight the disease burden that could be prevented through actions in water, sanitation and hygiene. This can assist in directing interventions, and more generally motivate policy action to prevent this disease burden that disproportionately affects children in the lower socio-economic segments of the population.

[1] http://www.who.int/whosis/en/, under "Burden of disease estimates", "GBD 2002 estimates" and "Revised GBD 2002 estimates for countries".

1. Introduction

1.1 Basis for quantification of disease

Health hazards and risk factors related to water, sanitation and hygiene (WSH) are of a composite nature. Various determining aspects may need to be taken into consideration, including:

- drinking-water is *a medium* that can serve to transmit pathogens and toxic chemicals;
- the lack of *services* to provide access to safe drinking-water and adequate sanitation, and the lack of solid waste management services increase the risk of several diseases;
- the failure to apply integrated water resources management principles in the *planning, design and operation* of dams, irrigation schemes and other hydraulic projects may result in changes in water ecologies that lead to the proliferation of vectors of certain diseases (e.g. malaria, schistosomiasis, lymphatic filariasis, arbovirus infections);
- water-associated *behaviours* including for example personal and domestic hygiene, water contact patterns and unsafe use of built environments; and
- the *management* of aquatic ecosystems, which may increase or decrease disease risks.

While the impact of some of these risks has been quantified at global level and can be quantified at national and sub-national level, the impact of others is still difficult to quantify with systematic methods. Table 1 provides an overview of the diseases concerned and the possibilities of quantification as proposed by this guide. For diarrhoea, this guide provides detailed methods for quantification. The linkage to malnutrition is outlined in this guide and quantification of the burden of malnutrition attributable to WSH is covered in detail in a separate guide (Malnutrition - EBD series No. 12). Several infectious diseases such as intestinal nematode infections, schistosomiasis, trachoma or dengue in certain regions are almost entirely attributable to WSH-related risks. Quantification of the WSH-attributable fraction of the burden of other diseases, including malaria, lymphatic filariasis, onchocerciasis, dengue, Japanese encephalitis and drownings is proposed to be achieved based on the basis of expert judgment and supported by systematic literature reviews.

The overall disease burden related to unsafe water, sanitation and hygiene was first examined at a global level in 1990 (Murray & Lopez, 1996), and was limited to diarrhoeal diseases. This estimate was revised in 2002 (WHO 2002; Prüss et al, 2002; Prüss-Üstün et al. 2004) based on a systematic and transparent method. Other estimates have since been performed, based on the same method (Cairncross and Valdmanis 2006). More recently, the impact of WSH on disease has been reassessed in a more comprehensive way (WHO 2007), which estimated that almost one tenth of the global burden of disease can be attributed to water, sanitation and hygiene (see section 19 for global results). Systematic literature reviews of the association between vector-borne disease burdens and water resources development were commissioned by WHO in 2004 from the Swiss Tropical Institute and showed that, for example for malaria, the vector-borne disease with the highest burden, there are great regional variations in populations at risk of the disease due to proximity of man-made reservoirs and irrigation schemes, and that changes in transmission seasonality and intensity in the wake of water resources development are caused by a complex mixture of contextual determinants (Keiser et al., 2005a).

Governance of water, sanitation and hygiene partially overlaps a number of sectors, such as occupation, energy or nutrition. Rather than trying to disentangle this into separate elements, the important issue is that some of this burden could also be prevented by encouraging other sectors to take complementary action, such as improving workers' protection.

Table 1 Diseases related to unsafe water, sanitation and hygiene[a]

Disease outcome	Comments
Infectious diarrhoea includes e.g. cholera, salmonellosis, amoebiasis, other bacterial, protozoal and viral intestinal diseases	Quantitative estimate proposed in this document (acute effects only)
Typhoid and paratyphoid fevers	Partly included in the estimate for infectious diarrhoea
Hepatitis A, E, F	Not addressed in this guide
Malnutrition	Quantitative estimate proposed[b]
Fluorosis	Not addressed in this guide
Arsenicosis	Not addressed in this guide
Legionellosis	Not addressed in this guide
Methaemoglobinaemia	Not addressed in this guide
Schistosomiasis	Considered to be 100% related to WSH risks
Trachoma	Considered to be 100% related to WSH risks; WHO is in the process of establishing criteria for certification of the elimination of blinding trachoma as a public health problem.
Intestinal nematode infections (ascariasis trichuriasis, hookworm disease, other)	Considered to be 100% due to unsafe WSH
Dracunculiasis	Considered to be 100% due to unsafe WSH, eradication of the disease is imminent.
Scabies	Not addressed in this guide
Dengue	Local assessment required for attributable fraction; globally estimated that 95% is attributable to WSH; expert judgement and systematic literature review recommended for certain regions
Lymphatic filariasis	Local assessment required for attributable fraction; globally estimated that 66% is attributable to WSH; expert judgement and systematic literature review recommended
Malaria	Local assessment required for attributable fraction; globally estimated that 42% is attributable to WSH; expert judgement and systematic literature review recommended
Japanese encephalitis	Local assessment required for attributable fraction; globally estimated that 95% is attributable to WSH; expert judgement and systematic literature review recommended
Onchocerciasis	Local assessment required for attributable fraction; globally estimated that 10% is attributable to WSH; expert judgement and systematic literature review recommended
Yellow fever	Not addressed in this guide
Impetigo	Not addressed in this guide
Drowning	Local assessment required; globally estimated that 72% is attributable to WSH; expert judgement recommended

[a] This list of diseases is not exhaustive - see Section 10, "Other diseases"
[b] Blössner and de Onis 2005
Sources: WHO 2002
Prüss-Üstün and Corvalán 2006
Keiser et al., 2005a, b; Erlanger et al., 2005; Steinmann et al., 2006

Water, sanitation and hygiene-related risks can actually be classified into three broad areas, and each of the areas impacts on certain diseases (although certain diseases are impacted by several groups of interventions). Table 2 illustrates such a grouping.

Table 2 Groups of WSH risks and related diseases

Groups of WSH risks and interventions	Main diseases impacted
Water supply, sanitation and hygiene	Infectious diarrhoea Malnutrition and consequences of malnutrition on most infectious diseases[a] Intestinal nematode infections (ascariasis trichuriasis, hookworm disease, other) schistosomiasis Trachoma lymphatic filariasis
Water resources management	Malaria Onchocerciasis Dengue Japanese encephalitis
Safety of water environments	Drownings

[a] Certain diseases that are a consequence of malnutrition are also a direct consequence of WSH. For the purpose of calculations, and in order to avoid an overestimate, those diseases are included only once as direct consequence of WSH, and not again as a consequence of malnutrition (this concerns diarrhoeal diseases, malaria, schistosomiasis, lymphatic filariasis, onchocerciasis, dengue, Japanese encephalitis, trachoma and intestinal nematode infections).

Counterfactual scenario

For estimating the burden of disease caused by a risk factor, a counterfactual (or baseline) exposure needs to be defined. The estimated disease burden is the burden that would be avoided if the current risk levels were reduced to the counterfactual exposure. For environmental risks, this counterfactual is generally the following: "Disease transmission/causation that could in principle be achieved without jeopardizing environmental sustainability". This means for example that the counterfactual scenario would be no disease transmission through water supply, sanitation and hygiene, due to absence of pathogens or harmful levels of chemicals in the water supply and excreta in the environment. This also means that wetlands would not be destroyed to prevent malaria transmission, but that the counterfactual would include well managed water bodies that would not affect environmental sustainability. Such a definition actually corresponds to disease that could in principle be prevented by "reasonable" actions.

Building on the basic counterfactual for environmental risks as defined above, it is possible to further refine, or illustrate, this counterfactual according to the specific type of WSH risk group as outlined in Table 2 above:

Counterfactual for water supply, sanitation and hygiene
Ideally regulated and best practice treatment of water supply; full treatment or isolation of excreta/sewage; and optimal personal hygiene practices. These would be characterized by the absence of pathogens in the water supply and of pathogens from human excreta in the environment, and entirely prevent the transmission of faecal-oral pathogens or exposure to harmful levels of water-borne chemicals through these pathways/media.

Counterfactual for water resources management
Best design in implementation and management practices of water resource management projects (e.g. dams, irrigation, drainage) that minimize the transmission of vector-borne diseases, without jeopardizing environmental sustainability.

This includes implementation of health safeguards, health risk mitigating measures and health promotion, contained in a public health management plan based on adequate assessment and evaluation of health risks of dams, irrigation schemes and other water resources developments. This should include contextual measures related to hydraulic structures, water management practices and human water contact patterns. Reduction of the most important risks through environmental engineering in existing projects using water resources for agricultural production, energy generation and other purposes must maintain ecological integrity (excluding, for example, the complete drainage of wetlands) and measures that contribute to environmental sustainability should be prioritized, as should those with dual benefits for example for the agricultural production system and for human health.

Counterfactual for safety of water environments
Optimal safety of natural and man-made water environments without compromising the environments, within reasonable limits (physical barriers, information, prevention and rescue service, other safety measures and regulations). Such measures should not jeopardize environmental sustainability (e.g. in terms of circulation/reproduction of animals)

1.2 Choosing the study population

The study population is the population for which the disease burden is calculated. This guide mainly addresses populations at the level of entire countries or at the level of states or regions within countries. To meet the objectives, the study population should be selected according to the following criteria:

- *Data availability and reliability.* Information about risks, exposures and/or outcomes should be available for the study population. The required exposure data (e.g. access to safe water and adequate sanitation in absolute and relative terms, entomological inoculation rate in relation with vector-borne diseases) and health data (e.g. diarrhoeal disease incidence/mortality, incidence and mortality of other water-associated diseases, nutritional status) are generally available at country level, and sometimes also at district level or city level.
- *Relative vulnerability.* If certain vulnerable populations within a study perimeter have been identified and the water associated disease burden needs to be quantified, the first essential condition is that segregated health data should be available. Such vulnerable groups may include women, children, certain occupational groups or groups residing in very specific ecosystems such as wetlands. Socioeconomic status will be an important modulating factor in identifying specific vulnerable groups.
- *Chance of success for specific interventions targeted at the population.* In the selection of a study population, the potential success or failure of targeted

WSH interventions and the level of certainty linked to different interventions should contribute to the final choice.

- *Representativeness*. The selection of the study population should favour those populations that make up a representative sample for larger population groups or other population groups in similar settings, with a view to possibly scaling up successful interventions.

2. Summary of the method

The quantitative assessment of health impacts due to unsafe WSH is based on five methodologies: (a) exposure-based method for infectious diarrhoea; (b) malnutrition described in detail in EBD series No. 12, of which, globally, 50% are estimated to be due to WSH-related risks; (c) full attribution to WSH for schistosomiasis, trachoma, ascariasis, trichuriasis, hookworm disease and, in certain regions, dengue; (d) expert judgement recommended for malaria, lymphatic filariasis, Japanese encephalitis, onchocerciasis, drownings and, in certain regions, dengue; (e) systematic literature reviews of the nature and magnitude of the association between water resources development and vector-borne diseases.

A) Set the framework

- define the objectives of the quantification: policy formulation, programme development or intervention testing;
- choose the study population of interest;
- select diseases of interest, among the following:
  - diarrhoea
  - malnutrition
  - intestinal nematode infections (ascariasis trichuriasis, hookworm disease, other)
  - schistosomiasis
  - trachoma
  - malaria
  - lymphatic filariasis
  - onchocerciasis
  - dengue
  - Japanese encephalitis
  - drownings
- collect health statistics (mortality, incidence or DALYs, for children under five and adults or alternative age groups), for the selected diseases.

B) Diarrhoeal diseases

- assess exposure to drinking water, sanitation and related hygiene, according to six defined typical scenarios, including the following (in brief):
  - Improved drinking water and sanitation in countries where more than 98% of the population has access to those services
  - Improved drinking water and improved sanitation
  - Improved sanitation, but no improved drinking water
  - Improved drinking water, but no improved sanitation
  - Neither improved drinking water nor improved sanitation;
- match the exposure scenarios with relative risk information;
- use the formula for estimating the attributable fraction: $AF = \frac{\Sigma p_i RR_i - 1}{\Sigma p_i RR_i}$
  (including the proportion of uneposed in the formula, $\sum p_i=1$)
- multiply the attributable fraction with the disease statistics (deaths, incidence or DALYs);
- estimate or describe uncertainty, analyse the sensitivity of the assumptions made.

C) Malnutrition

- Assess health consequences of childhood malnutrition (based on EBD series No. 12); required data include
  - mortality (and possible incidence or DALYs) from infectious diseases in children under the age of five years;
  - percentage of children with weight-for-age below two standard deviations below the mean;
- Apply 50% of the disease burden estimated for malnutrition (or estimate the locally applicable fraction on the basis of expert opinion), except of the diseases which are already directly caused by water, sanitation and hygiene.

D) Diseases almost entirely attributable to WSH

- collect health statistics (mortality, incidence or DALYs, for children under five and adults or alternative age groups), for the selected diseases;
- for schistosomiasis, distinguish between environmental determinants of transmission, and water-associated behavioural determinants as a further basis for policy formulation and intervention design.

E) Other diseases

- decide whether experts are going to be consulted on estimation of attributable fractions;
- if so, collect local data on the subject and design a procedure to consult experts;
- collect and consolidate expert opinion on attributable fractions;
- multiply the attributable fraction with the disease statistics (deaths, incidence or DALYs).

F) Systematic literature reviews

(optional, according to available resources/required accuracy, and in particular for vector-borne diseases)

- within the boundaries set for the study group, prepare an inventory of sources of articles and reports, including the international peer-reviewed literature, national scientific journals and grey literature;
- prepare a locally relevant transmission pathway framework;
- set criteria for a systematic literature review in accordance with the study objectives and the transmission pathway framework;
- carry out the review in an iterative way;
- test assumptions made in the process for their sensitivity;
- publish outcome of the review in a report.

G) Synthesis

- summarize and present results.

3. Diarrhoeal diseases

3.1 Introduction

The method presented in this guide proposes to roughly estimate the impact of unsafe water, inadequate sanitation and poor hygiene on the burden of diarrhoeal disease. It has been applied to and tested against global evidence, which is not region-specific. Should a solid body of such regional evidence be available, then it is possible to replace the global values for relative risks, or even the defined scenarios, with such data.

Provided that statistics on diarrhoea and on access to basic water and sanitation services are available[2], this rough estimation can be performed in a relatively short period. In case the coverage in improved sanitation services is below 98%, it is likely that the fraction of diarrhoea attributable to WSH ranges between 70 and 90%. This is due to the fact that even with only 2% of inadequately disposed excreta, the level of faecal-oral pathogens in the environment is likely to be high enough that water, sanitation and hygiene play the dominant role in disease transmission. Therefore, if access to adequate sanitation is incomplete, it may not be worth refining input data on exposure for the sake of estimating disease burden. For the purpose of estimating the benefit of improving coverage, more refined exposure data would, however, be useful.

The proposed method and available input data are currently not sensitive enough for developed countries. For these countries it would be useful to review recent studies documenting diarrhoea incidence related to water supply even where the population has full access to piped water supply (Payment 1991, 1997). Also, this method does not reassess diarrhoea occurrence in case of drastic change in water and sanitation service provision, which would probably greatly change in that case because WSH are the dominant risks for this disease. The method is therefore not appropriate to estimate the reduction in disease that would be achieved if the risk factor were removed or greatly modified. The spreadsheet provided upon request (EBDassessment@who.int) assisting in the estimates outlined in this guide also contains an exploratory section of the health benefits in diarrhoea that could be achieved with improvement of water and sanitation coverage.

3.2 Assessing exposure

Faecal-oral pathogens are transmitted through a number of pathways, including:

- Through the ingestion of water as occurs during drinking. This category includes diseases from faecal-oral pathogens (such as infectious diarrhoea).
- By poor personal and domestic hygiene, often when there is a lack of sufficient quantities of water. This includes person-to-person transmission of faecal-oral pathogens and foodborne transmission of faecal-oral pathogens.
- Associated with the unsafe use of wastewater, excreta and greywater in agriculture (WHO, 2006a).

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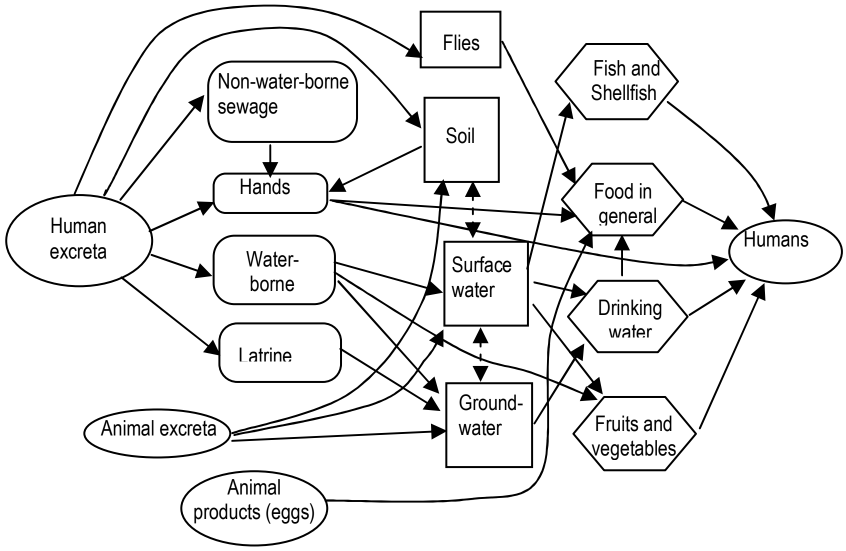
2 Access to improved water and sanitation services are, for many countries, are available in the WHO/UNICEF global assessment for the year 2000 (WHO/UNICEF 2000), http://www.who.int/water_sanitation_health/monitoring/en/index.html

Because of the complex and interconnected routes of transmission relating to unsafe WSH, especially for the faecal-oral diseases (as illustrated in Figure 1), infectious diarrhoea exposure currently has to be determined according to a number of typical scenarios based on the type and level of water and sanitation provision. In fact, the level of access to safe and adequate water and sanitation services are, so far, the best proxy for estimating disease transmission due to WSH.

Figure 1 Transmission pathways of faecal-oral diseases [a]



[a] Source: adapted from Prüss et al.2002

3.2.1 Scenario-based approach

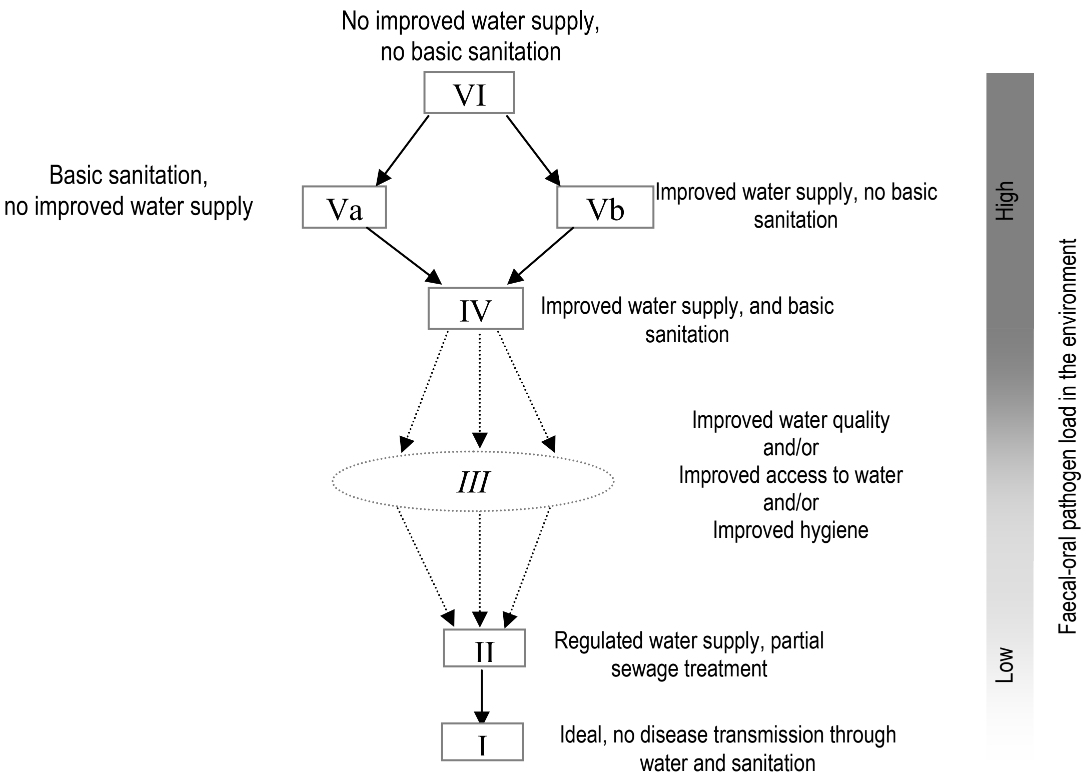
Although it could be considered that actual exposure occurs at household or individual level, improved sanitation (for example) can have health benefits not only to the users but also the community if there is reduced faecal contamination of the environment (Cairncross, 1992). Also information on both exposure and risk is generally only available at the community or regional level. Thus, in order to estimate the disease burden of diarrhoeal illness related to unsafe WSH it is necessary to use a scenario-based approach to define the exposure categories. The exposure categories, outlined in Table 2, are based on typical levels of access to water and sanitation, the load of faecal-oral pathogens in the environment (based on qualitative assessment of sources and disease circulation in the community) along with a representative combination of risk factors at commonly encountered levels.

Table 2 Exposure scenarios [a]

Scenario	Description	Environmental faecal-oral pathogen load
VI	Population not served with improved water supply and no improved sanitation in countries which are not extensively covered by those services (less than 98% coverage), and where water supply is not likely to be routinely controlled	Very high
Vb*	Population having access to improved water supply but not served with improved sanitation in countries which are not extensively covered by those services (less than 98% coverage), and where water supply is not likely to be routinely controlled	Very high
Va*	Population having access to improved sanitation but no improved water supply in countries where less than 98% of the population is served by water supply and sanitation services, and where water supply is likely not to be routinely controlled.	High
IV	Population having access to improved water supply and improved sanitation in countries where less than 98% of the population is served by water supply and sanitation services and where water supply is likely not to be routinely controlled.	High
III	IV and improved access/quality to drinking water; or IV and improved personal hygiene; or IV and drinking water disinfected at point of use, etc.	High
II	Population having access to improved water supply and sanitation services in countries where more than 98% of the population is served by those services; generally corresponds to regulated water supply and full sanitation coverage, with partial treatment of sewage and is typical in developed countries.	Medium to low
I	Ideal situation, corresponding to the absence of transmission of diarrhoeal disease through WSH	Very low

[a] Based on Prüss-Üstün et al. 2002; 2004
* Transitions between exposure levels Va and Vb do not generally occur

Figure 2 Scenarios determining risk of diarrhoeal disease from unsafe WSH[a]



[a] Source: Prüss-Üstün 2004

Scenario I represents the minimum theoretical risk, namely no disease transmission through unsafe WSH; this scenario does not occur on a large scale and, indeed, is probably negligible. Thus no groups of people are assigned to this scenario. Scenario II is the situation typically encountered in developed countries. These scenarios have low to medium loads of faecal-oral pathogens in the environment, characterized by more than 98% coverage of improved water supply and sanitation and a relatively low regional incidence of diarrhoea. Scenarios IV-VI are based on a high faecal-oral pathogen environment, typical for developing countries with less advanced water and sanitation provision.

The definition of "improved access to drinking water" and "improved sanitation" is defined in Table 3 below for the purpose of this guide. These definitions can be adapted to local circumstances and local technologies.

Table 3 Definitions of 'improved' and 'unimproved' drinking water sources and sanitation facilities

Status	Drinking water sources	Sanitation facilities[a]
Improved	Piped water into dwelling, plot or yard Public tap/ standpipe Tubewell/ borehole Protected dug well Protected spring Rainwater collection	Flush or pour-flush to: - piped sewer system - septic tank - pit latrine Ventilated improved pit latrine Pit latrine with slab Composting toilet
Unimproved	Unprotected dug well Unprotected spring Cart with small tank/ drum Bottled water[c] Tanker-truck Surface water (rivers, canals etc.)	Flush or pour-flush to elsewhere[b] Pit latrine without slab or open pit Bucket Hanging toilet or hanging latrine No facilities or bush or field

[a] Only facilities which are not shared or are not public are considered improved
[b] Excreta are flushed to the street, yard or plot, open sewer, a ditch, a drainage way or other location
[c] Bottled water is considered improved only when the household uses water from an improved source for cooking and personal hygiene
Source: WHO/UNICEF 2006

In summary, the exposure data needed for quantifying the disease attributable to water, sanitation and hygiene as proposed in this guide are met by filling in Table 4.

Table 4 Exposure data needs

Scenario*	Percentage population
VI	
Va	
Vb	
IV	
III	Probably 0% in any significant sections of the population
II	
I	0% (as this represents the ideal situation without transmission of diarrhoea from unsafe WSH)

* for descriptions of each scenario see Table 2.

3.2.2 Sources of exposure data

The exposure scenarios were selected according to available information on exposure-risk relationships (see Section 3.3) and the type of exposure information that is generally available at country level. Data on access to safe drinking-water and adequate sanitation may be available from the following sources:

- national or sub-national census reports
- national or sub-national household surveys
- project reports of local NGOs (though they may use alternative definitions).

Alternatively, information on exposure distribution to the various exposure scenarios is also contained within the Joint Monitoring Programme (JMP) on global water supply and sanitation assessment 2000 (WHO/UNICEF 2006). JMP is a compilation of Demographic Health Surveys (DHS)[3], Multiple Indicator Cluster Surveys (MICS)[4], the World Health Survey[5], other international surveys, and national census and surveys.

Table 5 displays some examples of country exposure distributions, already formatted for disease burden quantification (other country data are shown in Annex 2[6]).

Table 5 Distribution of the population of selected countries, in exposure scenarios[a]

Countries, Areas and Territories	Population	Improved drinking water coverage		Improved sanitation	Regulated supply	Improved water & sanitation	Improved sanitation Only	Improved water only	No improved supply nor sanitation
	Total	Total	Household connection	Total	Scenario II	Scenario IV	Scenario Va	Scenario Vb	Scenario IV
	(thousands)	%	%	%	%	%	%	%	%
Afghanistan	28,574	39	4	34	0	34	0	5	61
Albania	3,112	96	69	91	0	91	0	5	4
Algeria	32,358	85	74	92	0	85	7	0	8

The scenarios could also be defined separately for urban and rural areas. While exposure data are usually available separately for urban and rural areas (e.g. in the WHO/UNICEF 2006 assessment of drinking water and sanitation), segregated health statistics for urban and rural areas may be more difficult to obtain. Disease burden may also be estimated separately by district, provided that exposure data and health data are available by district.

[3] performed by Macro International and funded by the United States Agency for International Development
[4] performed by United Nations Children's Funds (UNICEF)
[5] performed by the World Health Organization (WHO)
[6] It is assumed, for these exposure distributions, that people with improved water supplies were most likely to have access to improved sanitation

3.3 Relative risks

The fact that for faecal-oral pathogens the water route is a major transmission pathway is well established (Andersson & Bohan 2001; Hunter 1997; Esrey et al. 1991). The following subsections briefly outline the evidence, derived from the peer-reviewed literature, for the causal links between infectious diarrhoea and water, sanitation and hygiene before going on to examine the relative risks associated with the scenarios outlined in the previous section.

3.3.1 Background on infectious diarrhoea causality

A large part of the studies that have examined WSH and diarrhoea are intervention studies, which have looked at changes in water supply, excreta disposal or hygiene practices, and have assessed the effects on diarrhoea morbidity (Fewtrell & Colford, 2004; Fewtrell et al., 2005). Case-control studies, particularly following outbreaks suspected to be caused by potable water contamination in the developed nations make up another significant group of investigations (Hunter et al. 2003).

Sanitation

Ideally, sanitation (here restricted to human excreta management) should result in the isolation and/or destruction of pathogenic material and, hence, a break in the transmission pathway. In a comprehensive literature review, Esrey et al. (1991) identified 30 studies, from a variety of different countries (including Bangladesh, Brazil, Chile, Guatemala, Kenya, Malaysia and Panama), that examined the impact of sanitation on disease transmission. Twenty-one of those studies reported health improvements (median 22% reduction in diarrhoea morbidity), with a greater median reduction seen in the rigorous studies (36% reduction). In a later meta-analysis only two sanitation intervention studies were identified that could be used in the analysis (Azurin & Alvero, 1974; Daniels et al. 1990), which estimated a significant reduction in diarrhoea levels of approximately 32% (Fewtrell & Colford 2004). Meddings et al. (2004) in a case-control study found that patients with diarrhoea were less likely than controls to live in houses with improved latrines (OR=0.57; 95% CI 0.42-0.77 for children aged less than five). In addition, several studies have isolated various faecal-oral pathogens from the faeces of sick people and the transmission of such pathogens isolated from infected faeces to human host has also been demonstrated (e.g. for *Shigella* spp., Dupont et al. 1989).

Water

The continuing occurrence and number of outbreaks of infectious disease caused by faecal-oral pathogens in developed countries attests to the efficiency of this mode of transmission. In the United States of America, for example, 19 outbreaks of gastroenteritis with an infectious etiology associated with drinking water were reported in the two year period 2001-2002 (Blackburn et al. 2004). In developing countries, it is not only water contaminated at source or during distribution that is an issue, but water stored within the home where it may become contaminated (Gundry et al. 2004), although arguably this is a matter of water quality management and domestic hygiene. Numerous epidemiological studies and outbreak investigations have also found an association between poor water quality and infectious diarrhoea (Hunter et al. 2003).

Hygiene

A number of studies have attempted to examine the role of personal and domestic hygiene, although in many cases some of the ‘hygiene’ measures or interventions could also impact on sanitation, and hygiene interventions may also interact with water quality. Six studies examined by Esrey et al. 1991 identified reductions in diarrhoea morbidity associated with hygiene interventions; these ranged from 14% to 48%, with a median reduction of 33%. Curtis and Cairncross (2003) conducted a systematic review and meta-analysis of the impact of handwashing with soap on diarrhoea morbidity. They found studies from diverse locations including the USA, Bangladesh, India, Myanmar, Guinea, Indonesia and Brazil and the results of the meta-analysis suggested that handwashing with soap could reduce diarrhoea morbidity by 47%. Similar results for all hygiene interventions were reported by Fewtrell & Colford (2004) in their meta-analysis. The temporal adoption of hygiene measures can be illustrated by the study by Ahmed et al. (1993). This group compared cleanliness and diarrhoea levels in villages with and without hygiene education interventions. Higher adoption rates of the intervention were associated with a better cleanliness state, which was paralleled by a decrease in diarrhoea and malnutrition rates. The differences were found to increase over time as more villagers adopted the intervention.

A review by Feachem (1984) documented the presence of pathogens on the hands following toilet activities, as did Hoque (2003), who also found that different handwashing practices affected the residual bacterial contamination of the hands.

3.3.2 Relative risks associated with exposure scenarios

The relative risk values for each of the exposure scenarios have been derived from the literature. They could be replaced by more locally applicable values if such were available. In that case, it should be ensured that the data are representative for the country and that they are, for example, not subject to seasonal effects.

For the global relative risks proposed here, selected major reviews, multi-country studies or studies of superior design to quantify the transition between two or more chosen exposure scenarios were selected. This literature includes the review and multi-country study by Esrey (Esrey et al. 1991; Esrey 1996), the reviews by Huttly (1997) and Mead (1999), in conjunction with key literature and high quality studies published since the review papers (Quick et al. 1999; Semenza et al. 1998; Payment et al. 1991; 1997). The major part of this literature is based on intervention studies and surveillance information. The final selection of used studies depended largely on the degree to which the study exposure data could be matched with the chosen exposure scenarios and also the sample size and quality of studies. Further details on the chosen studies are outlined in Table 6.

Table 6 Key studies and reviews

Study population	Population size	Outcome measured/ reported	Reductions	Comments	Reference
Representative populations from Burundi, Ghana, Togo, Uganda, Sri Lanka, Morocco, Bolivia and Guatemala	16 880	Diarrhoea morbidity nutritional status, child development	20.8–37.5% according to type of infrastructure	Detailed examination of effects of incremental improvements in water and sanitation based on survey data	Esrey 1996
Burma, USA, Bangladesh, India, Indonesia for handwashing; Bangladesh, Zaire, Thailand, Guatemala for various other behaviours	NA	Diarrhoea morbidity	Median reduction 35% for handwashing; Median 26% for	Review paper/ 5 intervention studies on handwashing and 5 on other hygiene behaviours	Huttly et al. 1997
Gastrointestinal illness in the USA population	More than 400 000 diagnosed patients	Foodborne illness and other diarrhoea	Approx. 60% of GI illness due to water, sanitation and hygiene[1]	Surveillance data	Mead et al. 1999
1400 families in Montreal, Canada	5 253	Diarrhoea morbidity	14–40%	Water quality intervention	Payment et al. 1997
606 households in Montreal, Canada	2 408	Diarrhoea morbidity	35%	Water quality intervention	Payment et al. 1991
Two Bolivian communities	791	Diarrhoea morbidity	45% for all age groups	Water quality intervention	Quick et al. 1999
Householders in Nukus, Uzbekistan	1 583	Diarrhoea morbidity	62–85%	Water quality intervention	Semenza et al. 1998

[1] extrapolated from study results for the purpose of this analysis

Relative risk for exposure scenario II

The ideal situation (scenario I) is the theoretical minimum, therefore the relative risk equals one (RR=1). In scenario II, the pathogen load is mostly transferred from land to water (e.g. in discharge of normally treated sewage, such as biological secondary treatment, to surface water). Such pathogens can potentially pass through potable water treatment systems, which can not guarantee 100% pathogen elimination in even the most advanced plants used in the developed nations. Water contaminated with such pathogens is also used for other purposes such as recreation and irrigation. Hygiene behaviour is still imperfect in scenario II, and small population groups may still be served with poorly regulated community supplied water.

The relative risk for scenario II was based on the review by Mead et al. (1999). Mead and co-workers assessed the level of all infectious foodborne illness in the USA, using data from a large number of surveys and other sources (including FoodNet, the National Notifiable Disease Surveillance System, the Public Laboratory Information System, the Foodborne Disease Outbreak Surveillance System, the National Hospital Discharge Survey, the National Vital Statistics System and a number of published studies). Based on the literature, they also estimated the percentage of each disease caused by foodborne transmission. This is a very comprehensive study based on more than 400 000 diagnosed cases, bringing together numerous different data sources and some assumptions relating to likely levels of underreporting. According to this study, about 35% of intestinal illness in the USA is foodborne. The level of faecal-oral illness due to unsafe WSH was estimated as 100% of the cases of infectious diarrhoea, less the percentage due to foodborne transmission. This is probably an underestimate as unsafe WSH is known to play a role in some foodborne transmission (e.g. through irrigation of food products with pathogen-contaminated water or via an infected food handler). After deduction of the portion of foodborne transmission through aerosols of certain viruses (estimated as up to 25% for rotavirus and astrovirus), the remaining fraction attributable to unsafe WSH is about 60%. This order of magnitude is supported by intervention studies acting on point-of-use treatment of drinking water in Canada (Payment et al. 1991, 1997) and a meta-analysis of hand-washing interventions in the United States, Canada and Australia (Fewtrell & Colford 2004), reporting reductions of 40%, 35% and 42% respectively. A preliminary assessment by Hunter et al. (2005) suggests that up to about 15% of gastrointestinal illness in the UK, may be associated with consumption of drinking water that has been contaminated as a result of a burst water main or other loss of pressure in the distribution system. A 60% reduction in disease corresponds to a relative risk of 2.5 (RR=1/(1-0.6)) for exposure scenario II.

Risk transition between scenarios II and IV

The shift between scenarios II and IV represents the transition between high and relatively low pathogen loads in the community environment, or more generally between developed and developing regions. Intervention studies are not available as it is not possible to transform environments "high" in pathogen load into environments "low" in pathogen load, which would imply completing the coverage in improved sanitation in a reasonable time frame and without simultaneous change in other major determinants of health.

Some studies do, however, describe elements of this risk transition between scenario II and IV by acting on selected characteristics of the differences of these scenarios, and their results were used to estimate the transmission between scenarios II and IV. These studies include the following:

- The transition between scenarios IV and II is associated with improved drinking-water quality: Introduction of point-of-use disinfection. Quick et al. (1999) examined the level of diarrhoea prevention that could be achieved through point-of-use water treatment along with safe water storage. The reason for selecting this study is that the intervention strongly reduces the pathway of transmission through drinking water, and "simulates" the reduction that could be achieved by improved drinking water quality and its handling inside the house. The study randomized 791 participants into two groups; the intervention group received a special storage container (preventing hand contact with the stored water) and a supply of disinfectant. The control group not receiving the intervention was similar in terms of demographic characteristics, sanitary conditions and baseline water quality. During the baseline investigations only 5% of household samples were free of *E. coli*. During the study period this varied between 0 and 13% of the control group (with the median level being between 5 000 and 85 000/100ml), while the intervention group exceeded 50% of households at all times, rising to almost 80% on one occasion (median *E. coli* counts were zero, throughout). Overall diarrhoea reductions of 44.7% in the total population and 54.5% in children were reported by Quick et al. (RR=1.81 and 2.20). The reduction of 44.7% was selected as a component in the transition between II and IV in this analysis.

- One additional study is worthy of note. This randomized intervention study was conducted in 240 households (120 with and 120 without access to municipal piped water), with a total population of 1 583, in Uzbekistan (Semenza et al. 1998). Residents from approximately half of the households without piped water were trained to chlorinate their drinking water within the home and store it in a safe manner. Diarrhoea morbidity was markedly lower in the home chlorination group 28.8/1 000 subjects/month, compared to 75.5/1 000 in the piped water group and 179.2/1 000 in the no piped water group (i.e. a 62% reduction in diarrhoea rates for an intervention with home-chlorination of drinking water, as compared to those living in areas with access to piped water (RR=2.6), in households without a piped supply, the same intervention achieved a 85% reduction in disease (RR=6.7)). The authors consider that home chlorination of water is unlikely to affect disease transmission via other routes, suggesting that a large fraction of the diarrhoeal pathogens in this area were spread through water.
- Scenario IV and improved personal hygiene: Reductions in diarrhoea morbidity have been reviewed by Huttly et al. (1997), and handwashing resulted in a median 35% reduction in diarrhoea incidence (RR=1.5). The results of this review outline possible achievements due to a reduction in the transmission pathway of hygiene, which in itself is conditioned by the pathogen load in the environment and ready access to water for hygiene purposes.

The literature currently does not provide solid evidence on the achievements from piped water.

Risk transition between scenarios IV and VI

The multicountry study conducted by Esrey (1996) provides data to allow calculation of relative risks between scenarios IV, Va, Vb and VI. This study examined whether incremental health effects relating to diarrhoea and nutritional status resulted from incremental improvements in water and sanitation conditions and was based on Demographic and Health Surveys (DHS) from eight countries from different regions (Ghana, Togo, Burundi, Uganda, Bolivia, Guatemala, Morocco and Sri Lanka). The Demographic and Health Surveys included information on diarrhoea prevalence, child weight, child height, child age, source of drinking water and type of sanitation facility. In addition, the survey data-sets were supplemented by field studies that determined current levels of diarrhoea prevalence in children aged 3–36 months. According to this study, a reduction of 20.8% in diarrhoeal disease rates (RR=1.26) can be observed when progressing from scenario VI to Vb (i.e. when providing an improved water supply), and 37.5% (RR=1.6) when progressing from VI to Va (i.e. when providing basic sanitation facilities). When progressing from VI to IV (i.e. when providing both an improved water supply and basic sanitation facilities), a reduction of 37.5% is also achieved. This implies that no further reduction in diarrhoeal disease is achieved when implementing an "improved water supply" in terms of protected sources for water collection (rather than piped supplies), when basic sanitation is already available. These data are supported by the results of Esrey's review (Esrey et al. 1991), which provides similar results for the same types of interventions.

The recent meta-analysis (Fewtrell et al. 2005) of risk reduction from water supply and sanitation interventions could not be used to provide relative risk values, as the analysis did not differentiate for the introduction of an improved water supply by sanitation status (i.e. whether or not improved sanitation was already in place). The results are nevertheless very similar to the risk reductions used in this guide.

Summary of relative risks for the proposed method

The resulting relative risks are obtained by multiplying the relative risks between each scenario and these are summarized, for our best estimate at an aggregated global level, in Table 7.

Table 7 Relative risks associated with scenarios

Scenario/ transition between scenarios	I	II	III	IV	Va (to IV)	Vb (to IV)2	VI (to Vb)	VI (to Va and IV)
Risk reduction[1]	NA	60%	Various*	45% and 35%	0%	NA	20.8%	37.5%
Partial relative risk1	NA	2.5	Various*	1.81 and 1.54	1.0	1.60/1.26 = 1.27	1.26	1.60
Absolute relative risks (compared to Scenario 1)	1	2.5	Various*	6.9	6.9	8.7	11.0	11.0

* see text

[1] towards lower scenario

[2] obtained by calculating the remaining risk differences between VI to Vb as compared to VI and IV

According to our model, the risks of diarrhoea in developing countries are 2.8 to 4.4 times higher (Table 7) than current risks in developed countries. The same order of magnitude of difference in diarrhoea rates was reported by various compilations of health statistics or studies (Murray and Lopez 1996b; Esrey 1996).

The scenarios proposed in this section are aimed at estimating the fraction of diarrhoea that is *attributable* to water, sanitation and hygiene. This means that it compares the prevailing situation to the ideal situation, i.e. absence of diarrhoea transmission through WSH, which is currently not even reached in populations of developed regions. Another approach, not considered here, could consist of estimating the health gain that could be achieved by providing improved drinking water or sanitation facilities to part of the population[7].

3.4 Calculation of the fraction of diarrhoea attributable to WSH

The relative risks for each exposure scenario are calculated as described in Section 3.2. The fraction of population in each exposure scenario is determined as described in Chapter 3.2. Now we can calculate the attributable fraction - AF (or impact fraction) of health effects from water, sanitation and hygiene using the following equation:

$$IF = \frac{\Sigma \text{ pi RRi} - 1}{\Sigma \text{ pi RRi}} \qquad \text{(Equation 1)}$$

[7] Such a calculation is possible with the spreadsheet accompanying this guide, available from EBDassessment@who.int

where:

p_i = the proportion of the population at exposure category "i". $\sum p_i = 1$

RR_i = the relative risk at exposure category "i", compared to the ideal level (with RR = 1).

The relative risk (RR_i) is, for the purpose of this analysis, the relative risk associated with each exposure scenario i as compared to risk of infectious diarrhoea in the ideal WSH scenario. The proportion of the population exposed (or unexposed) is the proportion of the population in each exposure scenario i (p_i).

Equation 1 takes into account various population groups exposed to the different exposure scenarios (e.g., the population with access to improved water supply but no improved sanitation facility).

To estimate the impact of changing the exposure from one distribution to another, for example through a public-health intervention, a more general formula than Equation 1 could be used (Equation 2). This formula can be used to estimate the fraction of the disease burden attributable to the risk factor if, for example, the population without access to sanitation services is halved. For further details on the various formulas see Chapter 4 of Volume 1 "Introduction and methods" of this series (Prüss-Üstün et al., 2003).

$$IF = \frac{\Sigma p_i RR_i - \Sigma p_i' RR_i}{\Sigma p_i RR_i} \qquad \text{(Equation 2)}$$

where:

p_i = the proportion of the population at exposure category "i" before intervention.

p_i' = the proportion of the population in exposure category "i" after an intervention or other change.

RR_i = the relative risk at exposure category "i" compared to the reference level.

3.5 Estimation of disease burden of diarrhoeal disease

The resulting attributable fractions should now be multiplied by the disease burden (in terms of incidence, mortality or DALYs) for the various age groups:

Attributable disease burden of diarrhoea (incidence, deaths, or DALYs)

= Attributable fraction x Total disease burden of diarrhoea (incidence, deaths, or DALYs)

Chapter 15 provides information on data sources for health statistics, including preliminary estimates for diarrhoea statistics.

4. Intestinal nematode infections

Ascariasis is caused by the large roundworm *Ascaris lumbricoides*. Eggs are passed in the faeces of an infected person and in poor sanitation conditions may contaminate water and soil. Ingestion of infective eggs, from contaminated soil or from uncooked products contaminated with soil or wastewater containing infective eggs, results the infection. Transmission does not occur from person to person. The eggs can survive for months or years in favourable conditions and can, thus, pose an infective hazard for a considerable period of time. Numerous studies have investigated the link of access to safe water and adequate sanitation with the disease (Esrey et al., 1991). In particular, increased risk was associated with being exposed to untreated wastewater (Cifuentes 1998, Habbari et al. 2000), no use of latrines (Toma et al., 1999, Arfaa et al., 1977), and households without soap (Olsen et al. 2001).

Trichuriasis is caused by ingestion of the human infectious eggs of the whipworm *Trichuris trichuria*. The infection is not directly transmittable from person to person. The modes of transmission are similar to ascariasis (Smith et al., 2001; Saldiva et al., 1999; Anderson et al., 1993). Also for trichuriasis, water supply and use of latrines were shown to reduce infections (e.g. Rajeswari et al., 1994, Narain et al., 2000).

Hookworm infection is caused by *Ancylostoma duodenale* or *Necator americanus*, and results from the ingestion or skin penetration of the hookworm larvae in soil. Larvae develop in soil through the deposit of faeces containing eggs from infected persons. Poor sanitation and hygiene practices are, therefore, at the root of this infection. The disease is not transmitted from person to person. Intervention studies showing prevention of the disease by water, sanitation and hygiene are also numerous (Esrey et al., 1991, Sorensen et al., 1994, Olsen et al., 2001).

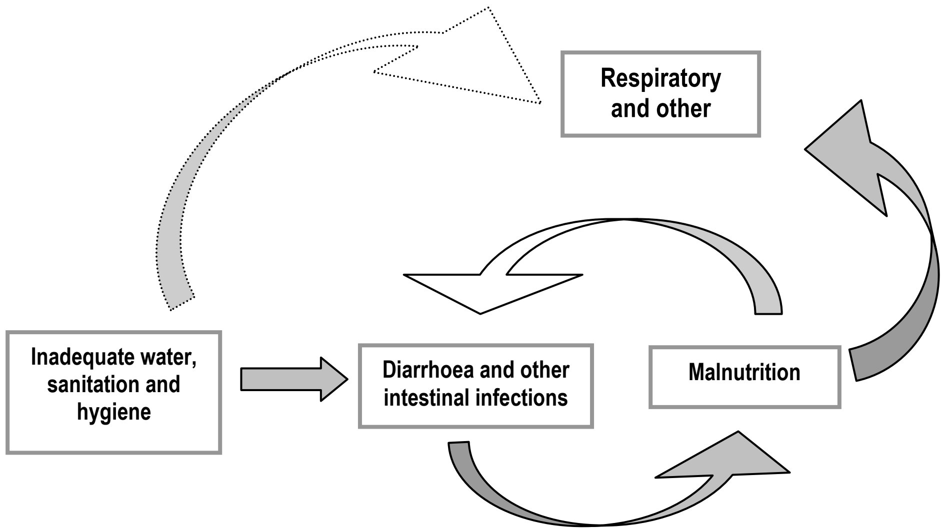
Knowledge on disease transmission suggests that 100% of intestinal nematode infections can be prevented by adequate water, sanitation and hygiene. Several studies on the reinfection by intestinal nematodes (Norhayati et al., 1995) show that reinfection rates are relatively high after treatment. For example, in a study of over 1800 children in Brazil, Moraes and Cairncross (2004) found that sewerage and drainage infrastructure could significantly reduce transmission (and reinfection). This suggests that long-term strategies incorporating education on personal hygiene, provision of toilets and of access to safe water are important elements in strategies to sustainably reduce the disease.

Estimated disease burden should be fully attributed to water, sanitation and hygiene. If such statistics are not available at the national level, prior estimates formulated by WHO could be used (Annex 3).

5. Childhood malnutrition

Water, sanitation and hygiene are closely linked to childhood malnutrition. WSH risks are a major cause of repeated gastro-intestinal infections, which may lead to reduced absorption of nutrients. This, in turn, causes malnutrition. The following sections outline this link, as well as the link to diseases caused as a consequence of childhood malnutrition (Figure 3). In simple terms, WSH risks cause malnutrition, and through malnutrition they contribute to a variety of infectious diseases. This is the rationale for including malnutrition in the present guide.

Figure 3 Main pathways linking WSH to malnutrition



5.1 What is malnutrition?

Malnutrition is a major public health issue affecting especially children in developing countries. The term malnutrition generally refers both to undernutrition and overnutrition, but in this section we refer solely to undernutrition. Many factors can contribute to malnutrition, most of which relate to poor diet or severe and repeated infections, particularly in underprivileged populations. These lead to deficiencies in calories, proteins, vitamins and minerals. Inadequate diet and disease, in turn, are closely linked to living conditions, the environment, and whether basic needs such as water, sanitation, food, housing and health care are met.

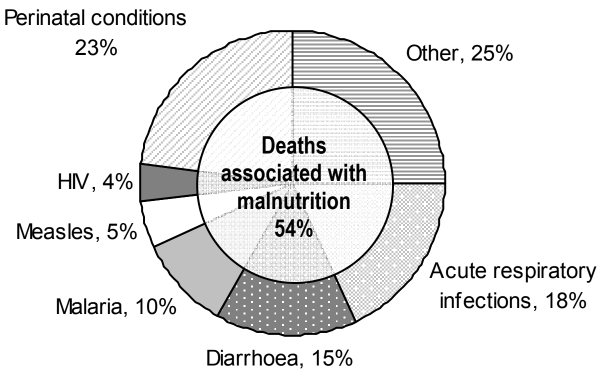
All ages are at risk, but underweight is most prevalent among children under five years of age, especially in the weaning and post-weaning period of 6-24 months.

For the purpose of quantifying disease associated with childhood malnutrition, child malnutrition should be measured in weight-for-age. This measure is not necessarily the best parameter for assessing malnutrition, but is best reflected in the scientific literature linking malnutrition to disease.

5.2 Consequences of malnutrition on disease

Malnutrition is both a health outcome and a risk factor for infections and exacerbated malnutrition, and it can increase the risk of morbidity and mortality of many infectious diseases. Infectious diseases are the main killers of children under the age of five years in developing countries, and malnutrition is the underlying cause of about half of these deaths. This is because malnutrition weakens the body's resistance to communicable diseases. Malnourished children are therefore more vulnerable to disease and generally have a poorer prognosis. While acute respiratory infections, diarrhoea, malaria and measles are the childhood infections with the greatest consequences, most other infectious diseases are equally affected by malnutrition.

Figure 4 Proportional mortality in children younger than five years old[a]



Source: WHO 2004

5.3 Environmental factors influencing malnutrition

As mentioned, malnutrition depends on food intake, the general health status and the physical environment. Water, sanitation and hygiene are linked to all of these three parameters. Mainly, repeated diarrhoeal diseases and parasite infestations themselves caused by inadequate water, sanitation and hygiene lead to reduced absorption of nutrients, which contribute to malnutrition. It has been shown that the levels of water and sanitation services significantly affect Z-scores[8] and weight gain in infants (Esrey, Habicht and Casella, 1992; Esrey, 1996; Checkley et al., 2004).

In addition to water and sanitation, land degradation, soil pollution, the degradation and destruction of ecosystems and climate change can also contribute to malnutrition to a certain extent. It has been estimated that climate change accounts for 2% of the burden of malnutrition (WHO, 2002). In a study on the linkage of the global disease burden and the environment (Prüss-Üstün and Corvalán, 2006), it was estimated that 50% of malnutrition is attributable to the environment, essentially to water, sanitation and hygiene (pooled expert opinion based on literature review).

When adding the estimated malnutrition burden to the other disease burden caused by water, sanitation and hygiene, the burden from diarrhoeal disease should not be double-counted (as it is already estimated in Section 3).

[8] Z-scores (or standard deviation units) tell how far a child deviates from the average, used in terms of height-for-age or other measure of nutritional status

5.4 Estimating the disease from WSH related malnutrition

A separate guide of the Environmental Burden of Disease series covers the quantification of disease burden caused by malnutrition (No. 12): "Malnutrition - Quantifying the health impact at national and local levels" (Blössner and de Onis 2005). This guide is accompanied by an excel spreadsheet to facilitate calculations. This guide assists in estimating the burden caused by childhood (and maternal) malnutrition, based on population data of weight-for-age in children and disease burden (deaths, incidence or DALYs) of infectious diseases and protein-energy malnutrition.

The basic method applied to estimate the consequences of malnutrition in terms of health impact from infectious diseases in children under the age of 5 years consists of the following steps (Blössner and de Onis 2005; Fishman et al. 2004):

- estimation of the number of children with a weight-for-age below -2 standard deviations (SD) of the mean;
- estimation of fractions of mortality due to diarrhoeal disease, malaria, measles, lower respiratory infections, other infectious diseases (besides HIV) and protein-energy malnutrition that are attributable to malnutrition, based on relative risks from the literature;
- calculation of disease burden attributable to malnutrition by multiplying mortality statistics with attributable fractions.

As about 50% of malnutrition is caused by unsafe environmental conditions, essentially water, sanitation and hygiene, roughly half of the burden from childhood malnutrition estimated by the method outlined in the document "Malnutrition - Quantifying the health impact at national and local levels" can be attributed to water, sanitation and hygiene. Only the infectious diseases (besides HIV) which are not already directly caused by WSH should be taken into account here to avoid double-counting. This fraction of 50% of malnutrition may be re-estimated locally to take into account the local circumstances, in particular if they are likely to differ significantly from the proposed average. This may be the case in situations where children are disproportionately vulnerable to the determinants of malnutrition. For such an estimation, a suitable question to experts would be the following: "How much (as a percentage) of malnutrition (in deaths and DALYs) could, in principle, be avoided by environmental improvements (essentially water, sanitation and hygiene), without jeopardizing environmental sustainability".

6. Schistosomiasis

Schistosomiasis is caused by infection with trematodes of species belonging to the genus *Schistosoma*. Transmission of the disease occurs when people come into contact with water containing cercariae (the mobile, infective larval stage of the life cycle), which penetrate the skin. Water is contaminated by infected humans who excrete the schistosome eggs in their faeces or urine (depending on the *Schistosoma* species). The final link in the chain of infection is provided by an intermediate snail host, which the parasite needs in order to complete its life cycle. The water, sanitation and hygiene risk factors determining schistosomiasis transmission can be categorized as infrastructural (access to adequate sanitation) and behavioural (hygiene habits, habits of urinating and defecation and contact patterns with contaminated water).

Esrey et al. (1991) identified 12 studies that related water and sanitation facilities to the prevalence rates of schistosomiasis. Reported decreases in infection rates related to improved access to water and sanitation varied between 59 and 87%, with the median value of the rigorous studies being a 77% reduction. A number of studies have examined reinfection with schistosomiasis following a drug-based intervention programme (such as mass treatment or case detection and targeted treatment), suggesting that (1) treatment alone will not sustainably eliminate the disease and (2) that the plateau prevalence rates achieved by such interventions reflect the context specific risk factors.

Current knowledge on disease transmission indicates that the disease is fully attributable to risks associated with unsafe WSH. Generally, lack of access to adequate sanitation will determine the contamination level of water bodies, lack of access to safe domestic water and to adequate sanitation will influence community exposure levels, and recreational and occupational water contact patterns will increase the risks for specific vulnerable groups.

Estimated morbidity or mortality of schistosomiasis should therefore entirely be attributed to the risk factor. In the case such estimates are not available on the national level, prior estimates are provided by WHO (see Annex 3).

7. Trachoma

Trachoma is a chronic contagious eye disease, which can result in blindness, caused by *Chlamydia trachomatis*. Transmission occurs by several routes (Dolin et al. 1997), all of which are hygiene-related (e.g. direct infection by flies, person-to-person from clothing used to wipe children's faces and by hand-to-face contact). Risk factors for the disease include lack of facial cleanliness, poor access to water supplies, lack of latrines and a high number of flies. Several environmental control measures are effective (Sutter & Ballard, 1983; Esrey et al., 1991; Emerson et al., 1999, 2000; Prüss and Mariotti, 2000), and trachoma can be considered to be almost 100% attributable to the environment.

Estimated morbidity or mortality of trachoma should therefore be attributed to the water, sanitation and hygiene. In the case such estimates are not available on the national level, prior estimates are provided by WHO (see Annex 3).

8. Vector-borne diseases

Water-associated vector-borne diseases are distributed according to the ecologies that will support their propagation. Latitude and altitude boundaries limit this distribution and rainfall patterns influence the level of seasonality of disease transmission. In a number of natural settings where one or more vector-borne diseases are endemic, environmental interventions to reduce transmission risks are feasible. Where vector species occur that are ecologically highly versatile, however, such interventions are less effective and appropriate.

The impact of human activities is superimposed over this natural distribution and is determined by a number of environmental and social factors, which provide an entry point for environmental interventions:

- Hydrological changes resulting from water resources development (introduction or extension of irrigation; construction of small of large dams) may
  - lead to the introduction of new vector breeding sites in areas where they were not present before (particularly arid and semi-arid zones, introducing vectors;
  - further extend the surface of existing vector breeding places, resulting in higher vector population densities;
  - prolong the breeding period into the dry season, thereby shifting the transmission pattern from seasonal to perennial;
  - increase the relative humidity, contributing to a longer average mosquito vector lifespan and enhancing the vectorial capacity of the vector population.

- Changes in patterns of human circulation, such as
  - permanent resettlement into a new development project, of non-immunes into disease endemic areas or of disease carriers into a non-endemic area;
  - seasonal migration associated with the agricultural cropping cycle.

- Infrastructural changes
  - improved housing with greater protection to insect vectors;
  - improved environmental sanitation, with less standing water and better drainage;
  - improved and reliable access to drinking water, eliminating the need for unsafe water storage at home;
  - better roads for improved access to health services and to health protective measures.

At the global level, systematic literature review has proved to be a valuable approach as a first step to the estimation of the vector-borne disease burden that can be attributed to water resources development projects. If possible, such a literature review should also be undertaken for publications concerning the study population. The following steps are proposed for a comprehensive review (adapted from: Keiser et al. 2005a):

- Prepare a causal web of vector-borne disease transmission pathways relevant to the study area (i.e. taking into account endemicity of diseases and the ecology of local vectors).

- Prepare an inventory of possible sources of relevant literature, i.e. web-based search engines, national council for science and technology, health sector institutions, universities, WHO and UNICEF offices and local NGOs. Some sources may be less obvious: in Sri Lanka, for example, a considerable amount of research reports on malaria have been published by the International Water Management Institute (e.g. Konradsen et al. 2000; Amerasinghe et al. 2001).
- Determine the distribution of human populations in relation to irrigation schemes and man-made reservoirs, based on a reasonable assumption of the flight range of local vectors, through national censuses and surveys and possibly local population databases, and considering possible informal settlements.
- Set the criteria for the systematic literature review and carry it out in an iterative way, until you are reasonably sure that all relevant information has been covered. For development projects, in principle, only studies and surveys should be included that provide reliable information from the pre-development baseline to the disease outcome when the project has become operational.
- Analyse, correlate and extrapolate the health information to the population at risk and prepare estimates of attributable fractions of the disease burden.
- If feasible, test the assumptions made in the analysis of the population at risk and the burden of disease extrapolation for their sensitivity.
- Prepare a final report on your findings.

8.1 Malaria

In humans, malaria is caused by a parasite belonging to the genus *Plasmodium*. The parasite is transmitted by the bite of an infected female mosquito of the genus *Anopheles*. The larval stages of *Anopheles* mosquitoes occur in a wide range of habitats, but most species share a preference for clear, unpolluted, stagnant or slowly moving fresh water (Muir, 1988). Some species of public health importance breed in brackish water.

The fraction of malaria that can be prevented by environmental management depends on the local conditions and opportunities to influence vector habitats, their propagation and disease transmission. The main management opportunities include the following:

- *Modify the environment.* Permanently change land, water or vegetation conditions to reduce vector habitats, often through infrastructural works.
- *Manipulate the environment.* Recurrent activities, often with community involvement, to create temporary unfavourable conditions for vector propagation.
- *Modify or manipulate human habitation or behaviour.* Reduce contact between humans and vectors.

Examples of environmental modification options to control malaria include:

- draining;
- levelling land;

- filling depressions, borrow pits, pools and ponds;
- contouring reservoirs;
- modifying river boundaries;
- lining canals to prevent seepage, and ensuring a proper gradient;
- constructing self-draining hydraulic structures, such as weirs, to avoid stagnant water;
- tree planting in areas with high water tables;
- designing small dams as cascading systems;
- designing overhead tanks and other water storage structures with practical covers.

Examples of environmental manipulation activities to control malaria include:

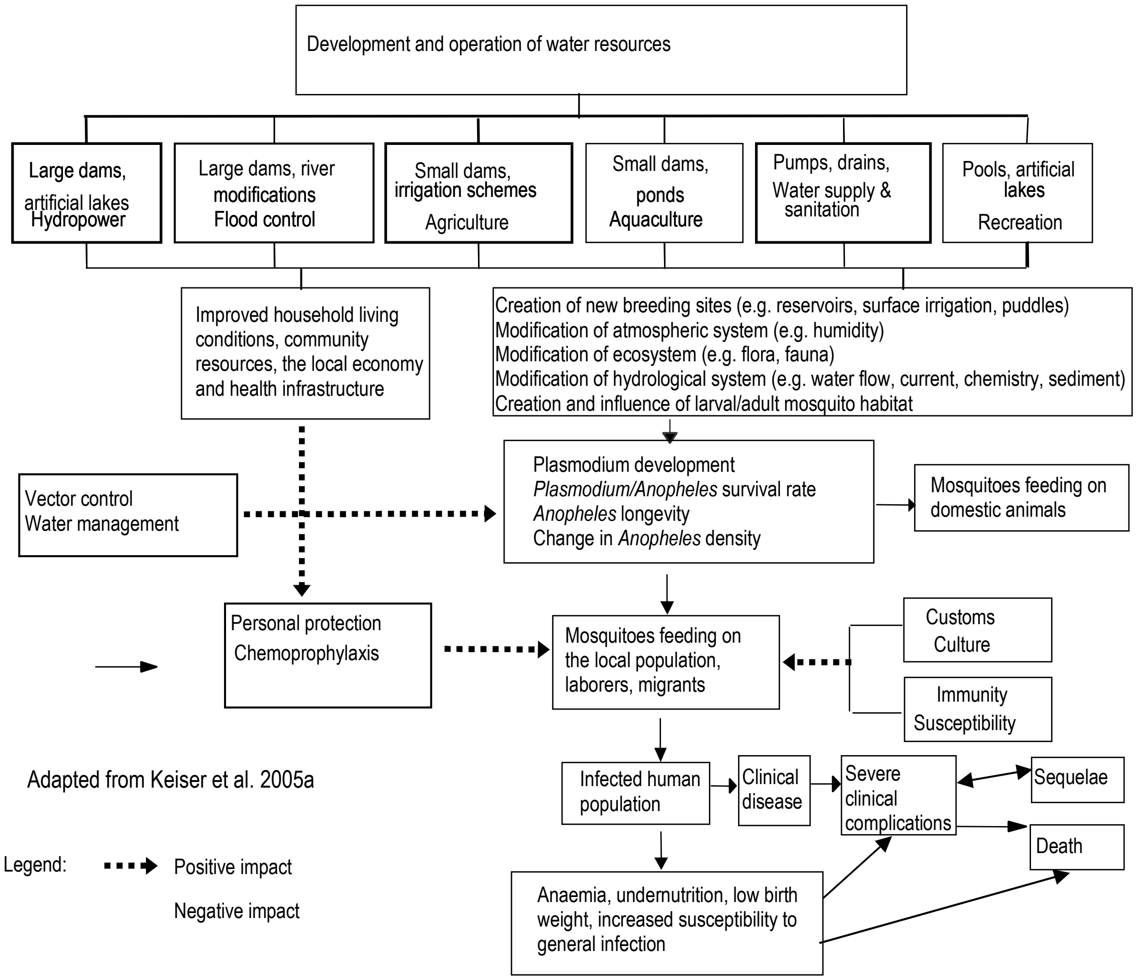
- removal of aquatic plants from water bodies where mosquito larvae may find shelter (de-weeding);
- alternate wetting and drying of irrigated paddy fields (formerly known as intermittent irrigation; van der Hoek et al., 2001);
- periodic flushing of natural and man-made waterways, where mosquito breeding may occur in standing pools;
- introduction of predators such as larvivorous fish;
- implementation of rule-curves for the management of reservoirs, to strand mosquito larvae on the shore through rapid draw down of water levels;
- synchronization of irrigation schedules in irrigated rice production systems;
- application of non-toxic surface tension reducing monolayers (particularly in small water collections in urban environments).

Changes in human habitation to modify contact with vectors can also lead to reduced burden. This may include screening of doors and windows, covering eaves with netting and peri-domestic environmental management to remove standing water. While the use of mosquito nets is, in principle, an environmental intervention, the use of insecticide treated mosquito nets is considered a chemical intervention because of its impact on vector lifespan.

In certain ecosystems environmental management is not a feasible option at all, for example in the forested areas of S.E. Asia where *Anopheles dirus* is the main vector. In situations of instability (humanitarian disasters, civil strive) environmental modification measures add a considerable element of resilience to disease prevention, as they remain functional while regular health services may break down.

A general example of a causal web for malaria transmission related to water resources development projects is presented in Figure 5.

Figure 5 Causal web for malaria transmission related to water resources development



To estimate how much malaria is attributable to the environment, expert judgment is required, based on the local circumstances of vector habitats and transmission patterns and opportunities for change. To produce an estimate, malaria transmission could be grouped into eco-epidemiological settings, including:

- deep forest and hills, including forest fringe;
- rural malaria attributable to water resource development and management (e.g. irrigation and large dams), wetlands, rivers and streams;
- coastal lagoons and other brackish waters;
- urban and peri-urban malaria.

Experts have estimated attributable fractions for six regions of the world. These are, however, regional averages. Local variations between countries in any of these regions may be considerable, and the regional estimates can therefore not substitute for national or even sub-regional studies.

Table 8 Regional means for fraction of malaria attributable to the environment

Region	Attributable fraction (%)		
	Mean	95% Confidence interval	
		5%	95%
Americas	64	51	77
Eastern Mediterranean	36	25	47
Europe	50	38	63
South-East Asia	42	30	54
Sub-Saharan Africa	42	28	55
Western Pacific	40	34	46

Source: Prüss-Üstün and Corvalán, 2006.

In addition to a systematic literature review, a panel of experts may be asked to estimate an attributable fraction, and the mean of such an estimate may be applied to the national burden of malaria. For such an estimation, a suitable question to experts would be the following: "How much (as a percentage) of malaria (in deaths and DALYs) could, in principle, be avoided by environmental improvements, without jeopardizing environmental sustainability".

The attributable fraction then needs to be multiplied against the disease statistics for malaria deaths, cases or DALYs. If not available from national statistics, estimates of malaria deaths and DALYs are available from WHO (Annex 3). Globally, it has been estimated that half a million deaths could be prevented every year by environmental management, mainly the measures related to the management of water bodies and drainage as described in this section.

8.2 Lymphatic filariasis

This disease is caused by parasitic worms that live in the lymphatic system and whose larvae are transmitted by the bite of an infected mosquito. The transmission pathways are region-specific and imply different vectors (Rozendaal, 1997; Erlanger et al. 2005). The country-specific portion of disease which could be prevented by environmental management should therefore rely on consideration of local conditions of vector habitats, disease transmission and potential disease prevention opportunities. A systematic review of locally available literature may provide a basis for an estimate of the contextual fraction of the filariasis burden that can be attributed to specific environmental determinants, including those of water resources development.

In urban settings of South-East Asia and in the Americas, the predominant species (*Wucheria bancrofti*) is linked to organically polluted water (open sewage drains and waste water treatment ponds) where its vector *Culex quinquefasciatus* breeds (Meyrowitsch et al., 1998; Erlanger et al., 2005).

In Africa, both *Culex* and *Anopheles gambiae* are key vectors in coastal areas, whereas inland *A. gambiae* complex and *A. funestus* are the main vectors. As a result, in sub-Saharan settings lymphatic filariasis is linked to freshwater collections and irrigation schemes (Appawu et al., 2001; Erlanger et al., 2005).

In parts of the Western Pacific region, filariasis is transmitted by *Aedes* species, including *A. polynesiensis* which breeds in crab holes. The less important *Brugia malayi* parasite, endemic mainly in India and Sri Lanka, is transmitted by mosquitoes belonging to the genus *Mansonia*, which propagate in the presence of aquatic weeds. Man-made reservoirs invaded by aquatic weed species have been shown to be major producers of *Mansonia* mosquitoes.

Attributable fractions have been estimated by groups of experts for three regions of the world. These are regional averages, and intra-regional variation may result in a very different picture when it comes to individual countries in these regions.

Table 9 Regional means for fraction of lymphatic filariasis attributable to the environment

Region	Attributable fraction (%)		
	Mean	95% Confidence interval	
		5%	95%
Africa	40	20	68
Americas	70	60	80
Asia and Western Pacific	82	50	98

Source: Prüss-Üstün and Corvalán, 2006.

To estimate the fraction of lymphatic filariasis transmission that can be interrupted using environmental management, experts may be consulted to provide estimates and the mean of these estimates may be applied to the national burden of lymphatic filariasis. For such an estimation, a suitable question to experts would be the following: "How much (as a percentage) of lymphatic filariasis (in deaths and DALYs) could, in principle, be avoided by environmental improvements, without jeopardizing environmental sustainability". In the absence of national statistics, WHO prior estimates for deaths and DALYs due to lymphatic filariasis are summarized in Annex 3.

8.3 Onchocerciasis

Onchocerciasis is caused by the pathogen *Onchocerca volvulus* which is transmitted by blackfly species belonging to the *Simulium damnosum* complex that breed in the highly oxygenated water of rapids and rapidly flowing streams. It is generally not considered as acceptable to modify natural environments such as streams, because of ecological and economic considerations. There are settings, however, where the construction of barrages may render stretches of rivers less receptive to blackfly breeding by “drowning” the rapids. Man-made hydraulic structures may be conducive to blackfly breeding; they include cascading canals in irrigation schemes and spillways of dams.

If the breeding grounds in the study area are exclusively natural streams, then as a general rule onchocerciasis should not be considered as preventable through environmental action. If, however, man-made infrastructures of water resources development projects contribute to disease transmission, then there would be a potential for preventing disease transmission (basically by considering the options at the design stage of such projects). In onchocerciasis endemic areas, blackfly breeding on spillways has been prevented, for example, by constructing dams with double spillways with alternating use, so larval stages never complete their development.

Evidence also suggests that disease transmission can be increased by forest degradation related to human activity, as deforested areas provide a favourable habitat for the vector of the more severe strain of the pathogen (Wilson et al., 2002; Adjami et al., 2004), mainly because of a shift in species. Such impacts are, however, difficult to evaluate and can generally not be reflected in the quantification of health impacts.

To estimate the fraction of the disease burden that could be prevented by environmental management, the nature and extent of the breeding places for vectors of *O. volvulus* in the study area should be investigated. The attribution of disease to "modifiable" environments, or man-made environments could then be estimated on the basis of expert opinion, after the synthesis of locally available evidence. For such an estimation, a suitable question to experts would be the following: "How much (as a percentage) of onchocerciasis (in deaths and DALYs) could, in principle, be avoided by environmental improvements, without jeopardizing environmental sustainability" (i.e. basically without modifying natural streams). Globally it was estimated that about 7-13% (with a mean of 10%) of the onchocerciasis burden was attributable to modifiable environments (Prüss-Üstün and Corvalán, 2006).

After an attributable fraction has been locally estimated, it should be multiplied against the onchocerciasis statistics of the country, or the disease occurrence in the area around water resource projects (depending on how the attributable fraction has been set). For comparison, disease burden estimates for countries are available from WHO (Annex 3).

8.4 Dengue

The dengue virus causing dengue fever, and dengue hemorrhagic fever/dengue shock syndrome is transmitted by mosquitoes of the genus *Aedes*, principally *Aedes aegypti*. The natural breeding habitats of this species are water collections in leaf axils of plants. It has flourished in the man-made environment, breeding in water collections in and around the house. The disease therefore can be prevented almost entirely by good peri-domestic environmental management of water bodies in the domestic (and sometimes natural) environment, covering tanks and eliminating drums, old tires, flower pots, ant traps, discarded food containers and other solid waste containing standing water. Depending on specific socio-cultural settings, the use of predators (fish, copepods) in drinking-water containers may also be an option to control dengue vectors.

Where other vectors transmit the disease, such as *Aedes albopictus* which is abundant in Asia (but is a less effective vector) and *Aedes polynesiensis*, which breeds in crab holes on a number of Pacific islands, the problem of dengue cannot be resolved simply by reducing or effectively managing *Aedes aegypti* breeding sites. Still, the disease is globally estimated to be for 95% controllable through environmental management measures.

The estimate of the preventable fraction of disease through environmental action should be based on the vector species locally incriminated in disease transmission. For example, *Aedes aegypti* being the predominant vector in the Americas, almost 100% of disease transmission is attributable to environmental components in that region. In Asia, however, the local situation of vector prevalence involved in disease transmission should be considered, possibly on the basis of expert opinion. For such an estimation, a suitable question to experts would be the following: "How much (as a percentage) of dengue (in deaths and DALYs) could, in principle, be avoided by environmental improvements, without jeopardizing environmental sustainability".

Disease occurrence on dengue should be locally assessed. If not available, WHO provides prior estimates on deaths and DALYs of dengue by country (Annex 3).

8.5 Japanese encephalitis

Vectors involved in the transmission of Japanese encephalitis (JE) include *Culex tritaeniorhynchus* and species belonging to the *C. gelidus* complex. The JE circulates in ardeid birds (e.g. herons, egrets - responsible for the virus long range distribution) and in pigs, which are an amplifying host. As the mosquito vectors are zoophile, under normal circumstances circulation of the virus remains within the bird and pig populations (Reuben et al., 1992). Extreme rainfall or the flooding of rice fields in semi arid zones at the start of the cropping season will lead to a rapid build-up of the mosquito population to densities where the virus spills over into the human population, causing JE outbreaks. The role of pigs was made dramatically apparent in the Srilankan JE outbreaks of the mid-1980s, the origin of which could be traced to the introduction of pigs in traditional irrigation rice production areas as a secondary source of income for local farmers (Peiris et al. 1992).

The association of the disease with the environment is almost total - an estimated 95% at regional level (i.e. the distribution area of the virus, East, Southeast and South Asia). JE therefore could be effectively prevented by environmental management, largely by managing irrigation areas (mainly rice fields) and the access of the mosquito vector species to farm animals, pigs in particular (Rozendaal, 1997; Keiser et al., 2005b). Irrigation management methods can be promoted most successfully in combination with measures to address water scarcity. Where water supplies to flooded rice fields lead to puddle formation, density-dependent reductions in larval populations have been observed, presumably because of the intensified interaction between the larvae and their predators.

It is unlikely that the fraction of JE attributable to the environment deviates greatly according to local conditions. The attributable fraction of 95% could therefore be applied and multiplied against the disease statistics (deaths, DALYs or incidence/prevalence) of JE. If not available, WHO provides prior estimates on deaths and DALYs of JE by country (Annex 3).

9. Drowning

Drowning can be *caused* by environmental factors, such as risks in recreational environments and in the built environment (e.g. unprotected wells or house cisterns), unsafe transport on waterways or by floods. It may also result from non-environmental factors such as alcohol consumption.

Many drownings can be *prevented* by known interventions. These include the following:

- implementing public education and awareness programmes on risks and safety measures to adopt in the vicinity of water bodies;
- improving recreational environments in the vicinity of water bodies;
- improving safety of water bodies (e.g. by installing physical barriers, maintaining prevention and rescue services, developing and enforcing regulations);
- improving occupational safety (e.g. by developing and enforcing regulations);
- building dams or adopting appropriate land use patterns to prevent drownings from floods.

Causes of drowning and opportunities for prevention need to be assessed locally. In Italy, for example, drownings were reduced by 75% over the last decades (Giustini et al., 2003). Globally, it was estimated that 54% (30-76%) of drownings were attributable to the environment and occupation in developed countries, and 74% (48-92%) in developing countries (Prüss-Üstün and Corvalán, 2006).

'Near drowning' represents a significant additional burden of disease which may exceed the burden due to drowning in some circumstances. The causes and preventive measures for near drowning are similar to those for drowning.

Studies on national or local burden of disease will require a development of understanding - normally through case investigation, of the more frequent contributory causes and through these and other information of the potentially effective preventive measures. After collection of the available local statistics/evidence, the attribution of disease to "modifiable" environments, or man-made environments could then be estimated on the basis of expert opinion. For such an estimation, a suitable question to experts would be the following: "How much (as a percentage) of drownings (in deaths and DALYs) could, in principle, be avoided by environmental improvements, without jeopardizing environmental sustainability". For the overall burden of disease from drownings, prior estimates for countries are available from WHO (Annex 3).

10. Other diseases

Water, sanitation and hygiene are related to a number of other diseases, for which the evidence is currently insufficient for quantification of health impacts. A few examples of risks or diseases which have not been addressed in this guide include the following:

- water hardness (most likely to be an effect due to Magnesium ingestion in water) - lack of which has been associated with cardiovascular diseases; calcium content of water could also play a role in preventing osteoporosis (WHO 2006b);
- spinal injury - related to recreational water environments, similar to drownings;
- legionellosis - associated with poorly maintained hot water systems;

- upper respiratory infections - related to poor recreational water quality;
- hepatitis B, C and HIV - related to injections performed with contaminated needles, that could be prevented by hygienic management of health-care wastes;
- natural contamination of drinking-water with arsenic and fluoride - associated with various cancers, crippling fluorosis and other health impacts, of particular concern in certain countries and areas;
- lead in drinking water - increased lead levels leading to permanent impacts on cognitive function in children due to leaded drinking water pipes;
- inadequate hydration - associated with urinary stone formation, urinary tract cancer, poor oral health and other outcomes.

Further research is needed to build the evidence that would allow the quantification of these health impacts at national and local levels.

11. Availability of disease statistics

11.1 National statistics

National statistics, or data detailed by sub-national units, on the incidence, mortality or DALYs (if a National Burden of Disease study has been conducted) of diseases linked to water, sanitation and hygiene are the data of choice for quantifying the disease burden using the proposed method. Where vulnerable groups are of interest, such as certain age groups, the disease statistics should also present segregated illness rates specific to these groups. The diseases of interest are all those that the users of this guide would like to quantify in terms of attributable fraction to water, sanitation and hygiene.

Where multiple studies or data sets on disease frequency exist, these should be checked for consistency and possible variations explained (e.g. difference in definition of diarrhoeal disease).

11.2 Poor availability or alternative sources of statistics

Where the required disease data are not available or are not detailed enough for the required study population, it may be possible to develop an approximate or preliminary estimate based on the disease statistics extrapolated from a larger region, based on the assumption that disease rates vary little. However, such approximation should be carried out with caution. For example, if access to water and sanitation services shows important differences, it is likely that diarrhoeal disease rates may also vary substantially and, therefore, such an extrapolation would be inappropriate.

Disease statistics on diarrhoeal incidence or prevalence and other major diseases of interest may also be available from alternative sources, such as the DHS (Demographic Health Surveys, www.measuredhs.com/), which provide survey results for numerous developing countries on-line or upon request.

For comparison, disease statistics and rates are available also from WHO on a regional basis and for all WHO Member States (www.who.int/evidence, by selecting

"Burden of disease statistics", "Burden of disease project", "Global burden of disease estimates", "GBD 2002 estimates", then "Revised GBD 2002 estimates for countries", then "Deaths and DALY estimates by Member States"). This comprehensive database contains estimates for deaths and DALYs for about 200 countries and about 100 major diseases and injury categories. Summaries of these statistics per country are reproduced in Annex 3 of this document for the year 2004. It is, however, advisable to check the WHO web site for updates.

It is also possible to improve national health information and statistics through, for example, purpose-designed surveys. An initiative coordinated by WHO, the Health Metrics Network, supports the development of better health information systems in view of generation of reliable health information at country level (http://www.who.int/healthmetrics/en/).

12. Estimating the total disease burden related to WSH

The total disease burden related to water, sanitation and hygiene is the sum of the individual disease burdens attributable to WSH, estimated as described in this guide. The reader may wish to select the diseases to be included in this estimate, according to the relevance in their study population, or consider only portions of the WSH risk factor (for example drinking water and sanitation services and hygiene).

The disease burden (expressed as mortality, incidence or in DALYs) should be estimated, for each considered disease, by multiplying the attributable fraction with the measure of disease (see section 3.4 for diarrhoea):

Attributable burden = attributable fraction x number of deaths, cases or DALYs

Deaths and DALYs attributable to WSH can then be added up, while incident cases of different diseases are not comparable. The results of the global analysis for example are presented in section 16.

13. Uncertainty

13.1 Uncertainty in estimating attributable diarrhoea

Relative risks

Although some of the relative risks used in this guide rely on multi-country studies, they all represent risks associated with the specific conditions of the populations and risks covered in those studies. As locally available water and sanitation services may differ, and practices may be specific to socio-economic and cultural settings, those relative risks may not entirely cover the prevailing local situation. It is of course possible to perform local assessments of relative risks. However, given the difficulties in designing representative studies, in particular due to the seasonal variation of risks, it may still be preferable to rely on multi-country studies. In view of the above, relative risks may present a significant source of uncertainty.

Exposure levels

Estimates of exposure to WSH-related risk factors need to match the definitions used in the studies assessing the relative risks. As technologies and practices of water, sanitation and hygiene practices are numerous, they are generally grouped into broad categories for the purpose of estimating health impacts. The uncertainty in exposure assessments will often depend on the data sources or surveys used for such assessments, and should be discussed on that basis.

Addressing uncertainty

Although the approach described in this guide is commensurate with much of the available data, it does have important limitations with respect to chosen measures of relative risk and exposure scenarios. There is inherent uncertainty in both the methodology and data sources, including often-neglected uncertainty in estimates of the total disease burden in the population. At present, however, there is no straightforward mechanism for capturing different sources of uncertainty and for calculating lower and upper bounds for estimates generated by local assessments. If reliable uncertainty information were available on both relative risks and exposure information, it would be possible to perform a Monte Carlo simulation[9]. However, the effort required to execute such an approach seems unsuitable for most local assessments, particularly as the additional information gained may not be substantial.

Given these limitations, we recommend that the final results are derived from the central estimates of relative risk and exposure distribution. Furthermore, uncertainties around relative risks and exposure levels should be described and discussed. A survey of water and sanitation services, based on a random population-based sample, will also enable calculation of a confidence interval for the exposure distribution. Presentation of uncertainty considerations are generally recommended in the final results. To explore likely ranges of results, calculations for attributable fractions can be repeated with the lower and upper relative risk confidence intervals, along with the central exposure level. Although, the ranges that result for attributable fractions and burdens cannot be interpreted in a statistical fashion, they serve simply as “low” and “high” scenarios, not lower and upper bounds around a central estimate, and only point to other possibilities for the actual impact. Alternatively, a series of scenarios can help explore the impact of uncertainties on final results.

13.2 Uncertainty in other disease estimates

Diseases almost fully attributable to water, sanitation and hygiene

As outlined in the above sections, certain diseases are practically entirely transmitted through water, sanitation and hygiene pathways, such as schistosomiasis or intestinal nematode infections. This does not mean that such diseases could only be prevented by action in the WSH sector. For example, prevention of schistosomiasis could also be carried out by worker's protection, but still by addressing WSH measures.

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[9] A Monte Carlo simulation calculates multiple scenarios of a model by repeatedly sampling values from the probability distributions for the uncertain input variables. It provides a probability distribution around the resulting values.

For these diseases that are almost entirely attributable to WSH, the main source of uncertainty will lie in the disease statistics, i.e. in the number of deaths, incidence (and possibly DALYs) of the disease for the study population.

Expert-based attributable fractions

Estimated attributable fractions based on expert opinion are usually relatively large. It is therefore recommended that experts provide a best estimate, and a possible range of their estimate (possibly in terms of a 95% "confidence" interval). It is also recommended to consult a number of experts, or convene a panel of experts.

It is likely that the accuracy of expert-based estimates is lower than estimates of disease burden based on evidence, such as measures of population exposure combined with risk estimates (as for diarrhoea) or on other statistics. Nevertheless, for some diseases, the use of expert opinions may currently be the only way to estimate the contribution of the environment to their burden, and hence highlight the opportunities for preventing disease through environmental change.

If several experts have been consulted for their estimates, the following options are possible to obtain one consolidated estimate:

- Ask experts to justify and discuss their estimates and agree on one final estimate (if possible with likely range).
- Add probabilities of expert opinions, with the resulting mean being the best estimate, and use the new resulting 95% confidence intervals. This can be done for example by assuming a triangular distribution with 95% confidence intervals for each reply (see Prüss-Üstün and Corvalán, 2006, for further details).

14. Practical example

14.1 Diarrhoea

The amount of diarrhoeal disease caused by water, sanitation and hygiene is estimated for the example of the Lao People's Democratic Republic, based on the Global Water Supply and Sanitation Assessment (WHO/UNICEF 2006) and health statistics estimated by WHO. Such an estimate is approximate only and could be revised with more accurate national information. The estimate is performed as follows:

1) Determine the population distribution for the exposure scenarios

Coverage data are based on the Global Assessment (WHO/UNICEF 2006). The report states the following for Lao People's Democratic Republic:

Coverage by improved drinking water:	51%
Coverage by improved sanitation:	30%

Based on these data, it is not possible to assess whether those served with improved water corresponded to those with improved sanitation. However, reports suggest that there is a strong societal preference for improved drinking water when compared to improved sanitation. To apportion the population among scenarios IV and Vb, one could assume that people with improved water supplies were likely to have access to improved sanitation. In other words, as only 51% have access to improved water, 49% are not served by any improved facility; the 30% of people with improved sanitation are assumed to also have access to improved drinking water; the remaining 21% of the 51% of people served with improved drinking water, who do not have access to improved sanitation:

No improved water supply and no basic sanitation (Scenario VI):	49% (i.e. 100%-51%)
Improved water supply and improved sanitation (Scenario IV):	30%
Improved water supply, no improved sanitation (Scenario Vb):	21% (i.e. 51%-30%)
Unexposed population:	0%
Total	100%

In this country, no significant part of the population is in any other scenario, given the low/incomplete coverage in sanitation.

2) Compile relative risks associated with the scenarios

The reference group for the risk scenarios is defined as: no transmission of diarrhoeal disease through unsafe water, sanitation and hygiene, but transmission only through other exposures, i.e. RR = 0. The relative risks used in this example are those proposed in this guide based on global averages, but they could be made more specific if region or country-specific data were available:

Scenario VI: RR=11

Scenario Vb: RR=8.7

Scenario IV: RR=6.9

(0% of the population in scenarios I and II)

3) Process the data

Using the formula for the impact fraction, $IF = \frac{\sum P_i RR_i - 1}{\sum P_i RR_i}$ results in the following:

$$IF = \frac{(0\%*1+30\%*6.9+21\%*8.7+49\%*11)-1}{0\%*1+30\%*6.9+21\%*8.7+49\%*11} = 89\%$$

4) Calculate the disease burden for diarrhoea

For 2002, the compilation of WHO's prior estimates for the Lao People's Democratic Republic reported 5 400 deaths and 176 000 DALYs for diarrhoea (WHO 2004)[1010]. To obtain the disease burden attributable to water, sanitation and hygiene, these estimates should be multiplied by the attributable fraction calculated above, i.e. 89%. The resulting estimates are as follows:

5 400 deaths x 89% = 4 800 deaths

176 000 DALYs x 89% = 156 600 DALYs

14.2 Diseases almost fully attributable to WSH

The diseases almost fully attributable to WSH include schistosomiasis, trachoma, intestinal nematode infections and Japanese encephalitis. Practically the full disease burden from these diseases could therefore be included in the WSH burden. For the Lao People's Democratic Republic, this disease burden amounts to the following[10]:

Table 10 Disease statistics for the Lao People's Democratic Republic

Disease	Deaths (000)	DALYs (000)
Schistosomiasis	0.0	0
Intestinal nematode infections	0.1	18
Trachoma	0.0	1
Japanese encephalitis	0.1	5

14.3 Other diseases

The burden of disease cannot be estimated precisely for the other diseases related to WSH that are mentioned in this guide, as it would require more in-depth local analysis or expert consultation of the situation.

15. Policy actions

An assessment of the burden of disease associated with water, sanitation and hygiene will typically identify that a significant burden of disease is associated with this risk factor. The conduct of the assessment will often assist in identifying major areas of concern and also areas that are not of concern based on specific local or national circumstances. Further information on water-related diseases is available at http://www.who.int/water_sanitation_health/diseases/en/

Most water-borne disease can be prevented and in many circumstances feasible preventive measures are available which have been shown to be cost effective. In developing countries some interventions show a positive return. Very often a useful

10 www.who.int/evidence, by selecting "Burden of disease statistics", "Burden of disease project", "Global burden of disease estimates", "GBD 2002 estimates", then "Revised GBD 2002 estimates for countries", then "Deaths and DALY estimates by Member States"

'next step' will therefore be to look at the scale of likely costs and impacts of technical and policy options to address this burden of disease. Guidance on conducting such analyses is under development by WHO and information on it is available through the WHO internet site at http://www.who.int/water_sanitation_health/economic/en/

In identifying potential remedial actions it is useful to categorize water-related disease into a number of major groups:

- True *water borne disease* in which the agent that causes disease is ingested directly through water. The 'agent' may be a microbe or a chemical.
- *Water hygiene related diseases* where hygiene and especially personal hygiene is important in prevention. Many of these diseases can also be water borne (e.g. infectious diarrhoea, bacillary dysentery, infectious hepatitis). Water hygiene related diseases also include skin and eye infections and infestations such as trachoma scabies, ringworm and conjunctivitis.
- *Water based diseases* - where the association is through the agent of disease requiring water to complete its life cycle. Schistosomiasis is the most globally prevalent example.
- *Water related insect vectors* where the disease is transmitted by a vector which requires water to complete its life cycle. Globally malaria is the most important example.
- There are also some *other water related diseases* that do not fit readily into this well-established categorization. These include legionellosis caused by a bacterium that multiplies especially in artificial water environments; and diseases associated with deficiencies of certain minerals in the diet to which water makes a significant contribution (for which the most important potential example is magnesium and cardiovascular disease).

In the following sections we explore briefly the types of interventions appropriate to each of these groups and the availability of guidance towards their prevention:

Water borne infectious disease

It is not possible with present information to precisely quantify the contributions of true water borne disease from that of food related disease and from water hygiene related disease. Nevertheless the fact that they contribute significantly is confirmed by studies on drinking-water quality and human health (see section 3.3) and by the ongoing occurrence of water borne disease outbreaks in developing and developed countries. Outbreaks may be very large and have wide social and economic impacts.

There is considerable information and experience available on effective measures to prevent water borne disease. Broadly two complementary approaches focus on controlling the source of the disease-causing microbes (pathogens from human and to a lesser extent animal excreta) through sanitation; and on the immediate safety of water being consumed.

- Further information on sanitation interventions is available at www.sanicon.net, http://www.who.int/water_sanitation_health/hygiene/en/; and http://www.who.int/water_sanitation_health/wastewater/en/;

- Further information on managing drinking-water quality is available at http://www.who.int/water_sanitation_health/dwq/en/; http://www.who.int/wsportal/en/; and http://www.who.int/household_water/en/

Water-borne disease caused by toxic chemicals

While there is a large number of chemicals of potential concern in drinking-water, a very small number are believed to be responsible for a significant burden of disease. These include fluoride[11] and arsenic[12], both of which are natural components of groundwater but occur in excessive concentrations in some regions. WHO has developed guidance on identifying those chemicals that are most likely to be of health significance in drinking water[13]. Extensive guidance on chemicals in drinking water and health is available in the WHO Guidelines for Drinking-water Quality[14].

Water hygiene related disease and diseases with water-related insect vectors

The principal activities involved in controlling water hygiene related disease are increasing access to water for hygiene[15] and encouraging use of water for hygiene. For trachoma, which is also a vector-borne disease, a major global effort is under way to reduce the disease and to eliminate blinding trachoma through the 'SAFE' strategy[16].

Water-based diseases

WHO defines Environmental Management for Vector Control as the planning, organization, carrying out and monitoring of activities for the modification and/or manipulation of environmental factors or their interaction with man with a view to preventing or minimizing vector propagation and reducing man-vector-pathogen contact. It may entail one or both of two approaches: environmental modification (permanent infrastructural changes of a capital-intensive nature) and environmental manipulation (recurrent actions aimed at achieving temporary unfavourable conditions for vector breeding).

The occurrence and prevalence of water based diseases such as schistosomiasis is influenced by the way that water is managed in rural and urban areas. Information on environmental management for control of insect vectors of disease is available at http://www.who.int/water_sanitation_health/resources/envmanagement/en/index.html.

In addition to the quantitative estimation of disease burden, health impact assessment provides a useful tool in assessing potential future disease burdens and approaches to their management. WHO defines Health Impact Assessment (HIA) as a combination of procedures, methods and tools by which a policy, programme or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population. Further information on HIA for water resources management is available at http://www.who.int/water_sanitation_health/resources/hia/en/index.html.

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11 1See http://www.who.int/water_sanitation_health/dwq/chemicals/fluoride/en/index.html

12 1See http://www.who.int/water_sanitation_health/dwq/arsenic/en/index.html

13 See http://www.who.int/water_sanitation_health/gdwqrevision/chempriorities/en/index.html

14 See http://www.who.int/water_sanitation_health/dwq/guidelines/en/index.html

15 See http://www.who.int/water_sanitation_health/diseases/wsh0302/en/index.html

16 See http://www.who.int/water_sanitation_health/

Other water-related diseases
Other diseases of global significance and the cause and/or prevention of which is linked to water sanitation and hygiene management include:

- Legionellosis caused by a bacterium that multiplies especially in artificial water environments. While the reported incidence of legionellosis in the developing world is low, this may in part be due to under-reporting. Legionellosis can be prevented by controlling excess growth of *Legionella pneumophila* in artificial water systems. Further information on legionellosis and its prevention is available at
  http://www.who.int/water_sanitation_health/emerging/legionella/en/index.html
- There is increasing interest in the possibility that water may make a significant protective contribution to some diseases which are associated with deficiencies of certain minerals in the diet or inadequate hydration. Most recent interest has focused on magnesium and cardiovascular disease (see
  http://www.who.int/water_sanitation_health/gdwqrevision/hardness/en/index.html
- Management of health care waste is a component of sanitation which is of particular concern to health because of its association with a significant burden of diseases such as HIV/AIDS and hepatitis B and C. Further information on healthcare waste management is available through
  http://www.healthcarewaste.org/en/115_overview.html

16. Global estimates of WSH-related burden of disease

WHO recently estimated the global burden of disease caused by the environment, based on a combination of results from the Comparative Risk Assessment (WHO 2002), a review of the literature and an expert survey (Prüss-Üstün and Corvalán 2006). The results of these estimates are summarized in Tables 11 and 12.

This estimate addresses the attributable burden of disease, i.e. the reduction of disease burden of disease that could be achieved if the three main groups of risks within the area of water, sanitation and hygiene were reduced to the specified baseline (or counterfactual) scenario (see Section 1.1). It should be noted that in principle, the preventable disease burden from various intervention areas cannot necessarily be summed up, as there may be interactions between exposures/outcomes or joint effects. For the purpose of these calculations, however, in order to avoid an overestimate, the outcomes with a direct WSH component are excluded from the estimation of the burden from malnutrition and its consequences. The diseases included only once as direct consequence of WSH, and not again as a consequence of malnutrition therefore include diarrhoeal diseases, malaria, schistosomiasis, lymphatic filariasis, onchocerciasis, dengue, Japanese encephalitis, trachoma, intestinal nematode infections and "other infectious diseases"[17].

[17] "other" infectious diseases as referred to in the WHO disease statistics (http://www.who.int/healthinfo/bodestimates/en/index.html)

Table 11 Deaths attributable to water, sanitation and hygiene, by WHO subregion in 2002 [a]
Data based on literature review/expert survey [b]

							AFRICA		THE AMERICAS		
							Mortality stratum		Mortality stratum		
Disease/disease group	Total		Children 0-14 years		Developed Countries	Developing Countries	High child, high adult	High child, very high adult	Very low child, very low adult	Low child, low adult	High child, high adult
Population (000)	6 224 985		1 830 140		1 366 867	4 858 118	311 273	360 965	333 580	445 161	73 810
	(000)	% [c]	(000)	% [c]	(000)	(000)	(000)	(000)	(000)	(000)	(000)
Total deaths	57 029		11 945		13 430	43 599	4 657	6 007	2 720	2 701	541
Total WSH-related deaths	3 575		3 011		73	3 503	826	821	10	58	35
% of total deaths	6.3%		25%		0.5%	8.0%	18%	14%	0.4%	2.1%	6.5%
Diarrhoeal diseases [d]	1 523	42.6	1 370	45.5	15	1 507	298	302	1	28	18
Intestinal nematode infections [e]	12	0.3	8	0.3	0	12	1	2	0	0	1
Malnutrition (only PEM)	71	2.0	71	2.4	0	71	17	22	0	4	2
Consequences of malnutrition [d]	792	22.1	792	26.3	9	783	191	161	0	2	5
Trachoma [e]	0	0.0	0	0.0	0	0	0	0	0	0	0
Schistosomiasis [e]	15	0.4	0	0.0	0	15	1	1	0	1	0
Lymphatic filariasis	0	0.0	0	0.0	0	0	0	0	0	0	0
Subtotal water supply, sanitation and hygiene	*2 413*	*67. 5*	*2 241*	*74. 4*	*24*	*2 389*	*508*	*488*	*1*	*36*	*26*
Malaria	526	14.7	482	16.0	0	526	232	241	0	1	0
Onchocerciasis	0	0.0	0	0.0	0	0	0	0	0	0	0
Dengue	18	0.5	14	0.5	0	18	0	0	0	1	1
Japanese encephalitis	13	0.4	7	0.2	0	13	0	0	0	0	0
Subtotal water resources management	*557*	*15. 6*	*502*	*16. 7*	*0*	*557*	*232*	*241*	*0*	*2*	*1*
Drownings	277	7.7	106	3.5	33	244	27	21	2	11	2
Subtotal safety of water environments	*277*	*7. 7*	*106*	*3. 5*	*33*	*244*	*27*	*21*	*2*	*11*	*2*
Other infectious [f]	328	9.2	162	5.4	15	312	60	71	7	9	6

PEM: Protein-energy malnutrition

a See Annex 1 for country grouping

b Not a formal WHO estimate; data based on Prüss-Üstün and Corvalán 2006

c Percentage of all deaths attributable to WSH-related risks

d Data further validated by Comparative Risk Assessment methods

e Included in the Comparative Risk Assessment

f Not attributable to one group alone

	EASTERN MEDITERRANEAN		EUROPE			SOUTH-EAST ASIA		WESTERN PACIFIC	
	Mortality stratum		Mortality stratum			Mortality stratum		Mortality stratum	
Disease/disease group	Low child, Low adult	High child, High adult	Very low child, Very low adult	Low child, low adult	Low child, High adult	Low child, Low adult	High child, High adult	Very low child, very low adult	Low child, low adult
Population (000)	142 528	360 296	415 323	222 846	239 717	298 234	1 292 598	155 400	1 562 136
	(000)	(000)	(000)	(000)	(000)	(000)	(000)	(000)	(000)
Total deaths	706	3 446	3 920	1 865	3 779	2 191	12 466	1 146	10 794
Total WSH-related deaths	21	405	8	22	23	75	958	10	303
% of total deaths	3.0%	12%	0.2%	1.2%	0.6%	3.4%	7.7%	0.9%	2.8%
Diarrhoeal diseases [d]	12	207	1	11	1	35	477	1	130
Intestinal nematode infections [e]	0	1	0	0	0	1	4	0	1
Malnutrition (only PEM)	1	9	0	0	0	2	11	0	3
Consequences of malnutrition [d]	1	97	0	5	0	8	272	4	47
Trachoma [e]	0	0	0	0	0	0	0	0	0
Schistosomiasis [e]	0	9	0	0	0	0	0	0	4
Lymphatic filariasis	0	0	0	0	0	0	0	0	0
Subtotal water supply, sanitation and hygiene	*16*	*367*	*6*	*17*	*2*	*57*	*858*	*7*	*200*
Malaria	1	20	0	0	0	5	22	0	5
Onchocerciasis	0	0	0	0	0	0	0	0	0
Dengue	0	1	0	0	0	3	8	0	4
Japanese encephalitis	0	2	0	0	0	0	8	0	3
Subtotal water resources management	*1*	*23*	*0*	*0*	*0*	*8*	*38*	*0*	*11*
Drownings	4	15	2	5	20	11	61	3	92
Subtotal safety of water environments	*4*	*15*	*2*	*5*	*20*	*11*	*61*	*3*	*92*
Other infectious [f]	2	44	4	1	1	11	94	2	16

Table 12 Burden of disease (in DALYs) attributable to environmental factors, by WHO subregions in 2002 [a]

Data based on literature review/expert survey [b]

							AFRICA		THE AMERICAS		
							Mortality stratum		Mortality stratum		
Disease/disease group	Total		Children 0–14 years		Developed Countries	Developing Countries	High child, high adult	High child, very high adult	Very low child, very low adult	Low child, low adult	High child, high adult
Population (000)	6 224 985		1 830 140		1 366 867	4 858 118	311 273	360 965	333 580	445 161	73 810
	(000)	% [c]	(000)	% [c]	(000)	(000)	(000)	(000)	(000)	(000)	(000)
Total DALYs	1 490 126		544 534		213 574	1 276 552	160 415	200 961	46 868	81 589	17 130
Total WSH-related DALYs	135 748		117 789		1 861	133 887	31 152	30 621	188	2 503	1 263
% of total DALYs	9.1%		22%		0.9%	10%	19%	15%	0.4%	3.1%	7.4%
Diarrhoeal diseases [d]	52 460	38.6	48 830	41.5	648	51 812	9 796	9 916	63	1 266	636
Intestinal nematode infections [e]	2 948	2.2	2 884	2.4	3	2 945	809	329	1	66	101
Malnutrition (only PEM)	7 104	5.2	7 104	6.0	83	7 021	1 239	1 412	0	244	104
Consequences of malnutrition [d]	28 475	21.0	28 475	24.2	181	28 294	6 853	5 744	0	95	177
Trachoma [e]	2 320	1.7	13	0.0	0	2 319	486	726	0	162	2
Schistosomiasis [e]	1 698	1.3	560	0.5	1	1 697	621	713	0	74	0
Lymphatic filariasis	3 784	2.8	1 211	1.0	1	3 783	391	415	0	0	0
Subtotal water supply, sanitation and hygiene	98 789	72. 8	89 077	75. 6	918	97 871	20 196	19 255	65	1 907	1 019
Malaria	19 241	14.2	17 984	15.3	11	19 230	8 350	8 647	0	55	16
Onchocerciasis	51	0.0	10	0.0	0	51	41	9	0	0	0
Dengue	586	0.4	512	0.4	0	586	1	4	0	30	36
Japanese encephalitis	671	0.5	459	0.4	0	671	0	0	0	0	0
Subtotal water resources management	20 550	15. 1	18 965	16. 1	12	20 539	8 392	8 660	0	85	52
Drownings	7 871	5.8	3 845	3.3	736	7 135	779	624	63	333	59
Subtotal safety of water environments	7 871	5. 8	3 845	3. 3	736	7 135	779	624	63	333	59
Other infectious [f]	8 538	6.3	5 902	5.0	196	8 343	1 784	2 081	59	178	133

PEM: Protein-energy malnutrition

a See Annex 1 for country grouping

b Not a formal WHO estimate; data based on Prüss-Üstün and Corvalán 2006

c Percentage of all DALYs attributable to WSH-related risks

d Data further validated by Comparative Risk Assessment methods

e Included in the Comparative Risk Assessment study

f Not attributable to one group alone

	EASTERN MEDITERRANEAN		EUROPE			SOUTH-EAST ASIA		WESTERN PACIFIC	
	Mortality stratum		Mortality stratum			Mortality stratum		Mortality stratum	
Disease/disease group	Low child, Low adult	High child, High adult	Very low child, Very low adult	Low child, low adult	Low child, High adult	Low child, Low adult	High child, High adult	Very low child, very low adult	Low child, low adult
Population (000)	142 528	360 296	415 323	222 846	239 717	298 234	1 292 598	155 400	1 562 136
	(000)	(000)	(000)	(000)	(000)	(000)	(000)	(000)	(000)
Total DALYs	24 074	115 005	51 725	37 697	60 900	62 463	364 110	16 384	248 495
Total WSH-related DALYs	933	14 711	157	800	615	3 036	36 212	101	13 455
% of total DALYs	3.9%	13%	0%	2.1%	1.0%	4.9%	10%	1%	5%
Diarrhoeal diseases [d]	480	6 865	66	409	82	1 257	15 962	28	5 633
Intestinal nematode infections [e]	1	225	0	1	0	135	669	2	611
Malnutrition (only PEM)	81	834	8	48	22	316	1 938	5	853
Consequences of malnutrition [d]	52	3 482	0	163	3	333	9 774	15	1 784
Trachoma [e]	91	283	0	0	0	0	168	0	400
Schistosomiasis [e]	29	197	0	0	0	3	4	0	55
Lymphatic filariasis	0	49	0	1	0	195	2 401	0	332
Subtotal water supply, sanitation and hygiene	735	11 936	75	622	106	2 238	30 916	50	9 669
Malaria	33	777	1	10	0	211	955	0	185
Onchocerciasis	0	1	0	0	0	0	0	0	0
Dengue	9	19	0	0	0	85	278	0	125
Japanese encephalitis	0	78	0	0	0	27	262	0	303
Subtotal water resources management	42	875	1	10	0	323	1 495	0	613
Drownings	113	477	40	122	475	291	1 714	35	2 745
Subtotal safety of water environments	113	477	40	122	475	291	1 714	35	2 745
Other infectious diseases [f]	43	1 423	41	45	33	184	2 087	16	428

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Annex 1 WHO Member States, by WHO subregion and mortality stratum [a] (Situation 2004)

Subregion and mortality stratum	Description	Broad grouping	Member States
Africa			
AFR-D	Africa with high child and high adult	High-mortality developing	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	Africa with high child and very high adult mortality	High-mortality developing	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.
Americas			
AMR-A	Americas with very low child and very low adult mortality	Developed	Canada, Cuba, United States of America.
AMR-B	Americas with low child and low adult mortality	Low-mortality developing	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	Americas with high child and high adult mortality	High-mortality developing	Bolivia, Ecuador, Guatemala, Haiti, Nicaragua, Peru.
South-East Asia			
SEAR-B	South-East Asia with low child and low adult mortality	Low-mortality developing	Indonesia, Sri Lanka, Thailand.
SEAR-D	South-East Asia with high child and high adult mortality	High-mortality developing	Bangladesh, Bhutan, Democratic People's Republic of Korea, India, Maldives, Myanmar, Nepal, Timor-Leste.
Europe			
EUR-A	Europe with very low child and very low adult mortality	Developed	Andorra, Austria, Belgium, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland, United Kingdom.
EUR-B	Europe with low child and low adult mortality	Developed	Albania, Armenia, Azerbaijan, Bosnia and Herzegovina, Bulgaria, Georgia, Kyrgyzstan, Poland, Romania, Serbia and Montenegro, Slovakia, Tajikistan, The Former Yugoslav Republic of Macedonia, Turkey, Turkmenistan, Uzbekistan.
EUR-C	Europe with low child and high adult mortality	Developed	Belarus, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, Republic of Moldova, Russian Federation, Ukraine.
Eastern Mediterranean			
EMR-B	Eastern Mediterranean with low child and low adult mortality	Low-mortality developing	Bahrain, Iran (Islamic Republic of), Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates.
EMR-D	Eastern Mediterranean with high child and high adult mortality	High-mortality developing	Afghanistan, Djibouti, Egypt, Iraq, Morocco, Pakistan, Somalia, Sudan, Yemen.
Western Pacific			
WPR-A	Western Pacific with very low child and very low adult mortality	Developed	Australia, Brunei Darussalam, Japan, New Zealand, Singapore.
WPR-B	Western Pacific with low child and low adult mortality	Low-mortality developing	Cambodia, China, Cook Islands, Fiji, Kiribati, Lao People's Democratic Republic, Malaysia, Marshall Islands, Micronesia (Federated States of), Mongolia, Nauru, Niue, Palau, Papua New Guinea, Philippines, Republic of Korea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, Viet Nam

[a] Source: WHO (2004).

Annex 2 Coverage estimates of countries, areas and territories, 2004
Data derived from the water and sanitation global assessment (WHO/UNICEF 2006)

Countries, Areas and Territories	Population	Improved Drinking Water Coverage Total		Improved sanitation	Regulated supply	Improved water & sanitation	Improved sanitation only	Improved water only	No improved supply nor sanitation
	Total	Total	Household Connection	Total	Scenario II	Scenario IV	Scenario Va	Scenario Vb	Scenario IV
	(thousands)	%	%	%	%	%	%	%	%
Afghanistan	28,574	39	4	34	0	34	0	5	61
Albania	3,112	96	69	91	0	91	0	5	4
Algeria	32,358	85	74	92	0	85	7	0	8
American Samoa	63	--	--	--	--	--	--	--	--
Andorra	67	100	--	100	100	0	0	0	0
Angola	15,490	53	6	31	0	31	0	22	47
Anguilla	12	60	45	99	0	60	39	0	1
Antigua and Barbuda	81	91	84	95	0	91	4	0	5
Argentina	38,372	96	79	91	0	91	0	5	4
Armenia	3,026	92	86	83	0	83	0	9	8
Aruba	98	100	100	--	--	--	--	--	--
Australia	19,942	100	88	100	100	0	0	0	0
Austria	8,171	100	100	100	100	0	0	0	0
Azerbaijan	8,355	77	47	54	0	54	0	23	23
Bahamas	319	97	70	100	0	97	3	0	0
Bahrain	716	--	--	--	--	--	--	--	--
Bangladesh	139,215	74	6	39	0	39	0	35	26
Barbados	269	100	--	100	100	0	0	0	0
Belarus	9,811	100	71	84	0	84	0	16	0
Belgium	10,400	100	100	100	100	0	0	0	0
Belize	264	91	81	47	0	47	0	44	9
Benin	8,177	67	12	33	0	33	0	34	33
Bermuda	64	--	--	--	--	--	--	--	--
Bhutan	2,116	62	--	70	0	62	8	0	30
Bolivia	9,009	85	73	46	0	46	0	39	15
Bosnia and Herzegovina	3,909	97	85	95	0	95	0	2	3
Botswana	1,769	95	46	42	0	42	0	53	5
Brazil	183,913	90	79	75	0	75	0	15	10
British Virgin Islands	22	98	97	100	98	0	2	0	0
Brunei Darussalam	366	--	--	--	--	--	--	--	--
Bulgaria	7,780	99	90	99	99	0	0	0	1
Burkina Faso	12,822	61	6	13	0	13	0	48	39
Burundi	7,282	79	5	36	0	36	0	43	21
Cambodia	13,798	41	9	17	0	17	0	24	59
Cameroon	16,038	66	14	51	0	51	0	15	34
Canada	31,958	100	88	100	100	0	0	0	0
Cape Verde	495	80	25	43	0	43	0	37	20
Cayman Islands	44	--	--	--	--	--	--	--	--
Central African Republic	3,986	75	4	27	0	27	0	48	25
Chad	9,448	42	4	9	0	9	0	33	58
Channel Islands	149	--	--	--	--	--	--	--	--
Chile	16,124	95	91	91	0	91	0	4	5
China	1,307,989	77	69	44	0	44	0	33	23

Countries, Areas and Territories	Population	Improved Drinking Water Coverage		Improved sanitation	Regulated supply	Improved water & sanitation	Improved sanitation only	Improved water only	No improved supply nor sanitation
		Total							
	Total	Total	Household Connection	Total	Scenario II	Scenario IV	Scenario Va	Scenario Vb	Scenario IV
	(thousands)	%	%	%	%	%	%	%	%
China, Hong Kong SAR	6,963	--	--	--	--	--	--	--	--
China, Macao SAR	457	--	--	--	--	--	--	--	--
Colombia	44,915	93	86	86	0	86	0	7	7
Comoros	777	86	14	33	0	33	0	53	14
Congo	3,883	58	28	27	0	27	0	31	42
Congo, Democratic Republic of the	55,853	46	9	30	0	30	0	16	54
Cook Islands	18	94	--	100	0	94	6	0	0
Costa Rica	4,253	97	92	92	0	92	0	5	3
Côte d'Ivoire	17,872	84	24	37	0	37	0	47	16
Croatia	4,540	100	83	100	100	0	0	0	0
Cuba	11,245	91	74	98	0	91	7	0	2
Cyprus	826	100	100	100	100	0	0	0	0
Czech Republic	10,229	100	95	98	98	0	0	2	0
Denmark	5,414	100	100	100	100	0	0	0	0
Djibouti	779	73	35	82	0	73	9	0	18
Dominica	79	97	87	84	0	84	0	13	3
Dominican Republic	8,768	95	80	78	0	78	0	17	5
Ecuador	13,040	94	68	89	0	89	0	5	6
Egypt	72,642	98	85	70	0	70	0	28	2
El Salvador	6,762	84	64	62	0	62	0	22	16
Equatorial Guinea	492	43	8	53	0	43	10	0	47
Eritrea	4,232	60	9	9	0	9	0	51	40
Estonia	1,335	100	90	97	0	97	0	3	0
Ethiopia	75,600	22	5	13	0	13	0	9	78
Faeroe Islands	47	--	--	--	--	--	--	--	--
Falkland Islands (Malvinas)	3	--	--	--	--	--	--	--	--
Fiji	841	47	20	72	0	47	25	0	28
Finland	5,235	100	97	100	100	0	0	0	0
France	60,257	100	100	--	--	--	--	--	--
French Guiana	183	84	79	78	0	78	0	6	16
French Polynesia	253	100	98	98	98	0	0	2	0
Gabon	1,362	88	45	36	0	36	0	52	12
Gambia	1,478	82	12	53	0	53	0	29	18
Georgia	4,518	82	57	94	0	82	12	0	6
Germany	82,645	100	100	100	100	0	0	0	0
Ghana	21,664	75	19	18	0	18	0	57	25
Gibraltar	28	--	--	--	--	--	--	--	--
Greece	11,098	--	--	--	--	--	--	--	--
Greenland	57	--	--	--	--	--	--	--	--
Grenada	102	95	82	96	0	95	1	0	4
Guadeloupe	445	98	98	64	0	64	0	34	2
Guam	167	100	--	99	99	0	0	1	0
Guatemala	12,295	95	76	86	0	86	0	9	5
Guinea	9,202	50	11	18	0	18	0	32	50
Guinea-Bissau	1,540	59	5	35	0	35	0	24	41
Guyana	750	83	53	70	0	70	0	13	17
Haiti	8,407	54	11	30	0	30	0	24	46

Countries, Areas and Territories	Population	Improved Drinking Water Coverage Total		Improved sanitation	Regulated supply	Improved water & sanitation	Improved sanitation only	Improved water only	No improved supply nor sanitation
	Total	Total	Household Connection	Total	Scenario II	Scenario IV	Scenario Va	Scenario Vb	Scenario IV
	(thousands)	%	%	%	%	%	%	%	%
Holy See	1	--	--	--	--	--	--	--	--
Honduras	7,048	87	75	69	0	69	0	18	13
Hungary	10,124	99	94	95	0	95	0	4	1
Iceland	292	100	100	100	100	0	0	0	0
India	1,087,124	86	19	33	0	33	0	53	14
Indonesia	220,077	77	17	55	0	55	0	22	23
Iran, Islamic Republic of	68,803	94	--	--	--	--	--	--	--
Iraq	28,057	81	74	79	0	79	0	2	19
Ireland	4,080	--	98	--	--	--	--	--	--
Isle of Man	77	--	--	--	--	--	--	--	--
Israel	6,601	100	100	--	--	--	--	--	--
Italy	58,033	--	99	--	--	--	--	--	--
Jamaica	2,639	93	70	80	0	80	0	13	7
Japan	127,923	100	96	100	100	0	0	0	0
Jordan	5,561	97	93	93	0	93	0	4	3
Kazakhstan	14,839	86	62	72	0	72	0	14	14
Kenya	33,467	61	28	43	0	43	0	18	39
Kiribati	97	65	36	40	0	40	0	25	35
Korea, Democratic People's Republic of	22,384	100	77	59	0	59	0	41	0
Korea, Republic of	47,645	92	85	--	--	--	--	--	--
Kuwait	2,606	--	--	--	--	--	--	--	--
Kyrgyzstan	5,204	77	45	59	0	59	0	18	23
Lao People's Democratic Republic	5,792	51	14	30	0	30	0	21	49
Latvia	2,318	99	81	78	0	78	0	21	1
Lebanon	3,540	100	98	98	98	0	0	2	0
Lesotho	1,798	79	16	37	0	37	0	42	21
Liberia	3,241	61	0	27	0	27	0	34	39
Libyan Arab Jamahiriya	5,740	--	--	97	--	--	--	--	--
Liechtenstein	34	--	--	--	--	--	--	--	--
Lithuania	3,443	--	80	--	--	--	--	--	--
Luxembourg	459	100	100	100	100	0	0	0	0
Macedonia, the former Yugoslav Republic of	2,030	--	--	--	--	--	--	--	--
Madagascar	18,113	46	6	32	0	32	0	14	54
Malawi	12,608	73	7	61	0	61	0	12	27
Malaysia	24,894	99	94	94	0	94	0	5	1
Maldives	321	83	22	59	0	59	0	24	17
Mali	13,124	50	11	46	0	46	0	4	50
Malta	400	100	100	--	--	--	--	--	--
Marshall Islands	60	87	--	82	0	82	0	5	13
Martinique	394	--	--	--	--	--	--	--	--
Mauritania	2,980	53	25	34	0	34	0	19	47
Mauritius	1,233	100	100	94	0	94	0	6	0
Mexico	105,699	97	90	79	0	79	0	18	3
Micronesia, Federated States of	110	94	--	28	0	28	0	66	6
Moldova, Republic of	4,218	92	41	68	0	68	0	24	8
Monaco	35	100	100	100	100	0	0	0	0

Countries, Areas and Territories	Population	Improved Drinking Water Coverage Total		Improved sanitation	Regulated supply	Improved water & sanitation	Improved sanitation only	Improved water only	No improved supply nor sanitation
	Total	Total	Household Connection	Total	Scenario II	Scenario IV	Scenario Va	Scenario Vb	Scenario IV
	(thousands)	%	%	%	%	%	%	%	%
Mongolia	2,614	62	28	59	0	59	0	3	38
Montserrat	4	100	--	96	0	96	0	4	0
Morocco	31,020	81	57	73	0	73	0	8	19
Mozambique	19,424	43	8	32	0	32	0	11	57
Myanmar	50,004	78	6	77	0	77	0	1	22
Namibia	2,009	87	48	25	0	25	0	62	13
Nauru	13	--	--	--	--	--	--	--	--
Nepal	26,591	90	17	35	0	35	0	55	10
Netherlands	16,226	100	100	100	100	0	0	0	0
Netherlands Antilles	181	--	--	--	--	--	--	--	--
New Caledonia	233	--	--	--	--	--	--	--	--
New Zealand	3,989	--	--	--	--	--	--	--	--
Nicaragua	5,376	79	60	47	0	47	0	32	21
Niger	13,499	46	8	13	0	13	0	33	54
Nigeria	128,709	48	9	44	0	44	0	4	52
Niue	1	100	100	100	100	0	0	0	0
Northern Mariana Islands	79	99	--	95	0	95	0	4	1
Norway	4,598	100	100	100	100	0	0	0	0
Occupied Palestinian Territory	3,587	92	81	73	0	73	0	19	8
Oman	2,534	--	--	--	--	--	--	--	--
Pakistan	154,794	91	27	59	0	59	0	32	9
Palau	20	85	--	83	0	83	0	2	15
Panama	3,175	90	86	73	0	73	0	17	10
Papua New Guinea	5,772	39	12	44	0	39	5	0	56
Paraguay	6,017	86	58	80	0	80	0	6	14
Peru	27,562	83	71	63	0	63	0	20	17
Philippines	81,617	85	45	72	0	72	0	13	15
Pitcairn	0	--	--	--	--	--	--	--	--
Poland	38,559	--	98	--	--	--	--	--	--
Portugal	10,441	--	92	--	--	--	--	--	--
Puerto Rico	3,932	--	--	--	--	--	--	--	--
Qatar	777	100	--	100	100	0	0	0	0
Réunion	773	--	--	--	--	--	--	--	--
Romania	21,790	57	49	--	--	--	--	--	--
Russian Federation	143,899	97	82	87	0	87	0	10	3
Rwanda	8,882	74	8	42	0	42	0	32	26
Saint Helena	5	--	--	--	--	--	--	--	--
Saint Kitts and Nevis	42	99	72	95	0	95	0	4	1
Saint Lucia	159	98	75	89	0	89	0	9	2
Saint Vincent and the Grenadines	118	--	--	--	--	--	--	--	--
Saint-Pierre-et-Miquelon	6	--	--	--	--	--	--	--	--
Samoa	184	88	57	100	0	88	12	0	0
San Marino	28	--	--	--	--	--	--	--	--
Sao Tome and Principe	153	79	25	25	0	25	0	54	21
Saudi Arabia	23,950	--	--	--	--	--	--	--	--
Senegal	11,386	76	46	57	0	57	0	19	24
Serbia and Montenegro	10,510	93	82	87	0	87	0	6	7

Countries, Areas and Territories	Population	Improved Drinking Water Coverage Total		Improved sanitation	Regulated supply	Improved water & sanitation	Improved sanitation only	Improved water only	No improved supply nor sanitation
	Total	Total	Household Connection	Total	Scenario II	Scenario IV	Scenario Va	Scenario Vb	Scenario IV
	(thousands)	%	%	%	%	%	%	%	%
Seychelles	80	88	88	--	--	--	--	--	--
Sierra Leone	5,336	57	12	39	0	39	0	18	43
Singapore	4,273	100	100	100	100	0	0	0	0
Slovakia	5,401	100	96	99	99	0	0	1	0
Slovenia	1,967	--	--	--	--	--	--	--	--
Solomon Islands	466	70	14	31	0	31	0	39	30
Somalia	7,964	29	1	26	0	26	0	3	71
South Africa	47,208	88	64	65	0	65	0	23	12
Spain	42,646	100	99	100	100	0	0	0	0
Sri Lanka	20,570	79	10	91	0	79	12	0	9
Sudan	35,523	70	26	34	0	34	0	36	30
Suriname	446	92	81	94	0	92	2	0	6
Swaziland	1,034	62	23	48	0	48	0	14	38
Sweden	9,008	100	100	100	100	0	0	0	0
Switzerland	7,240	100	100	100	100	0	0	0	0
Syrian Arab Republic	18,582	93	84	90	0	90	0	3	7
Tajikistan	6,430	59	34	51	0	51	0	8	41
Tanzania, United Republic of	37,627	62	18	47	0	47	0	15	38
Thailand	63,694	99	38	99	99	0	0	0	1
Timor-Leste	887	58	12	36	0	36	0	22	42
Togo	5,988	52	4	35	0	35	0	17	48
Tokelau	1	88	0	78	0	78	0	10	12
Tonga	102	100	75	96	0	96	0	4	0
Trinidad and Tobago	1,301	91	77	100	0	91	9	0	0
Tunisia	9,995	93	74	85	0	85	0	8	7
Turkey	72,220	96	92	88	0	88	0	8	4
Turkmenistan	4,766	72	53	62	0	62	0	10	28
Turks and Caicos Islands	25	100	68	96	0	96	0	4	0
Tuvalu	10	93	--	90	0	90	0	3	7
Uganda	27,821	60	1	43	0	43	0	17	40
Ukraine	46,989	96	76	96	0	96	0	0	4
United Arab Emirates	4,284	100	79	98	98	0	0	2	0
United Kingdom	59,479	100	100	--	--	--	--	--	--
United States of America	295,410	100	100	100	100	0	0	0	0
United States Virgin Islands	112	--	--	--	--	--	--	--	--
Uruguay	3,439	100	96	100	100	0	0	0	0
Uzbekistan	26,209	82	46	67	0	67	0	15	18
Vanuatu	207	60	39	50	0	50	0	10	40
Venezuela	26,282	83	81	68	0	68	0	15	17
Viet Nam	83,123	85	24	61	0	61	0	24	15
Wallis and Futuna Islands	15	100	99	80	0	80	0	20	0
Western Sahara	330	--	--	--	--	--	--	--	--
Yemen	20,329	67	23	43	0	43	0	24	33
Zambia	11,479	58	16	55	0	55	0	3	42
Zimbabwe	12,936	81	32	53	0	53	0	28	19

Annex 3 Estimates of selected country health statistics, 2002 (Source: World Health Organization (a))

World Health Organization

Department of Measurement and Health Information

Table 1. Estimated total deaths ('000), by cause and WHO Member State, 2002 (a)

GBD code	GBD cause (a)	Afghanistan	Albania	Algeria	Andorra	Angola	Antigua and Barbuda	Argentina	Armenia	Australia	Austria	Azerbaijan	Bahamas	Bahrain	Bangladesh	Barbados	Belarus
	Population ('000) (e)	*22,930*	*3,141*	*31,266*	*69*	*13,184*	*73*	*37,981*	*3,072*	*19,544*	*8,111*	*8,297*	*310*	*709*	*143,809*	*269*	*9,940*
W000	All Causes	484.5	22.1	173.3	0.6	306.6	0.6	281.4	26.1	126.6	70.4	64.2	1.8	2.3	1,106.8	2.3	143.6
W010	Diarrhoeal diseases	41.2	0.0	8.1	0.0	48.8	0.0	0.4	0.1	0.0	0.0	0.9	0.0	0.0	68.2	0.0	0.0
W020	Malaria	0.9	-	0.0	0.0	17.9	-	-	0.0	0.0	0.0	0.0	0.0	-	1.7	-	-
W024	Schistosomiasis	0.0	-	0.1	-	1.5	-	-	-	-	-	0.0	-	-	0.1	-	-
W026	lymphatic filariasis	0.0	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-	-
W027	Onchocerciasis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W029	Dengue	0.0	-	0.0	-	0.0	-	-	-	0.0	-	-	-	-	2.1	-	-
W030	Japanese encephalitis	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	-	-
W031	Trachoma	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-	-
W032	Intestinal nematode infections	0.0	0.0	0.1	-	0.1	-	0.0	-	0.0	0.0	-	-	-	0.2	-	-
W054	Protein-energy malnutrition	7.3	0.0	0.5	0.0	8.2	0.0	1.4	0.0	0.1	-	0.0	0.0	0.0	4.8	0.0	0.0
W154	Drownings	2.4	0.0	1.2	0.0	2.4	0.0	1.0	0.1	0.2	0.1	0.0	0.0	0.0	8.3	0.0	1.7

Table 2. Estimated total DALYs ('000), by cause and WHO Member State, 2002 (a, b)

GBD code	GBD cause (a)	Afghanistan	Albania	Algeria	Andorra	Angola	Antigua and Barbuda	Argentina	Armenia	Australia	Austria	Azerbaijan	Bahamas	Bahrain	Bangladesh	Barbados	Belarus
W000	All Causes	17,011	503	5,500	9	10,757	13	6,293	516	2,154	970	1,545	54	83	36,972	44	2,192
W010	Diarrhoeal diseases	1,343	1	295	0	1,608	0	49	4	5	2	37	0	1	2,298	0	3
W020	Malaria	64	-	0	0	681	-	0	1	0	0	5	0	-	122	-	-
W024	Schistosomiasis	0	-	66	-	48	0	-	-	-	-	0	-	-	1	-	-
W026	lymphatic filariasis	0	-	-	-	45	-	-	-	-	-	-	-	-	356	-	-
W027	Onchocerciasis	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
W029	Dengue	0	-	0	-	0	-	-	-	0	-	-	-	-	71	-	-
W030	Japanese encephalitis	1	-	-	-	-	-	-	-	-	-	-	-	-	24	-	-
W031	Trachoma	5	-	-	-	4	-	-	-	0	-	-	-	-	17	-	-
W032	Intestinal nematode infections	13	0	76	-	40	0	6	0	0	0	0	0	0	79	0	-
W054	Protein-energy malnutrition	338	2	50	0	345	0	28	1	0	0	5	0	0	686	0	1
W154	Drownings	79	1	35	0	72	0	28	2	6	2	1	0	0	248	0	41

a. www.who.int/evidence/bod; for notes, data sources and levels of evidence refer to notes sheet available from this site; check for updates

b. Standard DALYs with age-weighting and time discounting as reported in World Health Report 2004

Table 1. Estimated total deaths ('000), by cause and WHO Member State, 2002 (a), continued

GBD cause (a)	Belgium	Belize	Benin	Bhutan	Bolivia	Bosnia and Herzegovina	Botswana	Brazil	Brunei Darussalam	Bulgaria	Burkina Faso	Burundi	Cambodia	Cameroon	Canada	Cape Verde
Population ('000) (e)	*10,296*	*251*	*6,558*	*2,190*	*8,645*	*4,126*	*1,770*	*176,257*	*350*	*7,965*	*12,624*	*6,602*	*13,810*	*15,729*	*31,271*	*454*
All Causes	102.9	1.5	87.4	21.0	73.1	34.9	41.3	1,225.2	1.0	106.7	249.9	120.4	160.5	235.8	222.4	2.4
Diarrhoeal diseases	0.1	0.0	7.3	1.3	4.2	0.0	0.4	17.3	0.0	0.0	21.8	9.3	11.8	14.4	0.3	0.1
Malaria	0.0	0.0	12.5	0.0	0.0	-	0.2	0.6	-	-	25.7	4.7	3.4	19.7	0.0	0.0
Schistosomiasis	-	-	0.3	-	-	-	0.0	0.9	-	-	0.8	0.4	0.0	0.6	-	0.0
lymphatic filariasis	-	-	-	0.0	-	-	-	0.0	-	-	0.2	-	0.0	-	-	-
Onchocerciasis	-	-	-	-	-	-	-	0.0	-	-	-	-	-	-	-	-
Dengue	-	0.0	0.0	0.1	0.0	-	0.0	0.4	-	-	0.0	-	0.2	0.0	-	0.0
Japanese encephalitis	-	-	-	0.0	-	-	-	-	-	-	-	-	0.1	-	-	-
Trachoma	-	-	-	0.0	-	-	-	-	-	-	-	-	0.0	-	-	-
Intestinal nematode infections	-	-	0.0	0.0	0.0	-	0.0	0.1	-	-	0.1	0.0	0.3	0.1	0.0	0.0
Protein-energy malnutrition	0.1	0.0	1.0	0.1	1.6	0.0	0.0	11.3	-	0.0	2.3	0.6	1.5	1.6	0.2	0.0
Drownings	0.1	0.0	0.5	0.1	0.6	0.3	0.1	7.7	0.0	0.2	1.3	0.7	1.3	1.2	0.3	0.0

Table 2. Estimated total DALYs ('000), by cause and WHO Member State, 2002 (a,b), continued

GBD cause (a)	Belgium	Belize	Benin	Bhutan	Bolivia	Bosnia and Herzegovina	Botswana	Brazil	Brunei Darussalam	Bulgaria	Burkina Faso	Burundi	Cambodia	Cameroon	Canada	Cape Verde
All Causes	1,358	46	3,050	644	2,338	649	1,267	36,522	45	1,464	8,709	4,052	5,310	7,615	3,693	78
Diarrhoeal diseases	3	1	241	44	142	1	13	735	0	3	717	306	387	480	9	4
Malaria	0	0	450	1	3	-	6	41	-	-	927	184	122	724	0	0
Schistosomiasis	-	-	17	-	-	-	4	63	-	-	36	19	1	39	-	0
lymphatic filariasis	-	-	23	0	-	-	-	8	0	-	49	22	10	55	-	2
Onchocerciasis	-	-	0	-	-	-	-	0	-	-	0	4	-	23	-	-
Dengue	-	0	0	2	0	-	0	15	0	-	0	0	6	0	-	0
Japanese encephalitis	-	-	-	1	-	-	-	-	0	-	-	-	4	-	-	-
Trachoma	-	-	13	0	-	-	3	100	-	-	21	17	2	27	-	1
Intestinal nematode infections	-	0	20	1	9	-	2	30	0	-	40	8	49	46	0	1
Protein-energy malnutrition	1	1	52	10	48	1	5	244	1	1	132	47	134	92	1	1
Drownings	1	1	16	4	17	6	3	228	1	4	41	20	45	38	7	0

a. www.who.int/evidence/bod; for notes, data sources and levels of evidence refer to notes sheet available from this site; check for updates

b. Standard DALYs with age-weighting and time discounting as reported in World Health Report 2004

Table 1. Estimated total deaths ('000), by cause and WHO Member State, 2002 (a), continued

GBD cause (a)	Central African Republic	Chad	Chile	China	Colombia	Comoros	Congo	Cook Islands	Costa Rica	Croatia	Cuba	Cyprus	Czech Republic	Côte d'Ivoire	Democratic People's Republic of Korea	Democratic Republic of the Congo
Population ('000) (e)	*3,819*	*8,348*	*15,613*	*1,302,307*	*43,526*	*747*	*3,633*	*18*	*4,094*	*4,439*	*11,271*	*796*	*10,246*	*16,365*	*22,541*	*51,201*
All Causes	75.9	148.7	83.7	9,135.5	243.7	5.4	44.5	0.1	18.3	50.4	76.7	7.5	103.3	258.6	204.4	986.4
Diarrhoeal diseases	4.7	11.4	0.3	108.4	2.7	0.4	1.6	0.0	0.1	0.0	0.2	0.0	0.0	16.7	3.2	112.2
Malaria	6.0	16.4	-	0.4	0.2	0.5	5.0	-	0.0	-	-	-	-	25.1	0.0	97.7
Schistosomiasis	0.1	0.5	-	3.3	-	0.0	0.0	-	-	-	-	-	-	0.0	0.1	0.0
lymphatic filariasis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-
Onchocerciasis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dengue	0.0	-	-	-	0.0	0.0	0.0	0.0	0.0	-	0.0	-	-	0.0	-	0.0
Japanese encephalitis	-	-	-	2.5	-	-	-	-	-	-	-	-	-	-	0.1	-
Trachoma	-	-	-	-	0.0	-	-	-	-	-	-	-	-	-	0.0	-
Intestinal nematode infections	0.0	0.1	-	0.6	0.0	0.0	0.0	0.0	0.0	-	0.0	-	-	0.0	0.1	0.4
Protein-energy malnutrition	0.4	1.6	0.5	6.1	2.4	0.1	0.1	0.0	0.0	-	0.0	-	0.0	0.8	0.1	7.7
Drownings	0.5	0.7	0.5	112.9	1.4	0.0	0.3	0.0	0.2	0.1	0.3	0.0	0.2	2.4	1.1	7.2

Table 2. Estimated total DALYs ('000), by cause and WHO Member State, 2002 (a, b), continued

GBD cause (a)	Central African Republic	Chad	Chile	China	Colombia	Comoros	Congo	Cook Islands	Costa Rica	Croatia	Cuba	Cyprus	Czech Republic	Côte d'Ivoire	Democratic People's Republic of Korea	Democratic Republic of the Congo
All Causes	2,380	5,079	2,188	200,273	8,412	201	1,502	3	556	709	1,588	108	1,474	8,597	4,801	33,957
Diarrhoeal diseases	151	375	19	5,055	134	13	52	0	6	1	13	1	2	539	129	3,670
Malaria	216	597	-	72	22	19	185	-	1	-	-	-	-	915	3	3,631
Schistosomiasis	8	23	-	49	-	0	7	-	-	-	-	-	-	33	2	98
lymphatic filariasis	13	28	-	-	-	3	12	0	-	-	-	-	-	57	0	171
Onchocerciasis	9	18	-	-	0	-	0	-	-	-	-	-	-	3	-	-
Dengue	0	0	-	0	1	0	0	0	0	-	0	-	-	0	0	1
Japanese encephalitis	-	-	-	281	-	-	-	0	-	-	-	-	-	-	6	-
Trachoma	7	21	-	381	0	1	-	-	-	-	-	-	-	20	0	88
Intestinal nematode infections	4	26	2	596	9	2	4	0	1	-	1	0	-	19	12	65
Protein-energy malnutrition	20	95	4	1,089	64	4	13	0	1	0	1	0	0	55	41	479
Drownings	14	23	13	3,370	41	1	10	0	5	2	8	1	4	70	32	208

a. www.who.int/evidence/bod; for notes, data sources and levels of evidence refer to notes sheet available from this site; check for updates

b. Standard DALYs with age-weighting and time discounting as reported in World Health Report 2004

Table 1. Estimated total deaths ('000), by cause and WHO Member State, 2002 (a), continued

GBD cause (a)	Denmark	Djibouti	Dominica	Dominican Republic	Ecuador	Egypt	El Salvador	Equatorial Guinea	Eritrea	Estonia	Ethiopia	Fiji	Finland	France	Gabon	Gambia
Population ('000) (e)	*5,351*	*693*	*78*	*8,616*	*12,810*	*70,507*	*6,415*	*481*	*3,991*	*1,338*	*68,961*	*831*	*5,197*	*59,850*	*1,306*	*1,388*
All Causes	57.4	8.5	0.5	56.8	76.8	495.2	41.2	7.6	41.2	18.2	1,060.2	5.3	48.6	499.0	14.9	15.6
Diarrhoeal diseases	0.1	0.8	0.0	1.2	2.0	13.1	1.0	0.5	2.6	0.0	63.2	0.1	0.0	0.6	0.4	0.9
Malaria	-	0.0	-	0.0	0.1	4.9	-	0.9	2.5	-	31.9	-	-	0.0	1.2	1.3
Schistosomiasis	-	-	-	-	-	8.0	-	0.0	0.0	-	4.7	-	-	-	0.0	0.0
lymphatic filariasis	-	0.0	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-
Onchocerciasis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dengue	-	0.0	-	0.2	0.0	0.0	0.1	0.0	0.0	-	0.0	0.0	-	-	0.0	0.0
Japanese encephalitis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trachoma	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Intestinal nematode infections	-	0.0	0.0	-	0.0	0.0	-	0.0	0.0	-	1.1	-	-	-	0.0	0.0
Protein-energy malnutrition	0.0	0.1	0.0	0.7	0.8	0.5	0.4	0.1	0.2	0.0	17.0	0.0	0.0	2.0	0.1	0.1
Drownings	0.0	0.1	0.0	0.0	0.6	3.1	0.3	0.0	0.3	0.1	3.6	0.1	0.1	0.6	0.1	0.1

Table 2. Estimated total DALYs ('000), by cause and WHO Member State, 2002 (a, b), continued

GBD cause (a)	Denmark	Djibouti	Dominica	Dominican Republic	Ecuador	Egypt	El Salvador	Equatorial Guinea	Eritrea	Estonia	Ethiopia	Fiji	Finland	France	Gabon	Gambia
All Causes	750	286	14	1,673	2,364	13,692	1,310	253	1,482	264	36,287	163	668	7,406	462	515
Diarrhoeal diseases	2	28	0	49	77	464	38	15	87	0	2,100	2	1	18	15	31
Malaria	-	1	-	2	7	156	0	31	96	-	1,251	-	-	0	43	47
Schistosomiasis	-	1	-	2	-	88	-	1	8	-	203	-	-	-	3	3
lymphatic filariasis	-	0	-	0	-	3	-	2	-	-	232	1	-	-	5	5
Onchocerciasis	-	-	-	-	0	-	-	1	-	-	36	-	-	-	1	-
Dengue	-	0	-	8	0	0	2	0	0	-	1	0	-	-	0	0
Japanese encephalitis	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-
Trachoma	-	1	-	-	-	124	-	1	8	-	184	-	-	-	-	1
Intestinal nematode infections	-	2	0	2	11	8	1	1	5	-	108	1	-	-	4	4
Protein-energy malnutrition	0	4	0	19	25	129	16	4	19	0	922	1	0	8	6	6
Drownings	1	2	0	1	16	98	10	1	10	3	114	2	3	11	2	3

a. www.who.int/evidence/bod; for notes, data sources and levels of evidence refer to notes sheet available from this site; check for updates

b. Standard DALYs with age-weighting and time discounting as reported in World Health Report 2004

Table 1. Estimated total deaths ('000), by cause and WHO Member State, 2002 (a), continued

GBD cause (a)	Georgia	Germany	Ghana	Greece	Grenada	Guatemala	Guinea	Guinea-Bissau	Guyana	Haiti	Honduras	Hungary	Iceland	India	Indonesia	Iran (Islamic Republic of)
Population ('000) (e)	*5,177*	*82,414*	*20,471*	*10,970*	*80*	*12,036*	*8,359*	*1,449*	*764*	*8,218*	*6,781*	*9,923*	*287*	*1,049,550*	*217,131*	*68,070*
All Causes	61.3	815.4	209.0	114.0	0.8	81.9	114.4	26.6	7.3	112.3	41.8	122.2	1.9	10,378.5	1,626.1	384.5
Diarrhoeal diseases	0.0	0.3	9.7	-	0.0	3.4	9.5	1.6	0.3	5.6	1.7	0.0	0.0	456.4	35.5	8.7
Malaria	-	0.0	23.4	-	-	0.1	16.8	2.5	0.0	0.2	0.1	-	-	9.4	6.9	0.8
Schistosomiasis	-	-	1.3	-	-	0.0	0.4	0.1	-	-	0.0	-	-	-	0.1	-
lymphatic filariasis	-	-	-	-	-	0.0	-	-	0.0	-	0.0	-	-	0.1	0.0	-
Onchocerciasis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dengue	-	-	0.0	-	-	0.0	0.0	0.0	-	1.0	0.1	-	-	5.4	0.5	-
Japanese encephalitis	-	-	-	-	-	-	-	-	-	-	-	-	-	6.9	0.2	-
Trachoma	-	-	-	-	-	0.0	-	-	-	-	0.0	-	-	0.0	0.0	-
Intestinal nematode infections	-	0.0	0.1	-	-	1.1	0.1	0.0	0.0	0.0	0.0	-	-	3.2	0.0	-
Protein-energy malnutrition	-	0.1	1.2	-	0.0	1.2	1.2	0.1	0.1	1.4	1.1	0.0	0.0	47.2	9.8	2.2
Drownings	0.1	0.5	1.3	0.4	0.0	0.1	0.6	0.1	0.0	0.0	0.2	0.2	0.0	68.9	10.4	2.2

Table 2. Estimated total DALYs ('000), by cause and WHO Member State, 2002 (a, b), continued

GBD cause (a)	Georgia	Germany	Ghana	Greece	Grenada	Guatemala	Guinea	Guinea-Bissau	Guyana	Haiti	Honduras	Hungary	Iceland	India	Indonesia	Iran (Islamic Republic of)
All Causes	892	10,414	7,093	1,393	17	2,823	3,995	898	211	3,490	1,422	1,779	28	299,910	46,385	12,679
Diarrhoeal diseases	2	20	329	3	0	123	312	53	9	185	62	3	0	15,254	1,264	322
Malaria	6	0	861	-	-	8	602	89	1	9	18	-	-	844	354	68
Schistosomiasis	-	-	57	-	-	0	22	4	-	-	0	-	-	-	3	8
lymphatic filariasis	-	-	74	-	-	0	29	5	0	1	0	-	-	2,521	176	-
Onchocerciasis	-	-	0	-	-	1	4	0	-	-	-	-	-	-	-	-
Dengue	-	-	0	-	-	2	0	0	-	33	4	-	-	184	19	-
Japanese encephalitis	-	-	-	-	-	-	-	-	-	-	-	-	-	226	23	-
Trachoma	-	-	35	-	-	2	12	4	-	-	0	-	-	138	0	46
Intestinal nematode infections	-	0	57	-	0	46	25	4	0	8	3	-	-	595	191	0
Protein-energy malnutrition	1	3	85	0	0	60	62	9	3	43	47	1	0	4,223	627	101
Drownings	1	10	40	6	0	4	20	3	1	1	7	5	0	1,903	287	69

a. www.who.int/evidence/bod; for notes, data sources and levels of evidence refer to notes sheet available from this site; check for updates

b. Standard DALYs with age-weighting and time discounting as reported in World Health Report 2004

Table 1. Estimated total deaths ('000), by cause and WHO Member State, 2002 (a), continued

GBD cause (a)	Iraq	Ireland	Israel	Italy	Jamaica	Japan	Jordan	Kazakhstan	Kenya	Kiribati	Kuwait	Kyrgyzstan	Lao People's Democratic Republic	Latvia	Lebanon	Lesotho
Population ('000) (e)	*24,510*	*3,911*	*6,304*	*57,482*	*2,627*	*127,478*	*5,329*	*15,469*	*31,540*	*87*	*2,443*	*5,067*	*5,529*	*2,329*	*3,596*	*1,800*
All Causes	213.2	31.2	35.4	570.7	19.7	973.2	23.3	184.1	406.9	0.7	4.7	45.3	67.5	33.5	24.1	46.3
Diarrhoeal diseases	14.1	0.0	0.1	0.0	0.1	1.3	0.7	0.4	24.6	0.0	0.0	0.7	5.4	0.0	0.3	1.5
Malaria	0.1	0.0	-	0.0	-	0.0	-	0.0	18.1	0.0	0.0	-	1.2	-	-	0.0
Schistosomiasis	-	-	-	-	-	0.0	-	-	0.7	-	0.0	-	0.0	-	-	0.0
lymphatic filariasis	0.0	-	-	-	-	-	-	0.0	-	-	-	-	0.0	-	0.0	-
Onchocerciasis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dengue	0.0	-	-	-	-	-	-	-	0.0	0.0	-	-	0.2	-	0.0	0.0
Japanese encephalitis	-	-	-	-	-	0.0	-	-	-	-	-	-	0.1	-	-	-
Trachoma	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-	-	-
Intestinal nematode infections	0.0	-	-	0.0	0.0	0.0	-	0.0	0.1	-	-	0.0	0.1	-	0.0	0.0
Protein-energy malnutrition	3.3	0.0	0.0	0.2	0.2	1.3	0.0	0.1	1.4	0.0	-	0.0	1.0	0.0	0.0	0.1
Drownings	1.6	0.1	0.0	0.3	0.0	5.9	0.1	1.5	1.4	-	0.0	0.5	0.6	0.3	0.1	0.2
Table 2. Estimated total DALYs ('000), by cause and WHO Member State, 2002 (a, b), continued																
All Causes	8,279	488	659	6,789	387	13,296	843	3,752	13,298	24	259	1,141	2,230	482	653	1,348
Diarrhoeal diseases	469	1	2	13	7	37	26	16	818	1	2	26	176	1	11	49
Malaria	5	0	-	0	-	0	-	0	696	0	0	0	46	-	-	0
Schistosomiasis	4	-	-	-	-	0	2	-	71	-	0	-	0	-	-	4
lymphatic filariasis	0	-	-	-	-	-	-	0	111	0	-	-	4	-	0	-
Onchocerciasis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dengue	0	-	-	-	-	-	-	-	0	0	-	-	6	-	0	0
Japanese encephalitis	-	-	-	-	-	0	-	-	-	0	-	-	5	-	-	-
Trachoma	13	-	-	-	-	-	-	-	37	-	-	-	1	-	-	-
Intestinal nematode infections	3	-	-	0	0	0	0	0	37	0	0	0	18	-	0	2
Protein-energy malnutrition	165	0	1	2	2	13	2	6	121	1	0	4	63	0	1	10
Drownings	53	1	0	6	1	55	2	41	46	0	1	14	21	7	4	4

a. www.who.int/evidence/bod; for notes, data sources and levels of evidence refer to notes sheet available from this site; check for updates

b. Standard DALYs with age-weighting and time discounting as reported in World Health Report 2004

Table 1. Estimated total deaths ('000), by cause and WHO Member State, 2002 (a), continued

GBD cause (a)	Liberia	Libyan Arab Jamahiriya	Lithuania	Luxembourg	Madagascar	Malawi	Malaysia	Maldives	Mali	Malta	Marshall Islands	Mauritania	Mauritius	Mexico	Micronesia (Federated States of)	Monaco
Population ('000) (e)	*3,239*	*5,445*	*3,465*	*447*	*16,916*	*11,871*	*23,965*	*309*	*12,623*	*393*	*52*	*2,807*	*1,210*	*101,965*	*108*	*34*
All Causes	69.4	23.3	41.1	3.4	201.1	257.5	119.2	2.1	242.8	3.0	0.5	40.2	7.8	469.9	0.7	0.3
Diarrhoeal diseases	4.9	0.4	0.0	0.0	18.9	19.5	0.3	0.1	22.7	-	0.0	3.6	0.0	5.6	0.0	0.0
Malaria	6.6	-	0.0	-	22.3	20.0	0.0	0.0	22.7	-	0.0	2.6	0.0	0.0	0.0	-
Schistosomiasis	0.1	0.2	-	-	0.7	0.8	0.0	0.0	0.8	-	-	0.2	-	-	-	-
lymphatic filariasis	-	0.0	-	-	-	-	0.0	0.0	-	-	-	-	-	0.0	-	-
Onchocerciasis	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-	-
Dengue	0.0	0.0	-	-	-	0.0	0.1	0.0	-	-	0.0	0.0	0.0	0.0	0.0	-
Japanese encephalitis	-	-	-	-	-	-	0.0	0.0	-	-	-	-	-	-	-	-
Trachoma	-	-	-	-	-	-	0.0	0.0	-	-	-	-	-	-	-	-
Intestinal nematode infections	0.0	0.0	-	-	0.1	0.1	0.0	0.0	0.2	-	0.0	0.0	-	0.0	0.0	-
Protein-energy malnutrition	0.7	0.0	0.0	0.0	3.5	2.6	0.1	0.0	8.2	-	0.0	0.2	0.0	9.4	0.0	-
Drownings	0.4	0.1	0.5	0.0	1.2	1.9	0.8	0.0	1.5	0.0	0.0	0.2	0.0	2.8	0.0	-

Table 2. Estimated total DALYs ('000), by cause and WHO Member State, 2002 (a, b), continued

GBD cause (a)	Liberia	Libyan Arab Jamahiriya	Lithuania	Luxembourg	Madagascar	Malawi	Malaysia	Maldives	Mali	Malta	Marshall Islands	Mauritania	Mauritius	Mexico	Micronesia (Federated States of)	Monaco
All Causes	2,455	780	625	55	6,991	8,279	3,505	60	8,641	44	13	1,363	221	15,387	22	4
Diarrhoeal diseases	159	18	1	0	622	632	28	2	750	0	0	120	1	254	1	0
Malaria	237	0	0	-	821	734	7	0	826	-	0	100	0	5	0	-
Schistosomiasis	9	4	-	-	43	34	1	0	38	-	-	8	2	-	-	-
lymphatic filariasis	11	0	-	-	58	39	19	1	43	-	-	-	4	0	0	-
Onchocerciasis	6	-	-	-	-	7	-	-	0	-	-	-	-	0	-	-
Dengue	0	0	-	-	0	0	4	0	0	-	0	0	0	0	0	-
Japanese encephalitis	-	-	-	-	-	-	2	0	-	-	0	-	-	-	0	-
Trachoma	-	5	-	-	-	34	0	0	39	-	-	5	5	60	-	-
Intestinal nematode infections	10	0	-	-	51	16	22	0	43	-	0	8	2	20	0	-
Protein-energy malnutrition	34	3	1	0	205	142	39	1	280	0	0	20	1	172	0	0
Drownings	12	4	10	0	38	56	23	0	46	0	0	7	1	82	0	0

a. www.who.int/evidence/bod; for notes, data sources and levels of evidence refer to notes sheet available from this site; check for updates

b. Standard DALYs with age-weighting and time discounting as reported in World Health Report 2004

Table 1. Estimated total deaths ('000), by cause and WHO Member State, 2002 (a), continued

GBD cause (a)	Mongolia	Morocco	Mozambique	Myanmar	Namibia	Nauru	Nepal	Netherlands	New Zealand	Nicaragua	Niger	Nigeria	Niue	Norway	Oman	Pakistan
Population ('000) (e)	*2,559*	*30,072*	*18,537*	*48,852*	*1,961*	*13*	*24,609*	*16,067*	*3,846*	*5,335*	*11,544*	*120,911*	*2*	*4,514*	*2,768*	*149,911*
All Causes	19.4	153.8	385.3	519.9	28.3	0.1	233.3	139.4	27.3	25.7	244.6	2,006.1	0.0	45.2	8.3	1,386.4
Diarrhoeal diseases	0.9	6.6	30.1	24.9	0.8	0.0	16.7	0.0	0.0	1.4	25.3	134.5	-	0.1	0.2	118.4
Malaria	-	0.0	34.1	7.1	0.8	-	0.1	0.0	-	0.0	23.6	218.8	-	0.0	-	1.6
Schistosomiasis	-	0.0	2.1	-	0.0	0.0	0.1	-	-	-	1.4	6.8	-	-	0.0	-
lymphatic filariasis	-	0.0	-	0.0	-	-	0.0	-	-	-	-	-	-	-	-	0.0
Onchocerciasis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dengue	-	0.0	0.0	0.8	0.0	0.0	0.2	0.0	-	0.1	-	0.0	0.0	-	0.0	0.6
Japanese encephalitis	-	-	-	0.4	-	-	0.2	-	-	-	-	-	-	-	-	2.4
Trachoma	-	-	-	0.0	-	-	0.0	-	-	-	-	-	-	-	-	0.0
Intestinal nematode infections	-	0.0	0.1	0.2	0.0	0.0	0.1	-	-	0.0	0.0	0.3	0.0	-	0.0	0.8
Protein-energy malnutrition	-	0.2	3.7	3.3	0.1	0.0	2.0	0.1	0.0	0.6	1.5	16.0	0.0	-	0.0	7.8
Drownings	0.2	1.1	0.6	3.4	0.1	0.0	1.8	0.1	0.1	0.2	1.6	20.2	0.0	0.1	0.1	8.1

Table 2. Estimated total DALYs ('000), by cause and WHO Member State, 2002 (a, b), continued

GBD cause (a)	Mongolia	Morocco	Mozambique	Myanmar	Namibia	Nauru	Nepal	Netherlands	New Zealand	Nicaragua	Niger	Nigeria	Niue	Norway	Oman	Pakistan
All Causes	580	5,198	12,438	14,523	881	3	7,469	1,869	452	955	8,938	68,128	0	520	363	44,821
Diarrhoeal diseases	31	232	980	817	29	0	552	4	1	51	832	4,382	0	1	8	3,904
Malaria	-	1	1,221	267	33	-	15	0	-	5	877	7,866	-	0	0	170
Schistosomiasis	-	6	67	-	4	0	1	-	-	-	44	334	-	-	1	-
lymphatic filariasis	-	0	62	38	-	-	60	-	-	-	40	425	0	-	-	0
Onchocerciasis	-	-	-	-	-	-	-	-	-	-	0	327	-	-	-	-
Dengue	0	0	0	27	0	0	7	0	-	3	0	1	0	-	0	19
Japanese encephalitis	1	-	-	13	-	0	5	-	-	-	-	-	0	-	-	82
Trachoma	-	17	40	10	-	-	3	-	-	-	26	233	-	-	6	16
Intestinal nematode infections	1	3	23	120	2	0	15	-	-	6	37	356	0	-	0	110
Protein-energy malnutrition	2	58	181	272	7	0	156	1	0	23	122	967	0	0	3	678
Drownings	5	34	19	99	2	0	55	2	2	6	46	563	0	1	3	234

a. www.who.int/evidence/bod; for notes, data sources and levels of evidence refer to notes sheet available from this site; check for updates

b. Standard DALYs with age-weighting and time discounting as reported in World Health Report 2004

Table 1. Estimated total deaths ('000), by cause and WHO Member State, 2002 (a), continued

GBD cause (a)	Palau	Panama	Papua New Guinea	Paraguay	Peru	Philippines	Poland	Portugal	Qatar	Republic of Korea	Republic of Moldova	Romania	Russian Federation	Rwanda	Saint Kitts and Nevis	Saint Lucia
Population ('000) (e)	*20*	*3,064*	*5,586*	*5,740*	*26,767*	*78,580*	*38,622*	*10,049*	*601*	*47,430*	*4,270*	*22,387*	*144,082*	*8,272*	*42*	*148*
All Causes	0.1	13.9	46.7	26.9	170.1	448.5	351.9	94.3	1.5	275.0	48.2	258.7	2,405.7	131.5	0.4	0.9
Diarrhoeal diseases	0.0	0.2	2.4	0.9	4.4	12.2	0.0	0.0	0.0	0.3	0.0	0.1	0.9	13.3	0.0	0.0
Malaria	-	-	0.9	-	0.0	0.5	-	0.0	-	0.0	-	-	0.0	3.0	-	-
Schistosomiasis	-	-	0.0	-	-	0.2	-	-	-	-	-	-	0.0	0.1	-	-
lymphatic filariasis	-	-	0.0	-	-	0.0	-	-	-	-	-	-	-	-	-	-
Onchocerciasis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dengue	0.0	-	-	-	0.0	3.1	-	-	-	-	-	-	-	-	-	-
Japanese encephalitis	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-
Trachoma	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-
Intestinal nematode infections	0.0	0.0	0.1	-	0.0	0.1	-	-	-	-	-	-	-	0.0	-	0.0
Protein-energy malnutrition	0.0	0.1	1.0	0.2	3.0	2.7	0.1	0.1	-	0.3	0.0	0.1	0.3	1.3	0.0	0.0
Drownings	0.0	0.2	0.4	0.1	1.3	3.6	1.1	0.0	0.0	1.5	0.4	1.2	18.0	1.2	0.0	0.0

Table 2. Estimated total DALYs ('000), by cause and WHO Member State, 2002 (a, b), continued

GBD cause (a)	Palau	Panama	Papua New Guinea	Paraguay	Peru	Philippines	Poland	Portugal	Qatar	Republic of Korea	Republic of Moldova	Romania	Russian Federation	Rwanda	Saint Kitts and Nevis	Saint Lucia
All Causes	4	452	1,608	1,021	5,153	14,991	5,832	1,415	71	6,370	883	4,106	39,410	4,528	8	24
Diarrhoeal diseases	0	10	80	35	171	411	10	3	1	63	2	10	55	436	0	0
Malaria	-	0	33	2	8	34	-	0	-	0	-	-	2	121	-	-
Schistosomiasis	-	-	0	-	-	3	-	-	-	-	-	-	0	18	-	0
lymphatic filariasis	-	-	4	-	-	63	-	-	-	246	-	-	-	27	-	-
Onchocerciasis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dengue	0	-	0	-	0	109	-	-	-	0	-	-	-	0	-	-
Japanese encephalitis	0	-	2	-	-	8	-	-	-	6	-	-	-	-	-	-
Trachoma	-	-	0	-	-	-	-	-	2	-	-	-	-	14	-	-
Intestinal nematode infections	0	1	8	1	24	77	-	-	0	20	-	-	-	10	0	0
Protein-energy malnutrition	0	4	45	9	65	227	2	1	0	19	1	4	32	76	0	0
Drownings	0	5	13	4	37	115	25	1	0	36	9	28	417	32	0	0

a. www.who.int/evidence/bod; for notes, data sources and levels of evidence refer to notes sheet available from this site; check for updates

b. Standard DALYs with age-weighting and time discounting as reported in World Health Report 2004

Table 1. Estimated total deaths ('000), by cause and WHO Member State, 2002 (a), continued

GBD cause (a)	Saint Vincent and the Grenadines	Samoa	San Marino	Sao Tome and Principe	Saudi Arabia	Senegal	Serbia and Montenegro	Seychelles	Sierra Leone	Singapore	Slovakia	Slovenia	Solomon Islands	Somalia	South Africa	Spain
Population ('000) (e)	*119*	*176*	*27*	*157*	*23,520*	*9,855*	*10,535*	*80*	*4,764*	*4,183*	*5,398*	*1,986*	*463*	*9,480*	*44,759*	*40,977*
All Causes	0.8	1.1	0.3	1.4	97.3	102.8	120.9	0.5	131.7	18.1	49.9	18.2	3.0	175.3	679.8	355.7
Diarrhoeal diseases	0.0	0.0	-	0.1	1.7	7.3	0.1	0.0	12.9	0.0	0.0	0.0	0.2	15.6	13.6	0.3
Malaria	-	0.0	-	0.1	0.0	13.2	0.0	0.0	9.5	0.0	0.0	-	0.0	4.7	0.1	0.0
Schistosomiasis	-	-	-	0.0	0.0	0.3	-	-	0.6	-	-	-	-	0.3	0.0	-
lymphatic filariasis	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-	-
Onchocerciasis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dengue	-	0.0	-	0.0	0.3	0.0	-	-	0.0	-	-	-	0.0	0.0	-	-
Japanese encephalitis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trachoma	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Intestinal nematode infections	0.0	0.0	-	0.0	0.0	0.0	-	-	0.1	-	-	-	0.0	0.0	0.0	-
Protein-energy malnutrition	0.0	0.0	-	0.0	0.0	0.4	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.5	3.8	0.1
Drownings	0.0	0.0	0.0	0.0	1.6	0.7	0.2	0.0	0.7	0.0	0.2	0.0	0.0	0.8	1.4	0.6

Table 2. Estimated total DALYs ('000), by cause and WHO Member State, 2002 (a, b), continued

GBD cause (a)	Saint Vincent and the Grenadines	Samoa	San Marino	Sao Tome and Principe	Saudi Arabia	Senegal	Serbia and Montenegro	Seychelles	Sierra Leone	Singapore	Slovakia	Slovenia	Solomon Islands	Somalia	South Africa	Spain
All Causes	23	29	3	42	3,724	3,809	1,823	16	4,517	442	834	282	109	6,364	20,560	4,952
Diarrhoeal diseases	0	1	0	2	74	248	8	0	418	3	1	0	7	510	479	11
Malaria	-	0	-	3	9	482	0	0	340	0	0	-	1	176	3	0
Schistosomiasis	-	-	-	0	5	23	-	-	18	-	-	-	-	23	91	-
lymphatic filariasis	-	0	-	1	-	35	-	0	16	-	-	-	-	0	-	-
Onchocerciasis	-	-	-	-	-	1	-	-	4	-	-	-	-	-	-	-
Dengue	-	0	-	0	9	0	-	0	0	0	-	-	0	0	0	-
Japanese encephalitis	-	0	-	-	-	-	-	-	-	0	-	-	0	-	-	-
Trachoma	-	-	-	0	25	15	-	0	12	-	-	-	-	-	98	-
Intestinal nematode infections	0	0	-	0	0	29	-	0	15	3	-	-	1	28	44	-
Protein-energy malnutrition	0	0	0	1	44	37	1	0	78	4	0	0	2	107	172	2
Drownings	0	0	0	0	49	24	3	0	21	0	4	1	1	29	44	11

a. www.who.int/evidence/bod; for notes, data sources and levels of evidence refer to notes sheet available from this site; check for updates

b. Standard DALYs with age-weighting and time discounting as reported in World Health Report 2004

Table 1. Estimated total deaths ('000), by cause and WHO Member State, 2002 (a), continued

GBD cause (a)	Sri Lanka	Sudan	Suriname	Swaziland	Sweden	Switzerland	Syrian Arab Republic	Tajikistan	Thailand	The former Yugoslav Republic of Macedonia	Timor-Leste	Togo	Tonga	Trinidad and Tobago	Tunisia	Turkey
Population ('000) (e)	*18,910*	*32,878*	*432*	*1,069*	*8,867*	*7,171*	*17,381*	*6,195*	*62,193*	*2,046*	*739*	*4,801*	*103*	*1,298*	*9,728*	*70,318*
All Causes	145.5	346.2	3.3	26.0	91.1	60.9	70.9	54.3	419.1	19.0	6.8	62.5	0.6	11.8	55.8	436.9
Diarrhoeal diseases	0.7	19.5	0.0	0.6	0.1	0.0	2.1	2.0	4.6	0.0	0.1	3.0	0.0	0.0	0.7	6.9
Malaria	1.0	22.1	0.0	0.0	-	0.0	-	0.0	4.0	-	0.0	6.5	0.0	-	-	-
Schistosomiasis	0.0	1.7	0.0	0.0	-	-	-	-	-	-	0.0	0.1	-	-	-	0.0
lymphatic filariasis	0.0	0.0	-	-	-	-	-	-	-	-	0.0	-	-	0.0	0.0	0.0
Onchocerciasis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dengue	0.0	0.0	0.0	-	-	-	0.0	-	2.5	-	0.0	0.0	0.0	-	0.0	-
Japanese encephalitis	-	-	-	-	-	-	-	-	-	-	0.0	-	-	-	-	-
Trachoma	-	-	-	-	-	-	-	-	0.0	-	0.0	-	-	-	-	-
Intestinal nematode infections	0.0	0.0	0.0	0.0	-	-	-	-	0.5	0.0	0.0	0.0	0.0	-	0.0	0.0
Protein-energy malnutrition	0.1	2.6	0.0	0.3	0.1	0.0	0.1	0.2	0.5	0.0	0.0	0.1	0.0	0.0	0.0	0.5
Drownings	0.9	2.0	0.0	0.1	0.1	0.1	0.3	0.3	3.1	0.0	0.1	0.4	0.0	0.1	0.3	0.7

Table 2. Estimated total DALYs ('000), by cause and WHO Member State, 2002 (a, b), continued

GBD cause (a)	Sri Lanka	Sudan	Suriname	Swaziland	Sweden	Switzerland	Syrian Arab Republic	Tajikistan	Thailand	The former Yugoslav Republic of Macedonia	Timor-Leste	Togo	Tonga	Trinidad and Tobago	Tunisia	Turkey
All Causes	3,500	11,749	89	806	977	799	2,664	1,374	12,755	326	153	2,103	16	267	1,544	11,450
Diarrhoeal diseases	33	655	2	21	2	2	78	68	185	2	5	97	0	1	27	236
Malaria	41	796	0	1	-	0	0	13	161	-	1	239	0	-	0	114
Schistosomiasis	0	86	0	2	-	-	6	-	0	-	0	10	-	-	4	0
lymphatic filariasis	16	117	-	-	-	-	-	-	51	-	0	17	0	0	0	1
Onchocerciasis	-	10	-	-	-	-	-	-	-	-	-	3	-	-	-	-
Dengue	1	0	1	0	-	-	0	-	69	-	0	0	0	-	0	-
Japanese encephalitis	1	-	-	-	-	-	-	-	5	-	0	-	0	-	-	-
Trachoma	-	97	-	1	-	-	-	-	0	-	0	7	0	-	-	-
Intestinal nematode infections	16	88	0	1	-	-	0	0	60	0	1	14	0	0	0	0
Protein-energy malnutrition	16	197	0	12	1	0	16	15	60	0	1	16	0	0	3	39
Drownings	21	67	1	3	2	1	10	9	89	1	2	11	0	2	9	23

a. www.who.int/evidence/bod; for notes, data sources and levels of evidence refer to notes sheet available from this site; check for updates

b. Standard DALYs with age-weighting and time discounting as reported in World Health Report 2004

Table 1. Estimated total deaths ('000), by cause and WHO Member State, 2002 (a), continued

GBD cause (a)	Turkmenistan	Tuvalu	Uganda	Ukraine	United Arab Emirates	United Kingdom	United Republic of Tanzania	United States of America	Uruguay	Uzbekistan	Vanuatu	Venezuela (Bolivarian Republic of)	Viet Nam	Yemen	Zambia	Zimbabwe
Population ('000) (e)	*4,794*	*10*	*25,004*	*48,902*	*2,937*	*59,068*	*36,276*	*291,038*	*3,391*	*25,705*	*207*	*25,226*	*80,278*	*19,315*	*10,698*	*12,835*
All Causes	41.7	0.1	388.4	783.0	9.2	599.3	596.4	2,420.6	30.5	171.5	1.2	114.5	515.8	171.3	232.0	284.2
Diarrhoeal diseases	1.1	0.0	30.2	0.2	0.0	0.6	31.9	1.5	0.1	0.5	0.0	1.6	10.7	19.1	15.5	6.2
Malaria	-	-	41.3	0.0	0.0	0.0	56.7	0.0	-	0.0	0.0	0.0	4.3	1.4	19.3	0.4
Schistosomiasis	-	-	0.4	-	-	0.0	2.0	0.0	-	-	-	0.0	0.1	0.1	0.5	0.6
lymphatic filariasis	-	-	-	-	-	-	-	-	-	-	-	-	0.0	0.0	-	-
Onchocerciasis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dengue	-	0.0	0.0	-	0.0	-	0.0	0.0	-	-	0.0	0.0	0.2	0.0	-	-
Japanese encephalitis	-	-	-	-	-	-	-	-	-	-	-	-	0.2	-	-	-
Trachoma	-	-	-	-	-	-	-	-	-	-	-	-	0.0	-	-	-
Intestinal nematode infections	-	0.0	0.1	-	0.0	-	0.1	0.0	-	-	0.0	0.0	0.0	0.0	0.1	0.0
Protein-energy malnutrition	0.0	0.0	2.6	0.1	0.0	0.1	7.5	4.3	0.1	0.1	0.0	0.8	0.1	1.7	1.2	3.1
Drownings	0.4	0.0	1.8	5.1	0.2	0.2	3.5	3.8	0.1	1.1	0.0	0.6	4.2	1.6	0.6	0.7

Table 2. Estimated total DALYs ('000), by cause and WHO Member State, 2002 (a, b), continued

GBD cause (a)	Turkmenistan	Tuvalu	Uganda	Ukraine	United Arab Emirates	United Kingdom	United Republic of Tanzania	United States of America	Uruguay	Uzbekistan	Vanuatu	Venezuela (Bolivarian Republic of)	Viet Nam	Yemen	Zambia	Zimbabwe
All Causes	1,070	3	13,359	11,341	413	7,555	20,235	41,521	558	4,300	38	4,110	13,360	6,940	7,501	8,589
Diarrhoeal diseases	39	0	989	16	3	18	1,059	84	4	38	1	71	396	623	501	205
Malaria	0	-	1,530	0	0	0	2,063	0	-	0	0	4	166	100	696	29
Schistosomiasis	-	-	52	-	-	0	100	0	-	-	-	7	1	5	27	34
lymphatic filariasis	-	0	83	-	-	-	124	-	-	-	0	-	62	1	36	45
Onchocerciasis	-	-	22	-	-	-	-	-	-	-	-	1	-	0	-	-
Dengue	-	0	0	-	0	-	0	0	-	-	0	0	5	0	0	0
Japanese encephalitis	-	0	-	-	-	-	-	-	-	-	0	-	11	-	-	-
Trachoma	-	-	33	-	8	-	111	-	-	-	-	-	16	7	17	14
Intestinal nematode infections	0	0	32	-	0	-	44	0	0	0	0	6	191	3	14	15
Protein-energy malnutrition	6	0	185	12	0	3	378	34	2	28	0	33	226	181	79	123
Drownings	11	0	58	116	4	6	101	102	3	35	0	20	119	55	16	23

a. www.who.int/evidence/bod; for notes, data sources and levels of evidence refer to notes sheet available from this site; check for updates

b. Standard DALYs with age-weighting and time discounting as reported in World Health Report 2004