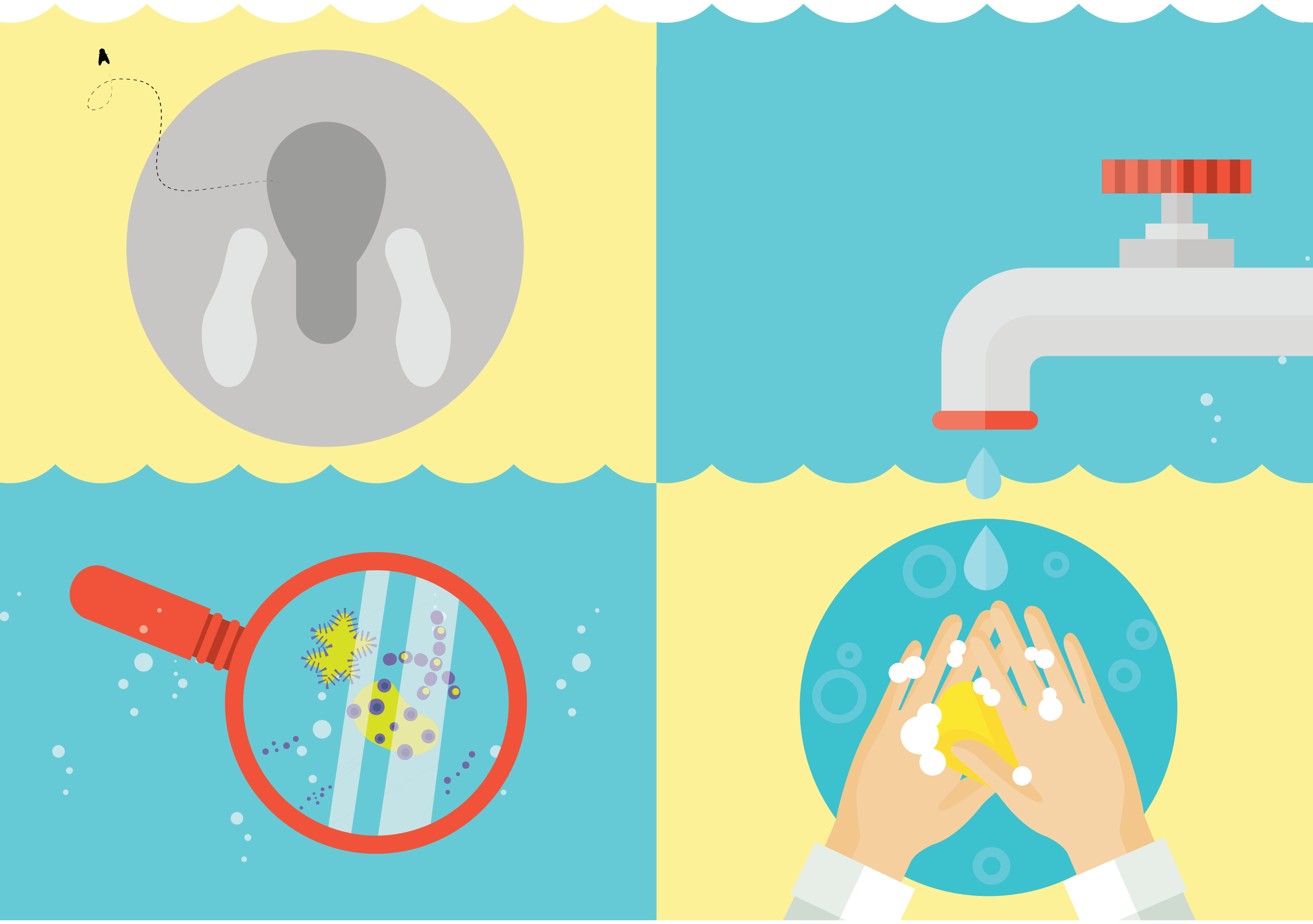
PREVENTING DIARRHOEA THROUGH BETTER WATER, SANITATION AND HYGIENE

Exposures and impacts in low- and middle-income countries



World Health Organization

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Acronyms and abbreviations

CI	Confidence Interval
DALY	Disability-adjusted Life Year
GBD	Global Burden of Disease
HWTS	Household Water Treatment and Safe Storage
IHME	Institute for Health Metrics and Evaluation
JMP	Joint Monitoring Programme for Water Supply and Sanitation
LMICs	Low- and Middle-Income Countries
MDG	Millennium Development Goal
PAF	Population Attributable Fraction
SSP	Sanitation Safety Plan
UNICEF	United Nations Children's Fund
VIP	Ventilated Improved Pit latrine
WASH	Water, Sanitation and Hygiene
WSP	Water Safety Plan
WHO	World Health Organization

Regions of the World Health Organization

AFR	African Region
AMR	Region of the Americas
EMR	Eastern Mediterranean Region
EUR	European Region
SEAR	South-East Asia Region
WPR	Western Pacific Region

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Foreword

In early 2013, WHO convened an expert group of scientists from 14 collaborating research institutions to update the assessment of the burden of diarrhoeal disease from inadequate water, sanitation and hygiene (WASH) and to reassess the effectiveness of WASH interventions. This group considered evolving and alternative methods for assessing the burden of disease and agreed on a rigorous new approach using meta-regression. In deriving the new figures, the experts incorporated the latest data on use of improved water and sanitation with minor adjustments, and drew upon the results from two new global reviews – on microbial water quality and of handwashing practices – specially prepared as part of this effort. These results are published in a series of Open Access articles in the scientific journal Tropical Medicine and International Health *(1–5)*.

This initiative responded to a need to update the previous WHO estimates *(6)*, published in 2009, which referred to the year 2004, and to revise the scenarios used as part of the comparative risk assessment method. In addition, a more recent global burden of disease assessment (the Global Burden of Disease Study 2010), which assessed 67 risk factors and risk factor clusters *(7)*, used a different WASH-related baseline scenario (or counterfactual) and, consequently, reported much lower estimates of diarrhoea than previous studies. Thus, there was also a need to address, in a transparent manner, the confusion caused by the widely divergent results of the two most recent estimates *(6, 7)*.

This report brings together and summarizes the information presented in the article series in a format suitable for policy- and decision-makers and those interested in water, sanitation, hygiene and public health. It confirms that lack of safe water, sanitation and hygiene remains one of the world's most urgent health issues, while acknowledging the impressive reductions in deaths from diarrhoea that have been seen in recent years. This good news comes against the backdrop of major and continued improvements in the provision of adequate drinking-water and sanitation. This report suggests that this expansion in water and sanitation service which has benefited hundreds of millions has also, quite plausibly, contributed to significantly reduce diarrhoea. Yet, despite progress, these estimates tell us that many people still suffer illness or death associated with absence of appropriate services, and that inadequate hygiene practices further add to that burden.

In bringing together current evidence on exposure to unsafe drinking-water, inadequate sanitation and hygiene, alongside the most up-to-date analysis on the health impacts of interventions, this document contributes to informed policy-making and targeting of resources. It underscores how further progress can be achieved in this unfinished global water and sanitation and health agenda.

Executive Summary

Methods

The global burden of diarrhoeal disease from inadequate water, sanitation and hygiene (WASH) was estimated for 145 low- and middle-income countries (LMICs) for the year 2012 using new global estimates of total mortality, combined with key exposures and recently developed risk estimates corresponding to those exposures. The estimates and methods used to generate them are the subject of a series of Open Access papers published in Tropical Medicine and International Health (2014, volume 19, issue 8)[1], which are summarized in this report.

A comparative risk assessment approach was used, similar to that of previous burden of disease studies. Country-wide exposure estimates, with sufficient data for the year 2012, were combined with matching exposure-risk relationships (taken from the most recent systematic analyses) to determine the proportion of diarrhoeal disease deaths that could be attributed to inadequate water, sanitation, and hygiene, both separately and in combination. These proportions were then applied to overall diarrhoeal mortality estimates to calculate the number of deaths attributable to inadequate WASH. All analyses were made at country-level.

Exposure estimates for drinking-water and sanitation were based on the database of the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP) *(8)*, with two adjustments:

- When drinking-water is collected outside the home, an otherwise *improved* drinking-water source was considered as *unimproved* if more than 30 minutes was required to collect water.
- Estimates of populations accessing *improved* sanitation facilities were adjusted to exclude *improved* facilities shared among two or more households; where country-level data on sharing were lacking, regional averages of shared facilities were used.

Exposure estimates for water and sanitation, therefore, differ slightly from those published by the JMP. Global and regional prevalences of handwashing practices were estimated in a systematic review of the literature.

The impacts of interventions to improve poor water, sanitation and hygiene on diarrhoeal disease were modelled through meta-regression analysis, drawing on 61 drinking-water, 11 sanitation, and 42 handwashing studies.

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[1] Bain R, Cronk R, Hossain R, Bonjour S, Onda K, Wright J, Yang H, Slaymaker T, Hunter P, Prüss-Ustün A, Bartram J. Global assessment of exposure to faecal contamination through drinking water based on a systematic review. http://onlinelibrary.wiley.com/doi/10.1111/tmi.12334/full

Clasen T, Prüss-Ustün A, Mathers C, Cumming O, Cairncross S, Colford JM. Estimating the impact of unsafe water, sanitation and hygiene on the global burden of disease: evolving and alternative methods. http://onlinelibrary.wiley.com/doi/10.1111/tmi.12330/full

Freeman MC, Stocks M, Cumming O, Jeandron A, Higgins J, Wolf J, Prüss-Ustün A, Bonjour S, Hunter PR, L. F, Curtis V. Hygiene and health: systematic review of handwashing practices worldwide and update of health effects. http://onlinelibrary.wiley.com/doi/10.1111/tmi.12339/full

Prüss-Ustün A, Bartram J, Clasen T, Colford JM, Cumming O, Curtis V, Bonjour S, Dangour AD, De France J, Fewtrell L, Freeman MC, Gordon B, Hunter PR, Johnston R, Mathers C, Mäusezahl D, Medlicott K, Neira M, Stocks M, Wolf J, Cairncross S. Burden of diarrhoeal disease from inadequate water, sanitation and hygiene in low- and middle-income settings: a retrospective analysis of data from 145 countries. http://onlinelibrary.wiley.com/doi/10.1111/tmi.12329/full

Wolf J, Prüss-Ustün A, Cumming O, Bartram J, Bonjour S, Cairncross S, Clasen T, Colford JM, Curtis V, De France J, Fewtrell L, Freeman MC, Gordon B, Hunter PR, Jeandron A, Johnston RB, Maüsezahl D, Mathers C, Neira M, Higgins J. Assessing the impact of drinking water and sanitation on diarrhoeal disease in low- and middle-income settings: systematic review and meta-regression. http://onlinelibrary.wiley.com/doi/10.1111/tmi.12331/full

Exposures

- Direct use of drinking-water from unimproved sources (without household water treatment) ranged from 3% to 38% by region, with an overall average of 12% among LMICs. Regional averages for access to piped water on premises ranged from 19% to 88%, with an LMIC average of 49% (Table 1), although this figure includes intermittent and poorly managed piped supplies which may be microbially compromised.
- Use of unimproved sanitation facilities ranged from 13% to 65% by region (Table 2). This proportion includes those who share an improved facility among two or more households.
- Approximately 19% of the world's population washes hands with soap after contact with excreta. This proportion is estimated to range between 13% and 17% in LMIC regions, and from 43% to 49% in high-income regions (Figure 13).

Impacts of interventions

- A modest reduction in diarrhoea (e.g. 11–16%) can be achieved through use of basic improved water or sanitation facilities, such as protected wells or improved latrines (Figures 6 and 11). The health benefit is limited because these drinking-water sources may be microbially contaminated and because basic sanitation may not adequately protect the wider community from exposure to excreta.
- Diarrhoea can be reduced significantly if water quality can be ensured up to the point-of-consumption. Effective and consistent application of household water treatment and safe storage can reduce diarrhoeal disease by between 28% and 45%, depending on the type of water supply (Figure 6).
- Limited evidence suggests that major diarrhoea reductions (e.g. 73%) can be achieved by transitioning to services that confer safe and continuous piped water supply (Figure 6).
- Similarly, limited evidence suggests that connection to a sewerage system that safely removes excreta from both the household and community yields great health benefits.
- Handwashing reduces the risk of diarrhoeal disease by 40%, however when an adjustment for unblinded studies was included, the effect estimate was reduced to 23% and became statistically nonsignificant.

Global burden of disease

- 842 000 deaths in LMICs are caused by inadequate WASH, representing 58% of total diarrhoeal deaths, and 1.5% of the total disease burden.
- Separated out by individual risk factor, 502 000 deaths can be attributed to unsafe and insufficient drinking-water, 280 000 deaths result from inadequate sanitation, and another 297 000 are due to inadequate handwashing. Because some people are exposed to multiple risk factors, the sum of deaths attributable to individual risk factors is different from when the risk factors are considered together.
- Diarrhoeal deaths among children under-five have more than halved from 1.5 million in 1990 to 622 000 in 2012. Inadequate WASH accounts for 361 000 of these deaths, or over 1000 child deaths per day.
- The current global burden of disease estimate of the impact of inadequate WASH (i.e. 58% of total diarrhoeal deaths) is substantially lower than the WHO 2000 estimate of 88%. This is attributed to a number of factors including the fall in global diarrhoeal deaths from 2.2 million in 2000 to 1.5 million in 2012 and the use of a far more conservative counterfactual, which retains a significant risk of diarrhoeal illness.

- Health impacts of poor WASH on diseases other than on diarrhoea have not been updated in this study. However, earlier work showed that poor water, sanitation, and hygiene have a major impact on undernutrition, and also on a number of neglected tropical diseases including schistosomiasis, trachoma and soil-transmitted helminths (intestinal worms).

- Water resource management also impacts on vector-borne diseases such as malaria and dengue fever, and accidental deaths through drowning.

The findings of this report underscore the importance of enabling universal access to at least a basic level of drinking-water and sanitation service. The report also suggests that that there are likely to be major health benefits from raising service levels to safe and continuous water supply and to connection to a sewerage system. Limited data suggest that these higher levels of services could significantly reduce diarrhoeal disease. These findings are consistent with WHO Guidelines which emphasize continuous improvements to protect public health.

1. Introduction

This document outlines the latest research on the burden of diarrhoea related to inadequate water, sanitation and hygiene (WASH). It is based on a series of articles published in the scientific literature.

The health benefits of WASH interventions have been known for a long time, well before disease transmission pathways were understood. Methods were developed to quantify the impact of such interventions at a global scale for the first Global Burden of Disease study, in 1990, by the World Health Organization (WHO), World Bank, and the Harvard School of Public Health *(9)*. Poor water supply, sanitation and personal and domestic hygiene was found to contribute substantially to diarrhoeal disease, as well as tropical diseases such as trachoma and intestinal worms. These disease burden estimates have been updated periodically by WHO, with the most recent estimates published in 2008 *(10)*. Other global estimates of water and sanitation-related disease risks have also been made, notably the 2010 Global Burden of Disease Study published in the Lancet *(7)*. In 2013, WHO convened a group of experts to update the methodology and produce revised estimates building on and addressing the identified weaknesses in earlier work. The results for low- and middle-income countries (LMICs) have been published in the journal Tropical Medicine and International Health *(1–5)*.

Inadequate WASH can cause various adverse health outcomes, through a number of different transmission pathways including *(11)*:

- ingestion of water (e.g. diarrhoea, arsenicosis, fluorosis);
- lack of water linked to inadequate personal hygiene (e.g. diarrhoea, trachoma, scabies);
- poor personal, domestic or agricultural hygiene (e.g. diarrhoea, Japanese encephalitis);
- contact with contaminated water (e.g. schistosomiasis);
- vectors proliferating in water (e.g. malaria, dengue fever); and
- contaminated water systems (e.g. legionellosis).

The impact of WASH on most of the diseases cannot be precisely enumerated, but has previously been estimated *(12)* and is summarized in Section 6.3. This report, thus, focuses on diarrhoea.

1.1 Disease burden methodology

The burden of diarrhoea attributable to inadequate WASH is estimated on the basis of the total diarrhoeal disease burden. The number of diarrhoeal deaths has dropped dramatically over recent decades from around 2.5–2.9 million deaths in 1990 *(9, 13)* to 1.5 million in 2012 *(14)*. Mortality from diarrhoea in children under-five has also decreased during the same period. In the current work, the impact of inadequate WASH on the burden of diarrhoea was estimated using comparative risk assessment methods *(7, 15, 16)*. This approach produces an estimate of the proportional reduction of disease or death that would occur if exposures were reduced to an alternative, baseline (or counterfactual) level, while other conditions remain unchanged. It is based on the proportion of people exposed and the relative risk of disease related to that exposure. Additional details on the methodology are available in the Annex and in the original papers *(1–5)*.

1.1.1 Exposure distribution in the population

Diarrhoeal disease is caused by ingestion of pathogens, principally through faecal-oral pathways. Three separate but inter-related risk factors were considered as part of the burden of disease analysis. Estimates of global exposures for **drinking-water** and **sanitation** are based on JMP data *(8)* and exposure by country was estimated using multilevel modelling *(17)*, while estimates of **handwashing** prevalence are based on a systematic review of the literature *(3)*.

1.1.2 Exposure-response relationship

The exposure-response relationships are based on systematic reviews of the epidemiological evidence for the impact of WASH interventions on diarrhoea in LMICs *(3, 5)*, combined with meta-analysis and meta-regression to calculate risk reduction factors.

1.2 Report structure

Sections 2, 3 and 4 summarize for drinking-water, sanitation and handwashing respectively the estimates of exposure in LMICs, the meta-regression results, and the resulting burden of diarrhoeal disease. Section 5 considers the integration of WASH interventions, while Section 6, the final section, considers the trends in diarrhoeal disease burden since 1990, compares the current results with previous estimates and, briefly, summarizes the WASH-related impacts on diseases other than diarrhoea. The Annex consists of a series of Tables that provides additional country- and regional-level information.

2. Drinking-water

2.1 Global access to drinking-water supplies

Data on the use of drinking-water sources are available from the JMP *(8)*, which has information for over 200 countries and territories, including all 145 of the LMICs covered in this analysis. The data are taken from nationally representative household surveys, in which respondents are asked to identify the main source of drinking-water used by the household. Based on the response, household members are classified as using either *improved* or *unimproved* sources. The *improved* category is further disaggregated into *piped on premises* and *other improved* (which includes standpipes, boreholes and protected wells and springs). In addition, surface water is reported separately from *other unimproved* sources, resulting in a *drinking-water ladder* (Figure 1).

The Millennium Development Goal (MDG) target for drinking-water (to halve by 2015 the proportion of the population without sustainable access to safe drinking-water) was met in 2010 and coverage has continued to rise. In 1990, 76% of the global population had access to improved drinking-water; in 2012 this figure had reached 89% (representing an increase of 2.3 billion people) although, as can be seen from Figure 2, coverage is uneven *(8)*. In 2012, 56% of the global population, almost 4 billion people, enjoyed the highest level of access, piped water on premises.

Figure 1. JMP drinking-water ladder

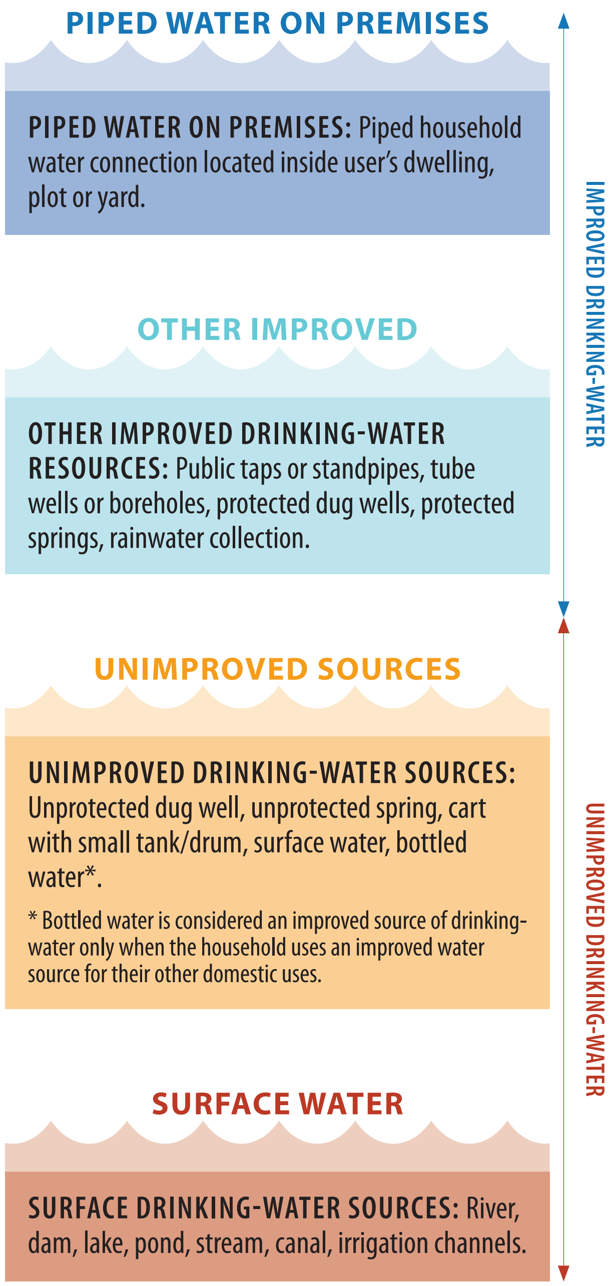
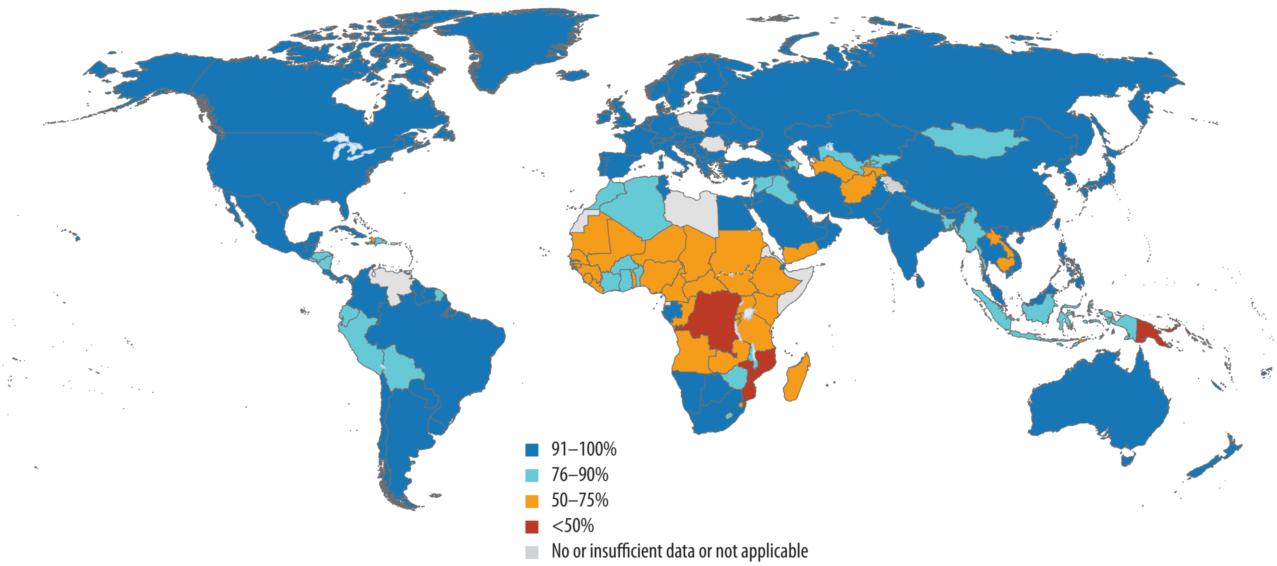


Figure 2. Global coverage of improved drinking-water, 2012 *(8)*



2.2 Faecal contamination of drinking-water supplies[1]

Drinking-water, even from an improved source, is not necessarily free of faecal pathogens and safe for health *(18)*. In order to provide a comprehensive picture of water quality by country and type of water source, a systematic review and analysis was conducted *(19)*. Coverage data from JMP were combined with 345 water quality studies and predictive models for the presence and level of microbial contamination of drinking-water supplies were developed. Water was considered as non-contaminated when complying with the guideline values for microbial quality *(20)*, i.e. containing zero *E. coli* or thermotolerant coliforms in a 100 mL sample. Other potential drinking-water contaminants such as chemicals have not been assessed here.

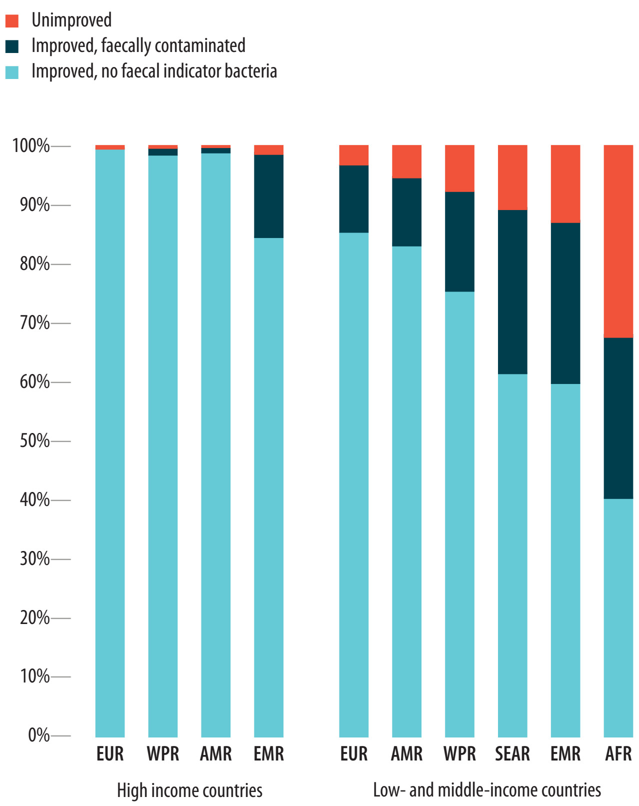
It was estimated that globally 26% of people drink water that is, at least occasionally, contaminated with faecal indicator bacteria. As would be expected, the situation varies between the different regions, and in LMICs the estimated population predicted to be exposed to contaminated drinking-water ranged from 14% in Europe to over 52% in Africa *(1)*. The regional situation, in both

1 Information presented in this section is based on the following publications containing additional details:

Bain R, Cronk R, Hossain R, Bonjour S, Onda K, Wright J, Yang H, Slaymaker T, Hunter P, Prüss-Ustün A, Bartram J. Global assessment of exposure to faecal contamination through drinking water based on a systematic review. Tropical Medicine & International Health. 2014. http://www.ncbi.nlm.nih.gov/pubmed/24811893

Bain R, Cronk R, Wright J, Yang H, Slaymaker T, Bartram J. Fecal contamination of drinking-water in low- and middle-income countries: a systematic review and meta-analysis. PLoS Medicine. 2014;11(5):e1001644. http://www.plosmedicine.org/article/info%3Adoi%2F10.1371%2Fjournal.pmed.1001644

Figure 3. Proportion of population accessing different types of drinking-water, by region and by microbial contamination level, 2012 *(1)*



See Annex Table 7 for grouping of countries by WHO region (AFR: Africa; AMR: Americas; EMR: Eastern Mediterranean; EUR: Europe; SEAR: South East Asia; WPR: Western Pacific). Microbially contaminated water has detectable E. coli or thermotolerant coliforms in a 100 mL sample, while samples showing no detectable faecal indicator bacteria (<1 per 100 mL) are compliant with WHO guideline values and most national standards.

high-income and LMI countries by water source and contamination is shown in Figure 3.

Based on this analysis of 2012 data, it is estimated that 1.9 billion people worldwide use either an unimproved source or an improved source that is faecally contaminated *(1)*. While microbial contamination is clearly widespread and affects all water source types, including piped supplies, contamination is more frequent in some improved sources, most notably protected groundwater and rural piped supplies.

IMPROVING WATER SAFETY

Water Safety Plans (WSPs) were first introduced by WHO in the 2004 Guidelines for Drinking-water Quality as the most effective means of consistently ensuring the safety of a drinking-water supply. WSPs require a risk assessment, encompassing all steps in water supply from catchment to consumer, followed by implementation and monitoring of control measures. WHO provides guidance and support to regulators and water suppliers on how to implement and scale up preventive risk management. Now, more than 50 countries report having a national strategy established to scale up WSP implementation.

http://www.who.int/water_sanitation_health/dwq/WSP/en/

2.3 Household water treatment

As was demonstrated in the previous section, drinking-water supplies are often microbially contaminated and, in many cases, rather than simply using the drinking-water as supplied, people may treat their water at the household level to make it safer to drink. Information on whether people treat their water is obtained in a number of household surveys and has been compiled and reviewed *(21)*. From the 67 countries where surveys provided data on household water treatment (HWT), all conducted in LMICs, an estimated 1.1 billion people (33% of households) report treating water in the household, with the practice being particularly common in the Western Pacific region (66.8%) and South East Asia region (45.4%). Boiling is the most commonly used method (used in 21% of study households) and it is known to be very efficient in reducing pathogens *(22, 23)*, however, its effectiveness for diarrhoea reduction when applied in households has been poorly documented, in part due to unsafe storage and handling leading to recontamination after boiling. Filtration is fairly commonly reported in South East Asia and Western Pacific regions, while chlorination is more common in Latin America & Caribbean and African countries (Figure 4).

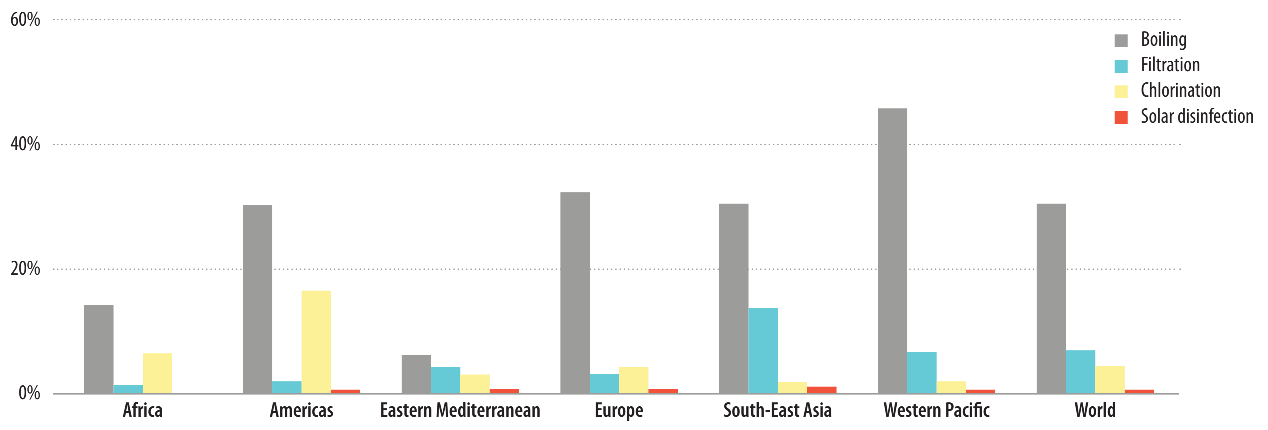
In order to protect health, HWT must effectively remove pathogens and be used both consistently and correctly *(24)*. While a number of technologies can be used at the household level to effectively remove pathogens *(25)*, concerns have been raised that studies estimating the resulting health impacts may overestimate the benefits as a result of methodological challenges *(26)*. It is known, for example, that non-blinded studies may

STATUS OF NATIONAL HOUSEHOLD WATER TREATMENT AND SAFE STORAGE (HWTS) POLICIES

Based on a WHO survey including responses from 46 countries, largely in sub-Saharan Africa, the majority (91%) of countries support HWTS through integration with health efforts. However, implementation challenges are great. Key identified challenges included: limited monitoring and evaluation of HWTS use and impact; poor coordination among ministries; and lack of regulation.

For more information on the review of national policies visit: http://www.who.int/household_water/WHOGlobalsurveyofHWTSPolicies_Final.pdf

Figure 4. Percentage of population reporting household water treatment, by WHO region, 2012 *(4)*



WHO INTERNATIONAL SCHEME TO EVALUATE HOUSEHOLD WATER TREATMENT TECHNOLOGIES

In 2014, WHO formally launched the International Scheme to Evaluate Household Water Treatment Technologies (the "Scheme") with a call for submissions for Round I of testing. The Scheme will provide independent testing and advice on household water treatment performance based on WHO criteria. The Scheme aims to work with national governments in building the technical capacity of research and laboratory institutions for conducting complimentary assessments of HWT and, in general, applying WHO Guidelines on Drinking-water Quality recommendations at the national level.

For more information on the Scheme, and products that have been or are currently being tested, visit: http://www.who.int/household_water/scheme/en/

be associated with bias when addressing subjectively assessed outcomes *(27, 28)*. As the systematic review did not identify a sufficient number of blinded studies for meta-analysis *(5)*, the effect of HWT on diarrhoeal disease was adjusted using a mean bias of similar study designs from other medical areas (as described by *(27)*). Such an adjustment is approximate and may be improved as further evidence accrues. After adjustment for non-blinding, it was found that household filters (as a group of technologies) still produced a statistically significant reduction in diarrhoeal disease, while chlorination and solar disinfection no longer showed a significant impact. It is speculated that this apparent lack of effect from household chlorination and solar disinfection may be due to a number of factors, such as incorrect or inconsistent use of the technology. It does not suggest that they are not effective at reducing microbial contamination, but that no additional health benefit can be ascribed to these technologies in the burden of disease calculations.

2.4 Drinking-water supplies used in LMICs

The WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP) monitors use of drinking-water supplies globally *(8)* and JMP data were used to quantify the use of 'piped water on premises', 'other improved sources' (public taps and standpipes, boreholes and tubewells, protected wells and springs, rainwater collection), and 'unimproved sources' in LMICs. The use of 'other improved sources' was adjusted by reclassifying an improved source requiring more than a 30-minute round-trip for collecting water as an unimproved source. Multilevel modelling was used in order to obtain time trends and estimates for countries without data *(17)*. In LMICs, 49% of people use piped water on premises as their main drinking-water source, a further 36% use another improved source and a total of 30% report filtering or boiling their water to improve its quality (Table 1). Information on the use of water sources on a country-by-country basis is provided in Annex Table 2.

2.5 Effect of improvements in drinking-water supply on diarrhoeal disease risk

In order to conceptualize the risk of diarrhoea from drinking-water, drinking-water sources were categorized into five groups, namely:

- Unimproved;
- Improved source (other than piped);
- Basic piped water on premises;
- Systematically managed piped water (continuous and safe supply); and
- Effective household water treatment and safe storage.

The splitting of piped water into two categories recognises that piped water supplied to LMICs is often of sub-optimal quality and intermittent requiring storage within the household.

However, currently available data don't allow disaggregation of piped water supplies into *basic* and

Table 1. Estimated use of drinking-water sources in LMICs in 2012 (proportion of total population)

WHO Region*	Piped water on premises			Other improved sources			Unimproved sources		
Filtering/boiling in the household:	Without	With	Total	Without	With	Total	Without	With	Total
Sub-Saharan Africa	0.16	0.03	0.19	0.36	0.04	0.40	0.38	0.04	0.42
Americas	0.58	0.30	0.88	0.05	0.01	0.06	0.05	0.01	0.06
Eastern Mediterranean	0.54	0.04	0.58	0.25	0.01	0.26	0.15	0.01	0.16
Europe	0.54	0.27	0.81	0.10	0.05	0.15	0.03	0.02	0.05
South-east Asia	0.16	0.09	0.25	0.48	0.14	0.62	0.09	0.04	0.13
Western Pacific	0.31	0.35	0.66	0.13	0.14	0.27	0.04	0.04	0.08
Total	0.31	0.18	0.49	0.27	0.09	0.36	0.12	0.03	0.15

**See Annex Table 7 for grouping of countries by WHO Region.*

SAFELY MANAGED DRINKING-WATER SUPPLIES

Full application of the Guidelines for Drinking-water Quality, including implementation of Water Safety Plans through rigorous risk management and water quality monitoring, yields optimal safety and a higher level of service. Experts and stakeholders in the water supply sector have called for such a category "safely managed drinking-water supplies" to be included in the post-2015 sustainable development agenda. However, the literature review yielded no examples of this highest level, and it was therefore not included in the model.

For more information visit: http://www.wssinfo.org/post-2015-monitoring/

systematically managed classes, so for the purposes of estimating burden of disease the two were combined.

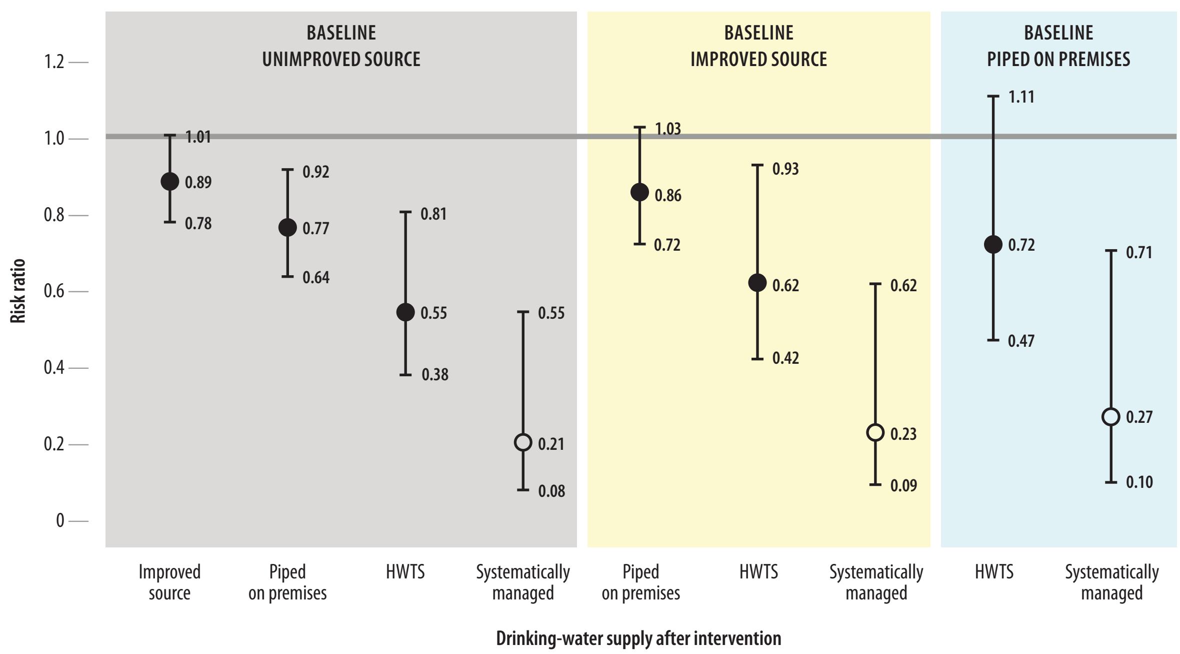
JMP data were used to model the proportion of total populations using drinking-water piped on premises, taken from other improved sources (e.g. boreholes, protected wells and springs), and from unimproved sources. The proportion of people filtering or boiling this water was also modelled for each of these categories (Table 1).

The meta-regression *(5)* then focused on quantifying the reductions in diarrhoeal disease that could be achieved through different transitions moving from lower to higher service level categories. These effects are shown in Figure 5 as risk ratios with 95% confidence intervals (CI), and in Figure 6 as the proportion of diarrhoeal disease risk that could be prevented due to the transition.

As might be expected (and can be seen from Figures 5 and 6), the greatest potential health gains were found when moving from poor baseline conditions (unimproved source) to good water quality. Among those using unimproved water sources, diarrhoeal disease could be reduced by 11% by switching to an improved water source other than water piped onto premises. Switching from unimproved to piped water on premises was found to reduce disease more substantially, by 23%. Effective household water treatment (taken as boiling or filtration and safe storage) showed the greatest disease reduction, of 45%. It can be assumed that truly safe piped water, consistently free from microbiological contamination, would have at least as large an effect on diarrhoeal disease.

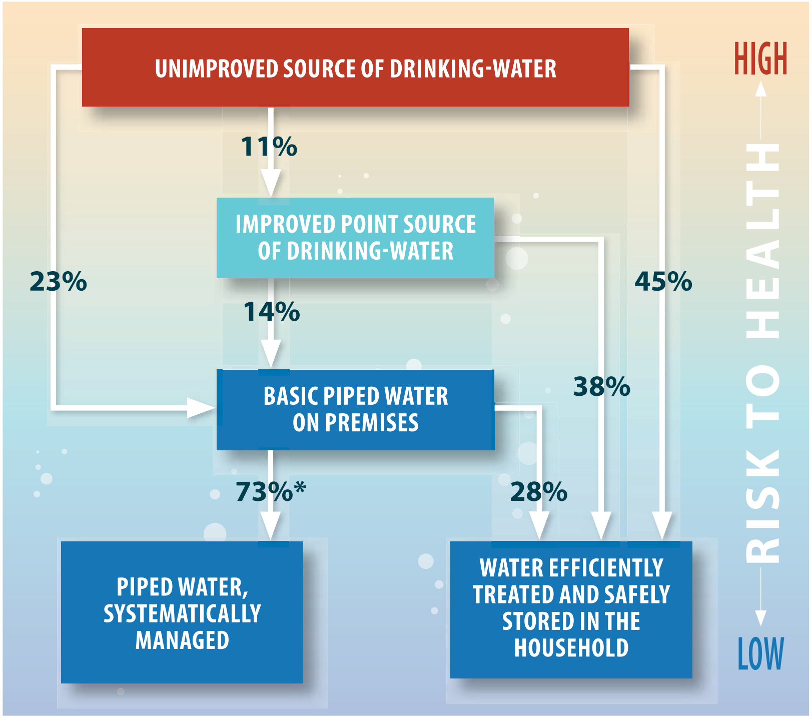
The systematic review identified several studies which documented a reduced risk of diarrhoeal disease when moving from community water sources (improved or unimproved) to piped water on premises, even when the piped supply was not necessarily providing microbiologically safe or continuous service. Only one study was found documenting the transition from basic on-site piped water to systematically managed water. In this study, operator training and certification led to significant improvements in the operation of a piped water system, including an increase in measurable free chlorine residual, and significant health benefits *(29)*. On the basis of this single study, the meta-regression suggests that very large health benefits could be gained

Figure 5. Risk ratios for transitions among drinking-water exposure groups (adjusted for non-blinding)



HWTS – only filtration with safe storage is considered in the model as an example of water efficiently treated and safely stored in the household. Transitions to systematically managed water supply are based on limited evidence and should be considered preliminary.

Figure 6. Drinking-water supply transitions and associated reductions in diarrhoeal disease risk



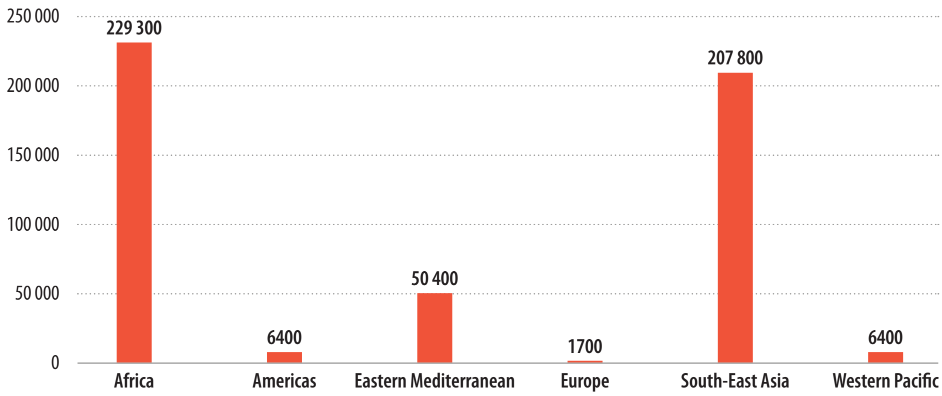
** These estimates are based on limited evidence and should therefore be considered as preliminary and have not been used in the estimation of disease burden.*

from this transition, with significant reductions in diarrhoea ranging from 73% to 79%, depending on baseline condition. However, because only one study is currently available to describe this transition, the estimates should be considered preliminary and they have not been used in estimation of global burden of disease from WASH.

2.6 Burden of diarrhoeal disease from inadequate drinking-water

Based on the distribution of use of the different types of water sources and the associated risks of diarrhoea, outlined in the preceeding sections, 502 000 diarrhoeal deaths in LMICs can be attributed to inadequate drinking-

Figure 7. Deaths from inadequate drinking-water in low- and middle-income countries by region, 2012



See Annex Table 7 for grouping of countries by WHO Region.

water. Of these deaths, 88% occur in Africa and South-East Asia (Figure 7). Estimates on a country-by-country basis are provided in Annex Table 1 and on a regional basis in Annex Table 3.

2.7 Policy implications

- Shifting from unimproved to improved point sources of drinking-water yields only modest health gains. This is because these sources are sometimes contaminated or because water may become subsequently contaminated before consumption (e.g. during transport, handling or household storage). Somewhat larger health gains can be gained by shifting to basic schemes for piped water on premises.

- Limited evidence hints that investing in the transition from basic piped water to systematically managed water supplies results in important health protection.

- Effective household water treatment combined with safe storage can provide significant protection against diarrhoea. Sustained and consistent application is necessary to realize these gains. This finding further supports the idea that improving the quality of drinking-water (either through HWTS or through improved delivery of safe piped water to the household) will have significant health gains. However, technologies must be evaluated and regulated to ensure that they meet performance standards, and securing correct and consistent use remains a challenge in introducing HWTS. Further operational and behavioural research is needed to provide the basis for addressing this challenge and optimizing uptake while safe drinking-water from other sources remains unavailable.

3. Sanitation

3.1 Global sanitation practices

The JMP also monitors use of sanitation facilities. As for drinking-water supplies, households are classified as using either *improved* or *unimproved* facilities on the basis of survey responses. JMP further disaggregates *unimproved* into *shared facilities* (which would otherwise be improved), *other unimproved*, and *open defecation* (Figure 8).

As a result of efforts put into meeting the MDG sanitation target (to halve, by 2015, the proportion of the population without sustainable access to basic sanitation) there has been an increase in the coverage of improved sanitation from 49% of the population in 1990 to 64% in 2012 (Figure 9), with almost 2 billion people gaining access to an improved sanitation facility during that period. Despite these improvements 2.5 billion people (67% of whom live in Asia) still use unimproved sanitation facilities, and of these 1 billion people practice open defecation. Based on these figures it is unlikely that the MDG sanitation target will be met.

3.2 Sanitation facilities used in LMICs

Estimates of the use of improved sanitation facilities are based on household surveys, with nationally representative information, which are available for almost all LMICs in the JMP database[1]. Estimates of improved sanitation facilities by country were adjusted by excluding facilities that are shared among two or more households; where country-level data on sharing were lacking, regional means of shared facilities were used. Exposure estimates therefore differ slightly from those published by the JMP.

Multilevel modelling was used in order to obtain time trends of use of an improved sanitation facility and estimates of shared facilities for all countries *(5)*. Globally, 58% of people in LMICs use an improved household sanitation facility which is not shared (Table 2). Information on a country-by-country basis is provided in Annex Table 2.

Figure 8. JMP sanitation ladder

IMPROVED

IMPROVED SANITATION FACILITIES: Are likely to ensure hygienic separation of human excretia from human contact. They include the following facilities:
- Flush /pour flush to:
  - piped sewer system
  - septic tank
  - pit latrine
- Ventilated improved pit (VIP) latrine
- Pit latrine with slab
- Composting toilet

SHARED

SHARED SANITATION FACILITIES: Sanitation facilities of an otherwise acceptable type shared between two or more households. Only facilities that are not shared or not public are considered improved.

IMPROVED SANITATION

UNIMPROVED FACILITIES

UNIMPROVED SANITATION FACILITIES: Do not ensure hygienic separation of human excretia from human contact. Unimproved facilities include pit latrines without a slab or platform, hanging latrines and bucket latrines.

OPEN DEFECATION

OPEN DEFECATION: When human faeces are disposed of in fields, forests, bushes, open bodies of water, beaches or other open spaces or disposed of with solid waste.

UNIMPROVED SANITATION

1 www.wssinfo.org

Figure 9. Global coverage of improved sanitation, 2012 *(8)*

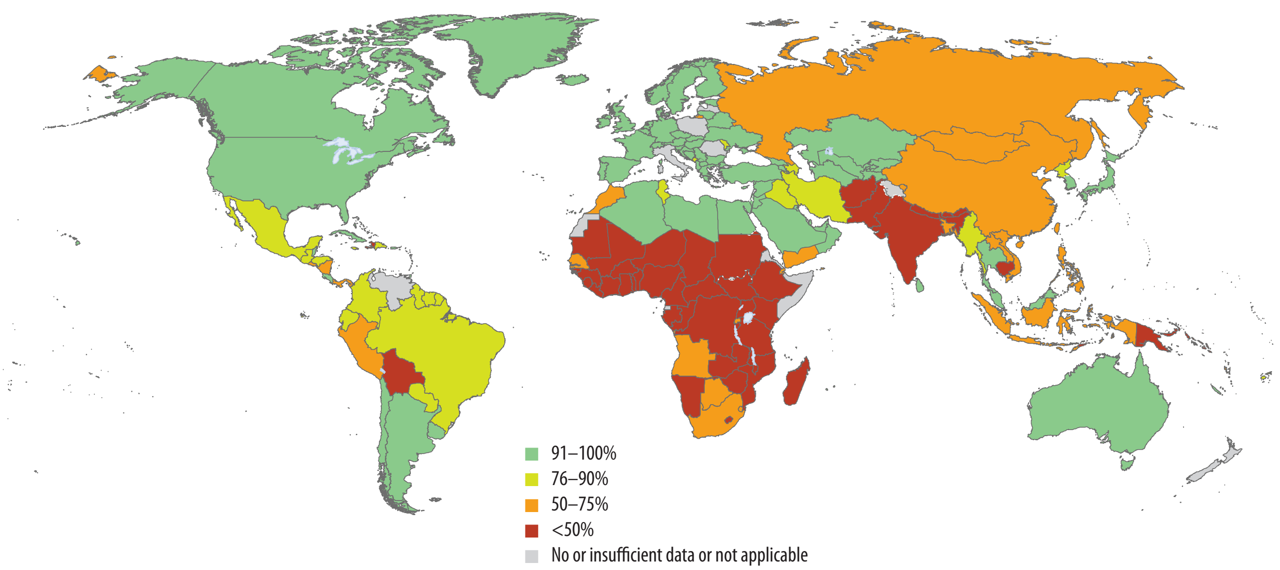


Table 2. Estimated use of improved sanitation facilities in LMICs, 2012 (proportion of total population)

WHO Region*	Use of improved sanitation facility
Sub-Saharan Africa	0.35
Americas	0.83
Eastern Mediterranean	0.68
Europe	0.87
South-east Asia	0.47
Western Pacific	0.64
Total	0.58

**See Annex Table 7 for grouping of countries by WHO Region.*

3.3 Effect of improvements in sanitation on diarrhoeal disease risk

Three exposure groups were considered in the analysis of the impact of sanitation interventions on the risk of diarrhoea:

- those using unimproved sanitation;
- those using improved (on-site) sanitation; and
- those living in communities with access to a sewerage system or other systems removing excreta entirely from the community.

Unimproved and improved facilities are defined following JMP definitions (Figure 8).

Meta-regression was used to quantify the reduction in diarrhoeal disease that could be achieved by implementing sanitation interventions; the effects are shown as risk ratios with 95% confidence intervals in Figure 10 and as percentage reductions in Figure 11.

It can be seen from Figure 11, that a mean diarrhoeal reduction of 28% could be achieved by shifting from

Figure 10. Risk ratios for transitions among sanitation exposure group

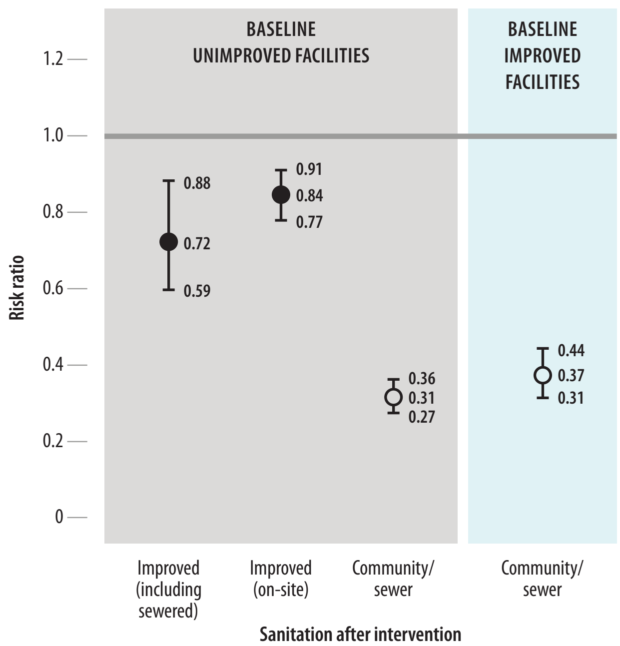
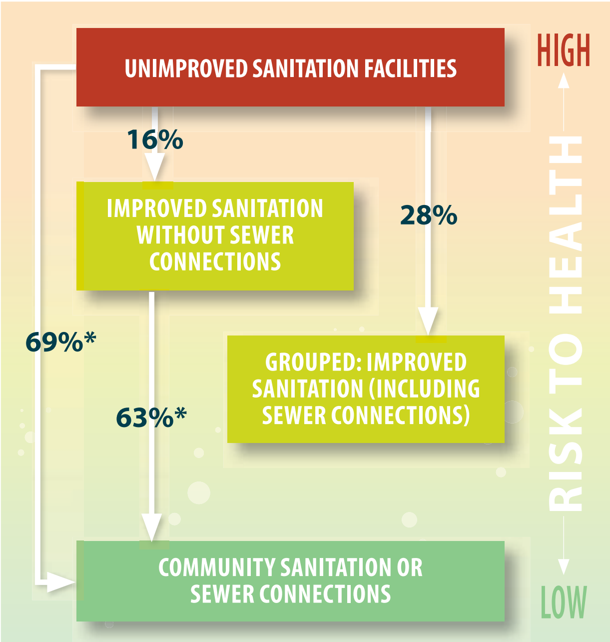


Figure 11. Sanitation transitions and associated reductions in diarrhoeal disease



** These estimates are based on limited evidence and should therefore be considered as preliminary, and have not been used in the current burden of disease estimate.*

a baseline of unimproved sanitation to improved sanitation (including sewered facilities). When sewerage connections are excluded from the analysis, the health gains are smaller (but still significant), with an expected reduction in disease risk of 16%.

Since poor sanitation for a small number of households can cause exposures for whole communities, health gains are expected to be greater when entire communities use sanitation facilities that exclude excreta from the environment *(30)*. While such "community level sanitation" could be achieved either through off-site technologies (e.g. sewers) or on-site technologies (e.g. latrines), only two studies were identified quantifying health gains to be realized in the transition to this higher level of service *(31, 32)*. Both of these studies involved sewered sanitation in urban settings, and might not be applicable to decentralized systems or behavioural change interventions which also result in coverage of whole communities. These studies found substantial health benefits resulting from the introduction of sewered sanitation: diarrhoeal disease could be reduced by 63% for those initially using basic improved sanitation and by 69% for those initially using unimproved sanitation. However, this analysis drew on a very small evidence base. Therefore, for the purposes of burden of disease calculations, all households using sewer connections were grouped with households using other improved sanitation facilities.

An even higher level of service was also envisaged, which would ensure safe management, treatment and reuse of excreta, thereby protecting both wider populations and the environment; however, no empirical evidence was available to quantify health gains associated with this level of service, and it was not considered further in this analysis.

SANITATION SAFETY PLANNING

WHO is testing a Sanitation Safety Planning (SSP) manual to operationalize the 2006 WHO Guidelines for Safe Use of Wastewater, Excreta and Greywater. SSPs use a risk assessment and risk management approach to prevent exposure to excreta along the sanitation chain from the household to final use or disposal. Ultimately SSP aims to close the loop with Water Safety Planning.

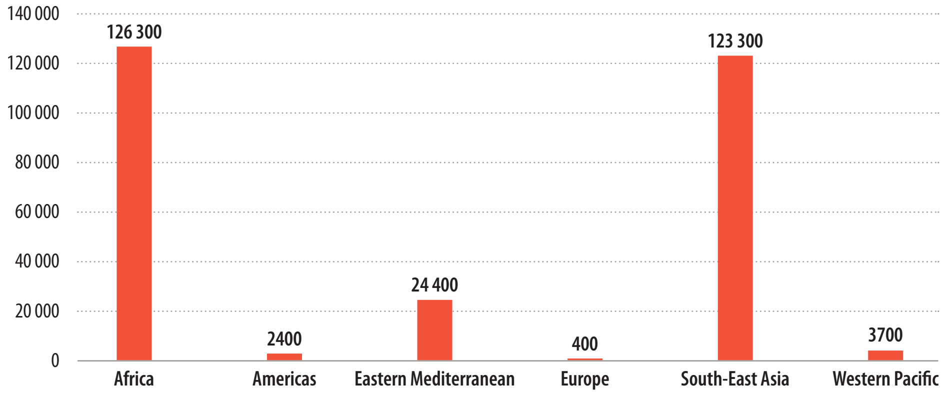
http://www.who.int/water_sanitation_health/wastewater/en/

http://www.who.int/water_sanitation_health/dwq/en/

3.4 Burden of diarrhoeal disease from inadequate sanitation

The burden of diarrhoeal disease was estimated from a combination of the distribution of the population using improved or unimproved sanitation facilities (Section 3.2) and the differences in the risk of diarrhoea experienced by those groups (Section 3.3). Thus, a total of 280 000 deaths in LMICs can be attributed to inadequate sanitation. The breakdown of these deaths is shown in Figure 12. As mentioned in the previous section, the estimated burden of disease (or health gains that can be achieved) would have been higher, if the risk reduction factor for sewered connections or higher levels of service was taken into account. Estimates of deaths that could be prevented through improving sanitation on a country-by-country basis and regional basis are available in Annex Tables 1 and 4, respectively.

Figure 12. Deaths from inadequate sanitation in LMICs by region, 2012



See Annex Table 7 for grouping of countries by WHO Region.

POTENTIAL FOR GREATER SANITATION BENEFITS

Diarrhoeal deaths attributable to inadequate sanitation may be higher than presented in this analysis, since improved sanitation and even sewered connections may not include full safe management of human waste. Exposure to untreated sewage and faecal sludge in wider populations is likely to cause significant amounts of disease, but has not been estimated in this analysis due to lack of data. High quality studies on the impact of safe excreta and wastewater management at community and wider population scale are needed for potential inclusion in subsequent burden of diarrhoea estimates.

Improvements in sanitation have benefits that extend well beyond reducing diarrhoea, including:

- Reducing the spread of neglected tropical diseases which affect millions of people – especially intestinal worms, schistosomiasis and trachoma;
- Promoting dignity and safety, and increasing school attendance especially for adolescent girls;
- Potential for safe resource recovery of renewable energy and nutrients.

Optimal sanitation service provision should be designed to prevent exposure to human waste along the entire sanitation chain, in order to protect wider populations and the environment. Thus, planners need to consider all elements of the service chain, including collection, transport, treatment and reuse.

3.5 Policy implications

- Provision of improved sanitation in households (flushing to a pit or septic tank, VIP, dry pit latrine with slab, or composting toilet) significantly reduces diarrhoea.
- Increasing access to basic sanitation at the household level remains an important but overlooked public health intervention for preventing diarrhoea. Governments should accelerate action on basic sanitation to meet the MDG target on sanitation with a focus on providing basic access to those currently unserved.
- Limited data suggest that the provision of higher levels of service, which protect whole communities from faecal exposure, provides significant additional protection from diarrhoea. Wherever possible, service providers should target high levels of community coverage to maximise health protection.

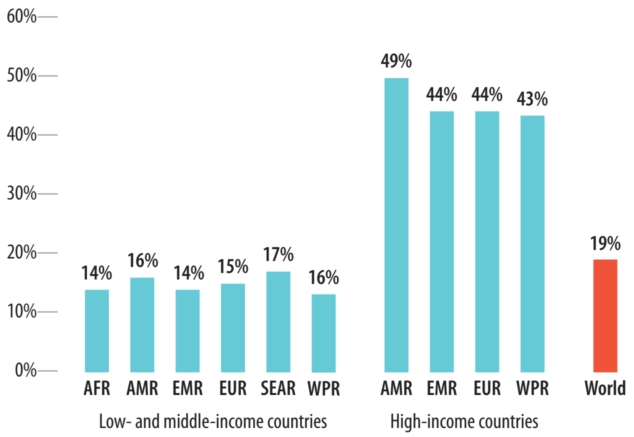
4. Handwashing

4.1 Global practices of handwashing with soap

Handwashing with soap after defecation or before the preparation of food has previously been shown to reduce diarrhoeal disease and acute respiratory infections *(33)*. Handwashing with soap is an important barrier to the spread of diarrhoeal, respiratory and possibly other infectious diseases as it prevents pathogens from reaching the domestic environment and food, and their subsequent ingestion.

The available literature was systematically searched for the observed frequency of handwashing with soap *(3)*. Based on 42 studies in 19 countries, country and regional handwashing prevalences were estimated using multilevel modelling. Regional means were assumed for countries without data. Globally, 19% of people worldwide were estimated to wash their hands after potential contact with excreta (Figure 13), and handwashing prevalence is somewhat higher in high-income countries than in LMICs but varies very little across countries within one region (see Annex Table 2).

Figure 13. Mean prevalence of handwashing with soap by region, 2012



No data were available for Eastern Mediterranean Region (EMR); global means for LMICs and high-income countries were used for this region.

MONITORING HANDWASHING PRACTICES *(8, 34)*

It is difficult to accurately capture handwashing practices through household surveys. Survey respondents typically report much higher handwashing frequency than is found through structured observation. However, household surveys have begun including an observation of the availability of soap and water in the place where household members usually wash their hands. In some surveys enumerators ask whether the household has any soap (or detergent, ash, mud or sand) in the house for washing hands; if so, the respondent is asked to show the handwashing material to the interviewer. Data on these two handwashing indicators are increasingly available, and in its 2014 update report the JMP reported on handwashing prevalence for the first time.

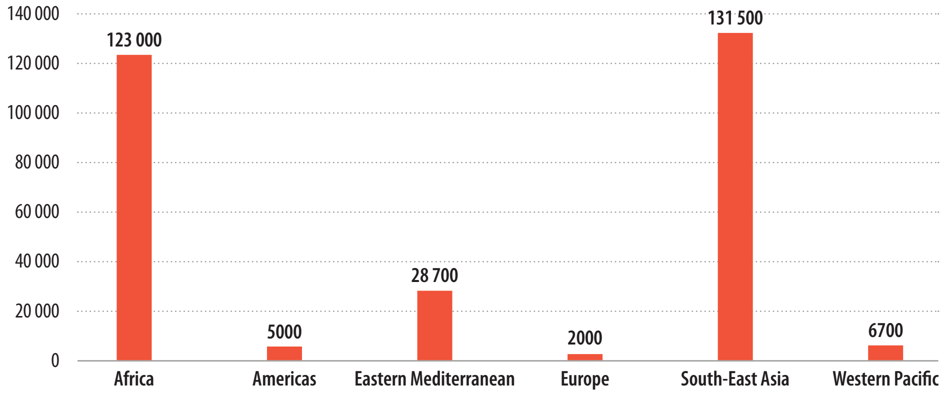
4.2 Effect of handwashing with soap on diarrhoeal disease risk

Interventions improving handwashing after toilet or latrine use or before food preparation can either be part of a broader hygiene promotion campaign, or can focus on handwashing alone. The relative risk for hygiene education focusing on handwashing with soap alone was estimated to reach 0.77 (95% CI: 0.32, 1.86) after bias adjustment for non-blinding of studies. Although this risk estimate is not statistically significant, which may be due to difficulties in designing good studies, it is the currently assumed most likely best estimate. This risk ratio is equivalent to an expected reduction in diarrhoeal disease risk of 23%.

4.3 Burden of disease from inadequate handwashing

The burden of disease was estimated by country (see Annex Tables 1 and 5) by combining global estimates of the prevalence of handwashing with soap and the risk of diarrhoea associated with inadequate handwashing. A total of 297 000 deaths can be attributed to inadequate handwashing (Figure 14). As a result of the adjustment for non-blinding, confidence intervals for the attributable disease burden are wide, and include zero. Nonetheless, this analysis represents the current best available estimate of the disease burden due to inadequate handwashing practices.

Figure 14. Deaths from inadequate handwashing practices in LMICs by region, 2012



See Annex Table 7 for grouping of countries by WHO Region.

HANDWASHING IN HEALTH CARE FACILITIES

Each year, hundreds of millions of patients around the world are affected by health care-associated infections, or "hospital" infections (also known as nosocomial infections). This disease burden is not accounted for in the current analysis, but was the subject of an earlier systematic review, which found that the prevalence of hospital infections varied between 5.7% and 19.1% in LMICs. Although hospital infections represent the most frequent adverse event in health care, the true burden remains unknown because of the difficulty in gathering reliable data. WHO's Global Patient Safety Challenge advocates reducing hospital infections through its annual SAVE LIVES: Clean Your Hands campaign.

http://www.who.int/gpsc/country_work/burden_hcai/en/

http://www.who.int/gpsc/5may/en/

4.4 Policy implications

Current handwashing prevalence is low, especially in LMICs where the levels of diarrhoea and respiratory infections are high. Thus, large potential health gains could be achieved from its widespread adoption and policies promoting handwashing merit further attention.

5. Integrated water, sanitation and hygiene interventions

The impact of combined interventions was investigated. Meta-regression revealed a significant positive effect when water and sanitation and hygiene interventions were implemented in concert, with a risk ratio of 0.88, equivalent to a 12% additional reduction in diarrhoeal disease risk *(5)*. This finding differs from previous literature reviews, although Waddington et al. *(35)* did find that some combinations were synergistic.

The exposures to faecal-oral pathogens through drinking-water, sanitation or hygiene are not independent, so some adjustment and assumptions are required in order to combine those exposures. Thus, the total disease burden does not correspond to the simple addition of the separate burden of those risks, but is slightly lower.

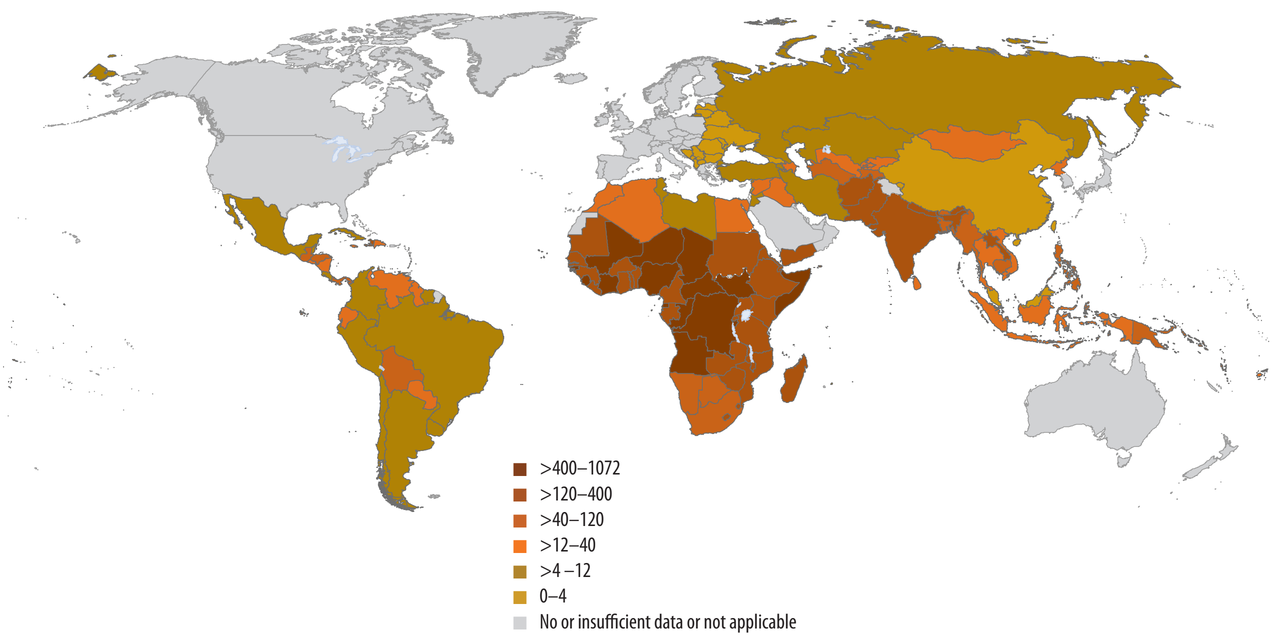
5.1 Burden of diarrhoeal disease from inadequate water, sanitation and hygiene

It was estimated that 502 000 diarrhoea deaths were attributable to inadequate drinking-water, and 280 000 deaths were caused as a result of inadequate sanitation. A further 297 000 deaths were likely to have resulted from inadequate handwashing practices. In total, 842 000 deaths were estimated to be caused by inadequate WASH in LMICs (Figure 15); this figure represents over half (58%) of the total diarrhoeal deaths in LMICs. In children under five years of age, 361 000 deaths (representing 5.6% of deaths for all causes in that age group) could be prevented through better water, sanitation and hygiene.

Current evidence indicates that the disease burden attributable to inadequate sanitation may be even higher, but the underlying evidence relating to community-wide sanitation (e.g. sewerage covering entire communities) needs to be confirmed before this can be taken into account. The same applies to the burden attributable to inadequate drinking-water; limited evidence suggests that the transition from basic piped water on premises to a higher level of service (e.g. regulated, safely managed water supplies) could also yield significant health benefits.

If sufficient data were available to model the impacts that moving to higher levels of drinking-water and sanitation services, the number of preventable deaths would be much higher.

Figure 15. Global map of diarrhoeal deaths due to inadequate water, sanitation and hygiene, 2012 (annual deaths per million population)



6. Trends, other estimates and non-diarrhoeal WASH-related illness

6.1 Trends since 1990

The number of deaths attributable to inadequate water, sanitation and hygiene has dramatically reduced; falling by over 50% from 1.8 million in 1990 (adjusted for comparability of methods) to 842 000 in 2012. Globally, total diarrhoea deaths have declined from 2.9 million in 1990 to 1.5 million in 2012. The number of global deaths in the under-5 age group due to diarrhoea has fallen to an even greater degree: from 1.5 million in 1990 to 622 000 in 2012.[1] While the reduction in deaths is probably due, at least in part, to improved access to health care, oral rehydration and reduced child undernutrition, it is likely that improvements in the provision of water and sanitation have also played a significant role in this marked reduction of diarrhoeal disease burden.

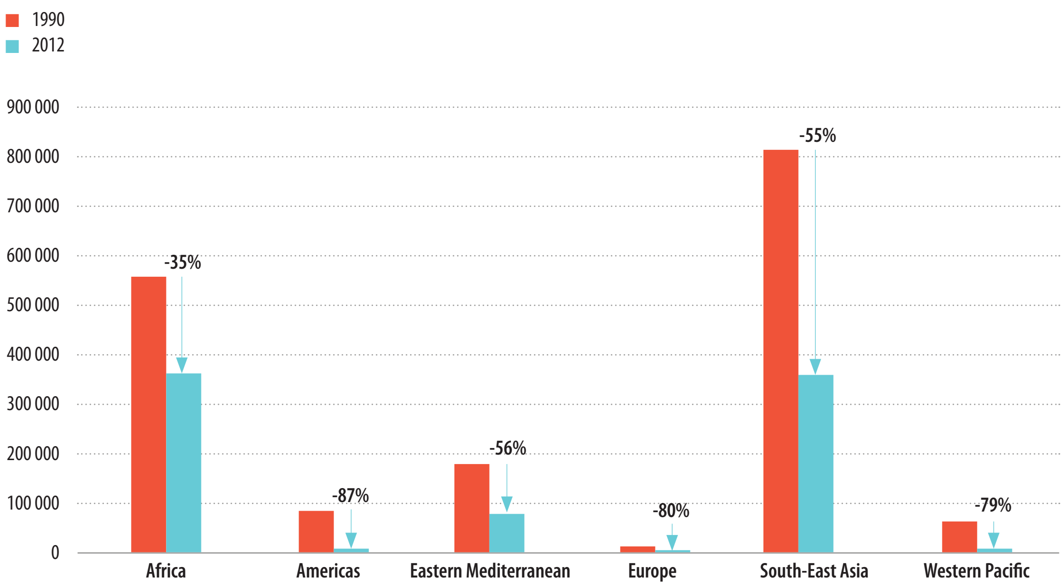
The greatest reductions in diarrhoeal disease burden in LMICs from 1990 (Figure 16) are seen in the Americas, Europe, and Western Pacific, regions that have seen correspondingly large improvements in access to improved drinking-water and sanitation over the same period.

6.2 Comparison with previous estimates of diarrhoea attributable to inadequate WASH

Estimates of diarrhoea attributable to inadequate water, sanitation and hygiene are sensitive to the main assumptions made, the baseline exposure (or *counterfactual*) with which comparisons are made and

1 Global figures on diarrhoeal deaths are available from the WHO Global Health Observatory; and *(9)*.

Figure 16. Decline in diarrhoea deaths attributable to inadequate WASH in LMICs in 1990 and 2012



the total global burden of diarrhoea. This section explores some of the differences between the current and earlier burden of disease estimates.

In 2000, WHO estimated that, globally, 88% of diarrhoeal mortality, amounting to 1.7 million deaths, could be attributed to inadequate WASH *(36)*. The new, much lower estimate of 842 000 deaths in part reflects the reduction of the total global diarrhoea burden from 2.0 million deaths in 2000 to 1.5 million deaths in 2012. However, an even more significant difference is in the baseline, or *counterfactual* scenario, used in the disease burden estimate. In the 2000 estimate, the baseline was ***no** disease transmission through water and sanitation*; a situation that is a lower level of risk than is commonly encountered even in high-income countries. The new estimate uses drinking filtered water and the use of basic sanitation facilities in an LMIC environment as counterfactuals. In essence, the previous estimate compared risks to an idealised high-income country situation, whereas the current estimate compares risks to an improved situation in LMICs, which still bears a significant likelihood of illness.

It should be noted that effective use of household water treatment is taken as an example of a drinking-water service that yields better quality drinking-water than either improved point sources or basic piped water, but is still below systematically managed piped water.

In 2000, the Disease Control Priorities (DCP) in Developing Countries project also examined the global burden of diarrhoeal disease due to inadequate WASH *(37)*. This study, which considered an intermediate counterfactual of piped water supply on the premises and an improved sanitation facility (i.e. between the *ideal* situation of WHO 2000 *(11, 38)* and the current estimate), attributed 71% of global diarrhoeal disease to WASH.

The GBD 2010 project by the Institute of Health Metric and Evaluation (IHME) attributed only 337 000 global diarrhoeal deaths to poor water and sanitation, representing 23% of all diarrhoea deaths *(7)*. The main differences with the current study are that:

- The GBD 2010 project uses *improved water source* as its counterfactual exposure, thus failing to account for the risks resulting from improved sources being microbially contaminated or being provided in insufficient quantity (e.g. as a result of a discontinuous supply); and

- The GBD 2010 study does not consider the impact of inadequate hand hygiene.

Thus, in summary, the key differences between the current approach and previous estimates are:

- Changes in the total number of diarrhoeal disease deaths used in the calculations;

- Use of different counterfactual scenarios, in particular for drinking-water supply and handwashing; and

- The current analysis relies on the latest systematic reviews to generate new estimates of relative risks resulting from transitions between different exposures with, where applicable, adjustment of risk ratios to account for possible bias.

6.3 Impact on diseases other than diarrhoea

The updated estimate of disease burden from inadequate WASH has focused on diarrhoeal disease, and has not re-analysed the impact on other diseases which have also been associated with this risk factor. Links have, however, been established or suggested for a number of conditions, including:

- soil-transmitted helminths;

- vector-borne diseases; and

- environmental enteropathy or undernutrition.

The impact of WASH on most of these diseases could however not be precisely enumerated, because of insufficient information on relevant exposures, or a lack of adequate exposure-response relationships. However, on the basis of reviews of the literature and expert opinion estimates of the fraction of disease attributable to WASH have been made, as shown in Table 3.

INTEGRATING WASH WITH HEALTH EFFORTS-GLOBAL ACTION PLAN FOR PNEUMONIA AND DIARRHOEA

The WHO/UNICEF Global Action Plan for Pneumonia and Diarrhoea sets forth an ambitious and comprehensive framework for ending preventable child deaths from pneumonia and diarrhoea by 2025. Achieving this goal will require meeting several prevention and treatment targets, including universal access to drinking-water, sanitation and hygiene in health care facilities and homes by 2030.

http://www.who.int/maternal_child_adolescent/documents/global_action_plan_pneumonia_diarrhoea/en/

Table 3. Health outcomes, other than diarrhoea, related to water, sanitation, and hygiene *(4)*

Health outcomes and range of the fraction of disease globally attributable to WASH*			
Contribution of WASH not quantified at global level	0–33%	33%–66%	66%–100%
Hepatitis A, E, F Legionellosis Scabies Arsenicosis Fluorosis Methaemoglobinaemia	Onchocerciasis	Lymphatic filariasis Malaria Undernutrition and its consequences Drowning	Ascariasis Hookworm Trichuriasis Dengue Schistosomiasis Japanese encephalitis Trachoma

**Estimates based on previous assessments combining systematic literature reviews with expert opinion.*

The number of global deaths for these non-diarrhoeal diseases, derived from the results of previous estimates (based on literature reviews combined with expert opinion), are as follows:

- In 2004, 881 000 non-diarrhoeal deaths were attributed to water supply, sanitation and hygiene, mainly through the effect on undernutrition and its consequences (854 000 deaths), but also from schistosomiasis (15 000 deaths) and intestinal nematode infections (12 000 deaths).
- The impacts of water resource management, mainly on malaria (526 000 deaths) but also dengue (18 000 deaths) and Japanese encephalitis (13 000 deaths), were estimated to amount to 557 000 deaths in the same year.
- Finally, an estimated 372 000 people died from drowning in 2012 *(40)*. Many of these deaths could be prevented through safer water environments.

Although these figures require updating, they do suggest that the impacts of WASH on other diseases and conditions could be at least as great as – and possibly much greater than – the impacts on diarrhoeal disease.

6.4 Policy implications

- The drop in diarrhoeal deaths seen in LMICs is likely due to a large number of factors but is related, at least in part, to increased access to improved drinking-water and sanitation and possibly other WASH improvements that have not be measured directly, such as water quality.
- Although the counterfactuals and assumptions used will affect the overall burden of disease estimate, this latest estimate indicates the major impact that improved WASH could have on reducing diarrhoeal disease in LMICs.
- The impact of WASH on other conditions and diseases is likely to be even greater than on diarrhoeal disease, further justifying investments in this area.

Annex

Country data on water-, sanitation- and hygiene-related exposure and disease burden

This Annex contains estimates of relevant country-level exposures and diarrhoea deaths attributable to inadequate water, sanitation and hygiene. Other diseases attributable to inadequate WASH are covered elsewhere *(12, 39)*.

These estimates address the attributable burden of disease – i.e. the reduction of disease burden that could be achieved if the risks of inadequate water, sanitation and hygiene could be reduced. Additional information on methods used can be found in *(4)*.

Exposure categories do not necessarily correspond to the definitions used in the WHO/UNICEF Joint Monitoring Programme *(8)*, see notes below for specific differences. Modelling of exposures has been performed by multilevel modelling *(17)*.

Methodology

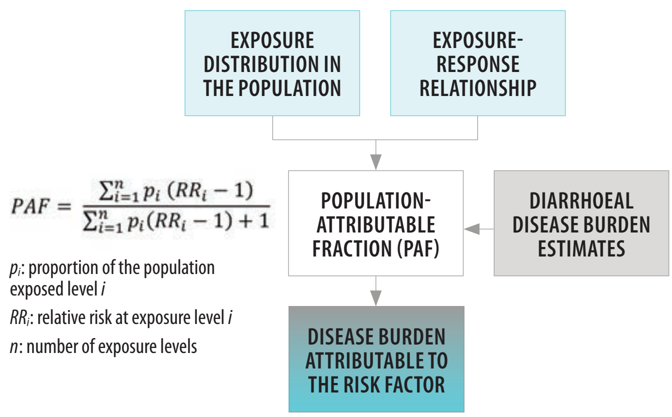
As outlined in the Introduction to the main report a comparative risk assessment methodology based upon defined counterfactual/baseline scenarios was used to estimate the burden of disease attributable to WASH. The defined counterfactual levels or the minimum risks defined for each of the risk factors were as follows:

- Drinking-water—use of household filtration or boiling of water with subsequent safe storage;
- Sanitation—use of an improved sanitation facility which is not shared;
- Hygiene—handwashing with soap after contact with excreta.

For each risk factor, the population-attributable fraction (PAF) was estimated by comparing current exposure distributions to the counterfactual distribution for each exposure level, sex and age group on a country-by-country basis (Annex Figure 1), where p_i is the proportion of the population exposed, RR_i is the relative risk at exposure level *i* and *n* is the number of exposure levels.

The burden of disease attributable to each risk factor was obtained by multiplying the PAFs by the total burden of disease of diarrhoea.

Figure 1. Approach used for estimation of attributable disease burden



Notes to Annex Table 2

- Category "Other improved water source": People living at distances greater than a 30 minute round-trip from an improved water source were assumed to use an unimproved water source, mainly because lower water use and increasing distance to a water source have been associated with an increased risk of diarrhoea.
- Category "Improved sanitation": People with access to a shared sanitation facility were assumed not to use an improved sanitation facility.
- Note that numbers may not add up as a result of rounding.
- Figures have been computed to ensure comparability; they are therefore not necessarily the official statistics of Member States, which use alternative rigorous methods.

Annex Table 1. Diarrhoea deaths, by country, attributable to inadequate water, sanitation, and hygiene in LMICs[a] for the year 2012

		Unsafe water deaths		Unsafe sanitation deaths		Unsafe hygiene deaths		Water and sanitation deaths		Water, sanitation and hygiene deaths	
Region[b]	Country	Mean	(95% CI)	Mean	(95% CI)	Mean	(95% CI)	Mean	(95% CI)	Mean	(95% CI)
EMR	Afghanistan	6 420	(3086, 8425)	3 127	(1062, 4791)	4 639	(0, 13 947)	8 296	(5770, 10 701)	9 867	(6466, 12 666)
EUR	Albania	5	(0, 7)		(0, 0)	2	(0, 6)	5	(3, 6)	7	(2, 11)
AFR	Algeria	577	(13, 892)	62	(18, 114)	348	(0, 1042)	616	(399, 829)	911	(325, 1408)
AFR	Angola	13 634	(6812, 18 163)	7 529	(2565, 11 302)	7 404	(0, 22 142)	18 385	(13 055, 23 446)	22 316	(14 605, 28 910)
AMR	Antigua and Barbuda	0	(0, 0)	0	(0, 0)	1	(0, 3)	0	(0, 0)	1	(0, 3)
AMR	Argentina	149	(0, 270)	10	(0, 23)	201	(0, 621)	154	(75, 234)	265	(35, 458)
EUR	Armenia	20	(0, 34)	2	(1, 4)	10	(0, 29)	21	(12, 31)	32	(6, 53)
EUR	Azerbaijan	88	(29, 134)	32	(9, 57)	141	(0, 419)	116	(73, 159)	195	(60, 319)
SEAR	Bangladesh	5 784	(1404, 8139)	2 288	(747, 3576)	8 264	(0, 24 756)	7 236	(4209, 10 233)	8 950	(4988, 12 175)
EUR	Belarus	10	(0, 18)	1	(0, 2)	46	(0, 138)	11	(6, 16)	19	(3, 33)
AMR	Belize	2	(0, 3)		(0, 1)	4	(0, 13)	2	(2, 3)	3	(1, 5)
AFR	Benin	1 877	(866, 2486)	1 191	(423, 1730)	1 499	(0, 4483)	2 607	(1861, 3277)	3 063	(2070, 3874)
SEAR	Bhutan	23	(6, 36)	17	(6, 27)	51	(0, 156)	38	(24, 50)	51	(25, 74)
AMR	Bolivia (Plurinational State of)	354	(8, 565)	229	(75, 356)	286	(0, 884)	526	(361, 681)	708	(345, 1016)
EUR	Bosnia and Herzegovina	2	(0, 3)	0	(0, 0)	2	(0, 6)	2	(1, 3)	3	(1, 4)
AFR	Botswana	106	(11, 160)	42	(13, 68)	83	(0, 247)	137	(95, 176)	183	(86, 264)
AMR	Brazil	1 137	(0, 1994)	326	(99, 542)	921	(0, 2872)	1 396	(862, 1928)	2 141	(609, 3448)
EUR	Bulgaria	3	(0, 6)	0	(0, 0)	6	(0, 17)	3	(2, 5)	6	(1, 11)
AFR	Burkina Faso	3 814	(1712, 5089)	2 453	(868, 3579)	3 391	(0, 10 028)	5 335	(3753, 6832)	6 338	(4207, 8064)
AFR	Burundi	4 188	(1925, 5528)	1 726	(557, 2720)	2 157	(0, 6451)	5 234	(3535, 6866)	6 325	(4067, 8236)
AFR	Cabo Verde	12	(4, 17)	8	(3, 11)	26	(0, 79)	18	(13, 22)	22	(13, 29)
WPR	Cambodia	377	(159, 536)	317	(109, 476)	884	(0, 2622)	621	(411, 820)	817	(454, 1130)
AFR	Cameroon	5 589	(2624, 7373)	2 374	(777, 3679)	4 115	(0, 12 307)	7 053	(4809, 9107)	8 547	(5454, 11 169)
AFR	Central African Republic	2 957	(1308, 3913)	1 510	(508, 2311)	1 383	(0, 4136)	3 865	(2631, 5017)	4 566	(2978, 5839)
AFR	Chad	6 758	(3211, 8892)	4 312	(1532, 6235)	2 793	(0, 8352)	9 370	(6611, 11 809)	10 961	(7568, 13 831)
AMR	Chile	54	(0, 93)	2	(1, 4)	25	(0, 89)	55	(30, 81)	76	(12, 134)
WPR	China	2 015	(276, 3256)	1 402	(374, 2509)	1 771	(0, 5254)	3 145	(1989, 4283)	4 745	(1922, 7279)
AMR	Colombia	158	(0, 267)	47	(14, 80)	176	(0, 545)	193	(124, 262)	292	(87, 465)
AFR	Comoros	117	(42, 163)	65	(22, 99)	86	(0, 258)	161	(108, 210)	198	(121, 264)
AFR	Congo	1 206	(590, 1607)	764	(269, 1129)	793	(0, 2371)	1 713	(1232, 2170)	2 045	(1324, 2635)
WPR	Cook Islands		(0, 0)		(0, 0)		(0, 1)	0	(0, 0)	0	(0, 1)

		Unsafe water deaths		Unsafe sanitation deaths		Unsafe hygiene deaths		Water and sanitation deaths		Water, sanitation and hygiene deaths	
Region[b]	Country	Mean	(95% CI)	Mean	(95% CI)	Mean	(95% CI)	Mean	(95% CI)	Mean	(95% CI)
AMR	Costa Rica	18	(0, 31)	2	(1, 3)	12	(0, 38)	19	(10, 28)	31	(6, 53)
AFR	Côte d'Ivoire	4 921	(2181, 6601)	3 121	(1089, 4613)	2 886	(0, 8630)	6 923	(5052, 8646)	8 303	(5360, 10 619)
AMR	Cuba	49	(4, 77)	7	(2, 12)	36	(0, 110)	54	(34, 73)	82	(26, 130)
SEAR	Democratic People's Republic of Korea	146	(0, 263)	67	(19, 119)	239	(0, 725)	198	(117, 275)	332	(90, 546)
AFR	Democratic Republic of the Congo	43 213	(20 522, 57 039)	22 779	(7701, 34 948)	26 610	(0, 79 577)	57 048	(39 763, 73 276)	67 827	(45 029, 86 810)
EMR	Djibouti	131	(33, 189)	55	(16, 90)	121	(0, 365)	170	(123, 216)	216	(116, 301)
AMR	Dominica	0	(0, 0)	0	(0, 0)	1	(0, 3)	0	(0, 0)	0	(0, 1)
AMR	Dominican Republic	112	(27, 168)	26	(8, 44)	161	(0, 499)	129	(88, 170)	190	(81, 286)
AMR	Ecuador	147	(0, 241)	23	(6, 44)	120	(0, 371)	164	(105, 225)	255	(78, 407)
EMR	Egypt	779	(0, 1311)	39	(10, 74)	785	(0, 2359)	801	(434, 1173)	1 208	(228, 2011)
AMR	El Salvador	80	(10, 124)	30	(9, 50)	86	(0, 265)	103	(72, 135)	146	(62, 219)
AFRHI	Equatorial Guinea	272	(128, 361)	102	(33, 162)	195	(0, 583)	336	(223, 443)	411	(253, 539)
AFR	Eritrea	1 237	(600, 1629)	800	(286, 1166)	630	(0, 1885)	1 735	(1234, 2188)	2 040	(1351, 2576)
AFR	Ethiopia	17 019	(7877, 22 307)	9 367	(3248, 13 904)	11 186	(0, 33 763)	22 562	(15 707, 28 506)	26 088	(17 974, 32 721)
WPR	Fiji	12	(1, 20)	3	(0, 8)	17	(0, 50)	15	(9, 21)	25	(7, 42)
AFR	Gabon	259	(98, 361)	148	(49, 227)	196	(0, 587)	365	(256, 467)	453	(268, 606)
AFR	Gambia	242	(103, 328)	82	(26, 133)	201	(0, 602)	298	(199, 389)	372	(213, 503)
EUR	Georgia	5	(0, 8)	0	(0, 1)	16	(0, 47)	5	(3, 7)	8	(3, 12)
AFR	Ghana	2 853	(1082, 3870)	1 886	(665, 2739)	2 446	(0, 7234)	4 031	(2759, 5195)	4 763	(3102, 6075)
AMR	Grenada	1	(0, 1)		(0, 0)	1	(0, 4)	1	(0, 1)	1	(0, 1)
AMR	Guatemala	718	(0, 1173)	204	(62, 346)	325	(0, 1005)	870	(574, 1159)	1 296	(439, 2024)
AFR	Guinea	2 713	(1178, 3647)	1 726	(617, 2530)	1 848	(0, 5525)	3 799	(2615, 4887)	4 506	(2955, 5762)
AFR	Guinea-Bissau	488	(213, 647)	289	(102, 424)	426	(0, 1274)	664	(463, 851)	778	(516, 983)
AMR	Guyana	19	(3, 28)	4	(1, 6)	20	(0, 63)	22	(14, 29)	30	(12, 45)
AMR	Haiti	1 770	(806, 2354)	933	(314, 1462)	553	(0, 1712)	2 343	(1572, 3021)	2 790	(1777, 3599)
AMR	Honduras	333	(0, 544)	99	(31, 164)	99	(0, 305)	407	(265, 546)	595	(222, 919)
SEAR	India	193 517	(60 971, 273 518)	115 404	(39 429, 173 317)	138 026	(0, 420 294)	271 328	(172 527, 362 268)	334 778	(197 825, 446 149)
SEAR	Indonesia	1 648	(622, 2645)	3 295	(1045, 5225)	7 543	(0, 22 897)	4 742	(2625, 6832)	8 815	(2296, 15 021)
EMR	Iran	432	(0, 729)	37	(9, 75)	561	(0, 1688)	459	(259, 656)	690	(141, 1140)

Region[b]	Country	Unsafe water deaths		Unsafe sanitation deaths		Unsafe hygiene deaths		Water and sanitation deaths		Water, sanitation and hygiene deaths	
		Mean	(95% CI)	Mean	(95% CI)	Mean	(95% CI)	Mean	(95% CI)	Mean	(95% CI)
EMR	Iraq	817	(77, 1229)	113	(28, 216)	637	(0, 1916)	896	(602, 1191)	1 256	(491, 1892)
AMR	Jamaica	28	(7, 41)	7	(2, 12)	35	(0, 109)	33	(21, 45)	50	(19, 78)
EMR	Jordan	39	(0, 67)	1	(0, 2)	46	(0, 139)	40	(22, 58)	66	(13, 110)
EUR	Kazakhstan	78	(16, 126)	6	(2, 11)	153	(0, 455)	85	(44, 128)	168	(27, 296)
AFR	Kenya	7 735	(3697, 10 475)	4 864	(1658, 7280)	4 531	(0, 13 873)	10 984	(7741, 14 110)	13 497	(8465, 17 669)
WPR	Kiribati	7	(3, 10)	6	(2, 9)	3	(0, 10)	12	(8, 15)	16	(8, 22)
EUR	Kyrgyzstan	59	(15, 88)	5	(1, 10)	50	(0, 148)	64	(38, 89)	97	(34, 155)
WPR	Lao People's Democratic Republic	379	(157, 568)	273	(87, 448)	298	(0, 884)	602	(368, 825)	909	(377, 1388)
EUR	Latvia	1	(0, 1)	0	(0, 0)	0	(0, 1)	1	(0, 1)	1	(0, 2)
EMR	Lebanon	11	(0, 20)	1	(0, 1)	22	(0, 67)	12	(6, 18)	18	(3, 31)
AFR	Lesotho	344	(154, 462)	194	(66, 292)	189	(0, 564)	468	(323, 606)	566	(358, 735)
AFR	Liberia	643	(253, 862)	391	(138, 569)	449	(0, 1342)	877	(600, 1125)	1 028	(675, 1300)
EMR	Libya	25	(0, 39)	2	(0, 3)	23	(0, 70)	26	(16, 36)	38	(12, 60)
EUR	Lithuania	1	(0, 2)		(0, 0)	1	(0, 2)	1	(1, 2)	2	(0, 3)
AFR	Madagascar	3 005	(1339, 4163)	2 482	(887, 3623)	2 182	(0, 6479)	4 748	(3212, 6101)	5 840	(3696, 7696)
AFR	Malawi	2 573	(1127, 3462)	1 115	(371, 1711)	1 428	(0, 4271)	3 273	(2164, 4324)	4 008	(2484, 5283)
WPR	Malaysia	51	(0, 97)	7	(1, 15)	453	(0, 1343)	56	(28, 84)	110	(15, 196)
SEAR	Maldives	1	(0, 2)	0	(0, 0)	4	(0, 11)	1	(1, 2)	2	(1, 3)
AFR	Mali	5 321	(2542, 6974)	2 963	(1031, 4385)	4 489	(0, 13 425)	7 139	(5063, 9080)	8 444	(5577, 10 714)
WPR	Marshall Islands	2	(0, 3)	1	(0, 1)	2	(0, 5)	3	(1, 4)	4	(1, 6)
AFR	Mauritania	682	(328, 898)	388	(138, 575)	474	(0, 1417)	922	(669, 1157)	1 084	(723, 1374)
AFR	Mauritius	7	(0, 12)	1	(0, 2)	4	(0, 13)	7	(4, 11)	11	(2, 19)
AMR	Mexico	729	(0, 1246)	172	(51, 295)	638	(0, 1974)	859	(527, 1184)	1 330	(373, 2146)
WPR	Micronesia	4	(1, 6)	3	(1, 6)	3	(0, 10)	7	(4, 10)	10	(5, 14)
WPR	Mongolia	44	(16, 65)	18	(5, 31)	37	(0, 110)	58	(34, 82)	85	(39, 127)
EUR	Montenegro	0	(0, 0)	0	(0, 0)	0	(0, 1)	0	(0, 0)	0	(0, 1)
EMR	Morocco	693	(211, 978)	134	(38, 237)	361	(0, 1086)	785	(554, 1004)	1 048	(516, 1504)
AFR	Mozambique	6 008	(2820, 7889)	3 545	(1235, 5187)	3 497	(0, 10 458)	8 118	(5833, 10 303)	9 499	(6504, 11 925)
SEAR	Myanmar	3 280	(900, 4790)	866	(243, 1491)	2 272	(0, 6896)	3 905	(2046, 5717)	5 394	(2542, 7855)
AFR	Namibia	126	(48, 174)	75	(25, 114)	93	(0, 277)	178	(124, 227)	219	(133, 292)
WPR	Nauru	0	(0, 0)	0	(0, 0)	0	(0, 1)	0	(0, 0)	0	(0, 1)

		Unsafe water deaths		Unsafe sanitation deaths		Unsafe hygiene deaths		Water and sanitation deaths		Water, sanitation and hygiene deaths	
Region[b]	Country	Mean	(95% CI)	Mean	(95% CI)	Mean	(95% CI)	Mean	(95% CI)	Mean	(95% CI)
SEAR	Nepal	2 084	(584, 2949)	1 187	(408, 1790)	1 829	(0, 5458)	2 878	(1768, 3909)	3 522	(2105, 4703)
AMR	Nicaragua	101	(27, 150)	52	(16, 84)	95	(0, 295)	140	(97, 179)	187	(95, 268)
AFR	Niger	6 802	(3258, 8989)	4 402	(1563, 6387)	3 384	(0, 10 118)	9 478	(6727, 11 927)	11 081	(7665, 13 964)
AFR	Nigeria	51 889	(24 168, 68 511)	27 077	(9350, 40 439)	31 218	(0, 93 357)	68 254	(46 724, 87 438)	80 968	(53 271, 103 585)
WPR	Niue	0	(0, 0)		(0, 0)		(0, 0)	0	(0, 0)	0	(0, 0)
EMR	Pakistan	22 046	(7961, 30473)	10 635	(3508, 16 382)	14 833	(0, 44 595)	28 992	(19 514, 38 044)	36 127	(21 780, 48 263)
WPR	Palau	0	(0, 0)	0	(0, 0)	0	(0, 1)	0	(0, 0)	1	(0, 1)
AMR	Panama	79	(0, 138)	30	(9, 52)	54	(0, 167)	103	(65, 140)	153	(48, 241)
WPR	Papua New Guinea	401	(175, 574)	360	(124, 541)	296	(0, 877)	669	(443, 881)	858	(508, 1166)
AMR	Paraguay	83	(11, 128)	25	(8, 44)	55	(0, 170)	103	(70, 134)	147	(62, 222)
AMR	Peru	100	(24, 166)	96	(30, 160)	235	(0, 700)	187	(114, 257)	352	(90, 602)
WPR	Philippines	2 794	(854, 4038)	801	(245, 1355)	2 644	(0, 7842)	3 394	(2047, 4690)	4 723	(2246, 6894)
EUR	Republic of Moldova	2	(1, 3)		(0, 1)	1	(0, 2)	2	(1, 3)	3	(1, 5)
EUR	Romania	8	(2, 12)	2	(0, 3)	6	(0, 16)	9	(6, 12)	14	(5, 22)
EUR	Russian Federation	453	(0, 732)	145	(42, 256)	618	(0, 2086)	560	(362, 748)	719	(271, 1097)
AFR	Rwanda	1 249	(528, 1736)	507	(154, 833)	1 643	(0, 4914)	1 606	(1000, 2194)	2 119	(1132, 2961)
AMR	Saint Lucia	1	(0, 1)	0	(0, 1)	2	(0, 7)	1	(1, 1)	1	(1, 2)
AMR	Saint Vincent and the Grenadines	0	(0, 1)	0	(0, 0)	1	(0, 4)	1	(0, 1)	1	(0, 1)
WPR	Samoa	3	(0, 6)	1	(0, 1)	3	(0, 9)	4	(2, 5)	7	(1, 12)
AFR	Sao Tome and Principe	15	(7, 21)	9	(3, 14)	18	(0, 54)	21	(15, 27)	26	(17, 33)
AFR	Senegal	2 222	(1060, 2972)	970	(316, 1508)	1 251	(0, 3760)	2 844	(2066, 3587)	3 482	(2178, 4570)
EUR	Serbia	14	(0, 24)	1	(0, 1)	12	(0, 37)	15	(8, 21)	25	(5, 43)
AFR	Seychelles	2	(0, 3)	0	(0, 0)	5	(0, 16)	2	(1, 3)	3	(1, 4)
AFR	Sierra Leone	3 310	(1573, 4313)	2 025	(724, 2926)	1 741	(0, 5207)	4 504	(3220, 5655)	5 231	(3659, 6522)
WPR	Solomon Islands	24	(8, 36)	23	(8, 35)	9	(0, 28)	42	(27, 56)	56	(31, 78)
EMR	Somalia	6 013	(2540, 8096)	3 334	(1170, 4985)	3 104	(0, 9331)	8 047	(5529, 10 358)	9 597	(6366, 12 358)
AFR	South Africa	3 812	(657, 5665)	1 038	(311, 1762)	2 934	(0, 8775)	4 564	(3158, 5897)	6 258	(2854, 9229)
EMR	South Sudan	3 247	(1457, 4328)	1 778	(546, 2913)	2 274	(0, 6801)	4 249	(2952, 5431)	5 217	(3366, 6720)
SEAR	Sri Lanka	421	(129, 620)	68	(17, 133)	476	(0, 1445)	481	(240, 718)	705	(284, 1083)
EMR	Sudan	7 566	(3754, 9989)	4 457	(1524, 6651)	4 498	(0, 13 522)	10 310	(7532, 12 879)	12 309	(8235, 15 648)

Region[b]	Country	Unsafe water deaths		Unsafe sanitation deaths		Unsafe hygiene deaths		Water and sanitation deaths		Water, sanitation and hygiene deaths	
		Mean	(95% CI)	Mean	(95% CI)	Mean	(95% CI)	Mean	(95% CI)	Mean	(95% CI)
AMR	Suriname	2	(0, 4)	1	(0, 1)	6	(0, 17)	3	(2, 4)	4	(1, 6)
AFR	Swaziland	179	(89, 237)	66	(21, 105)	116	(0, 346)	222	(157, 281)	276	(169, 368)
EMR	Syria	248	(0, 395)	18	(5, 34)	160	(0, 481)	260	(158, 362)	379	(108, 599)
EUR	Tajikistan	235	(92, 361)	37	(6, 78)	198	(0, 591)	264	(154, 372)	579	(87, 1043)
SEAR	Thailand	833	(215, 1218)	38	(7, 81)	1 563	(0, 4656)	879	(439, 1317)	1 241	(489, 1888)
EUR	The former Yugoslav Republic of Macedonia	1	(0, 1)	0	(0, 0)	0	(0, 1)	1	(0, 1)	1	(0, 1)
SEAR	Timor-Leste	34	(14, 52)	48	(16, 75)	79	(0, 241)	76	(44, 104)	114	(49, 174)
AFR	Togo	1 495	(702, 1964)	922	(331, 1340)	880	(0, 2633)	2 043	(1457, 2577)	2 377	(1651, 2972)
WPR	Tonga	2	(0, 4)	1	(0, 1)	2	(0, 6)	3	(2, 4)	5	(1, 8)
EMR	Tunisia	52	(0, 82)	7	(2, 12)	56	(0, 169)	57	(38, 77)	82	(28, 128)
EUR	Turkey	286	(0, 532)	50	(14, 93)	283	(0, 844)	329	(177, 478)	560	(88, 961)
EUR	Turkmenistan	184	(64, 266)	13	(4, 23)	95	(0, 284)	195	(121, 268)	299	(118, 466)
WPR	Tuvalu	0	(0, 0)	0	(0, 0)	0	(0, 1)	0	(0, 0)		(0, 1)
AFR	Uganda	6 509	(2916, 8764)	3 615	(1246, 5452)	5 564	(0, 16 540)	8 857	(6013, 11 446)	10 816	(6831, 14 135)
EUR	Ukraine	91	(13, 145)	9	(2, 17)	304	(0, 906)	103	(55, 150)	169	(46, 283)
AFR	United Republic of Tanzania	7 130	(3264, 9666)	5 275	(1884, 7652)	5 208	(0, 15 574)	10 610	(7287, 13 526)	12 913	(8330, 16 641)
AMR	Uruguay	19	(0, 34)	0	(0, 1)	9	(0, 34)	19	(9, 29)	27	(1, 49)
EUR	Uzbekistan	131	(49, 225)	48	(5, 108)	532	(0, 1586)	179	(86, 275)	657	(0, 1371)
WPR	Vanuatu	11	(3, 15)	4	(1, 7)	4	(0, 10)	14	(8, 19)	17	(9, 24)
AMR	Venezuela	200	(0, 342)	45	(13, 80)	190	(0, 587)	236	(151, 323)	364	(100, 589)
WPR	Viet Nam	321	(82, 541)	488	(149, 808)	2 031	(0, 6024)	783	(406, 1145)	1 772	(255, 3259)
EMR	Yemen	1 888	(850, 2531)	704	(224, 1137)	1 648	(0, 4953)	2 301	(1643, 2932)	2 945	(1742, 3961)
AFR	Zambia	2 079	(952, 2765)	986	(328, 1504)	2 005	(0, 5996)	2 698	(1862, 3492)	3 308	(2107, 4336)
AFR	Zimbabwe	2 126	(939, 2882)	1 046	(340, 1622)	535	(0, 1601)	2 821	(1958, 3620)	3 539	(2137, 4724)
Total LMICs		502 061	(217 119, 671 945)	280 443	(95 699, 417 482)	296 860	(0, 885 355)	684 456	(580 456, 780 463)	841 818	(699 059, 963 626)

AFR: Africa; AMR: America; EMR: Eastern Mediterranean; EUR: Europe; SEAR: South East Asia; WPR: Western Pacific.

[a] Equatorial Guinea has been included in this analysis despite being classified as high-income country in 2012.

[b] World Bank Income classification, July 2012 (The World Bank 2012).

Annex Table 2. Selected levels of exposure, by country, to inadequate water, sanitation and hygiene in LMICs[a], for the year 2012

		Proportion of the population					
Region[b]	Country	Piped water to premises	Other improved water source	Unimproved water source	Filtered or boiled in the household[c]	Improved sanitation	Practice of handwashing after potential contact with excreta[c]
EMR	Afghanistan	0.09	0.41	0.50	0.03	0.37	0.14
EUR	Albania	0.82	0.14	0.04	0.07	0.96	0.15
AFR	Algeria	0.78	0.12	0.10	0.15	0.92	0.14
AFR	Angola	0.20	0.30	0.50	0.13	0.35	0.14
AMR	Antigua and Barbuda	0.87	0.11	0.02	0.12	0.91	0.49
AMR	Argentina	0.96	0.03	0.01	0.33	0.96	0.16
EUR	Armenia	0.96	0.03	0.01	0.08	0.92	0.15
EUR	Azerbaijan	0.57	0.25	0.18	0.61	0.83	0.15
SEAR	Bangladesh	0.10	0.73	0.17	0.09	0.57	0.18
EUR	Belarus	0.89	0.10	0.01	0.40	0.94	0.15
AMR	Belize	0.77	0.18	0.05	0.13	0.88	0.16
AFR	Benin	0.17	0.53	0.31	0.01	0.16	0.14
SEAR	Bhutan	0.61	0.32	0.07	0.45	0.50	0.17
AMR	Bolivia	0.82	0.06	0.12	0.30	0.51	0.16
EUR	Bosnia and Herzegovina	0.87	0.11	0.01	0.04	0.97	0.15
AFR	Botswana	0.73	0.20	0.07	0.14	0.67	0.14
AMR	Brazil	0.92	0.05	0.03	0.32	0.83	0.16
EUR	Bulgaria	0.96	0.03	0.00	0.40	0.98	0.15
AFR	Burkina Faso	0.07	0.56	0.37	0.08	0.16	0.08
AFR	Burundi	0.07	0.51	0.42	0.04	0.50	0.14
AFR	Cabo Verde	0.54	0.29	0.16	0.12	0.37	0.14
WPR	Cambodia	0.20	0.47	0.34	0.51	0.36	0.13
AFR	Cameroon	0.16	0.50	0.34	0.02	0.49	0.14
AFR	Central African Republic	0.04	0.57	0.39	0.01	0.33	0.14
AFR	Chad	0.07	0.40	0.53	0.08	0.14	0.14
AMR	Chile	0.95	0.03	0.02	0.17	0.97	0.49
WPR	China	0.70	0.23	0.07	0.52	0.62	0.13
AMR	Colombia	0.89	0.05	0.07	0.31	0.81	0.16
AFR	Comoros	0.34	0.53	0.13	0.10	0.40	0.14
AFR	Congo	0.30	0.37	0.33	0.11	0.25	0.14
WPR	Cook Islands	0.77	0.23	0.00	0.52	0.87	0.13
AMR	Costa Rica	0.95	0.02	0.03	0.31	0.94	0.16
AFR	Côte d'Ivoire	0.41	0.36	0.23	0.01	0.24	0.14
AMR	Cuba	0.78	0.16	0.06	0.28	0.91	0.16
SEAR	Democratic People's Republic of Korea	0.88	0.11	0.01	0.52	0.78	0.17
AFR	Democratic Republic of the Congo	0.09	0.33	0.57	0.09	0.33	0.14
EMR	Djibouti	0.65	0.20	0.15	0.03	0.60	0.14
AMR	Dominica	0.79	0.17	0.04	0.30	0.81	0.16
AMR	Dominican Republic	0.69	0.17	0.13	0.28	0.83	0.16
AMR	Ecuador	0.85	0.06	0.09	0.30	0.90	0.16
EMR	Egypt	0.93	0.05	0.02	0.03	0.96	0.14
AMR	El Salvador	0.75	0.16	0.09	0.29	0.73	0.16
AFRHI	Equatorial Guinea	0.08	0.50	0.42	0.09	0.57	0.14

Region[b]	Country	Proportion of the population					
		Piped water to premises	Other improved water source	Unimproved water source	Filtered or boiled in the household[c]	Improved sanitation	Practice of handwashing after potential contact with excreta[c]
AFR	Eritrea	0.12	0.46	0.42	0.08	0.16	0.14
AFR	Ethiopia	0.10	0.27	0.63	0.02	0.25	0.22
WPR	Fiji	0.74	0.22	0.04	0.52	0.86	0.13
AFR	Gabon	0.52	0.32	0.16	0.14	0.43	0.14
AFR	Gambia	0.36	0.45	0.19	0.01	0.64	0.14
EUR	Georgia	0.78	0.17	0.05	0.05	0.94	0.15
AFR	Ghana	0.18	0.61	0.20	0.02	0.15	0.13
AMR	Grenada	0.83	0.13	0.04	0.29	0.92	0.16
AMR	Guatemala	0.84	0.09	0.07	0.29	0.81	0.16
AFR	Guinea	0.12	0.57	0.31	0.09	0.20	0.14
AFR	Guinea-Bissau	0.06	0.56	0.38	0.03	0.21	0.14
AMR	Guyana	0.68	0.26	0.06	0.13	0.84	0.16
AMR	Haiti	0.12	0.56	0.32	0.03	0.34	0.16
AMR	Honduras	0.87	0.02	0.12	0.27	0.80	0.16
SEAR	India	0.26	0.62	0.12	0.16	0.37	0.15
SEAR	Indonesia	0.23	0.61	0.16	0.90	0.62	0.17
EMR	Iran	0.93	0.02	0.05	0.09	0.94	0.14
EMR	Iraq	0.77	0.10	0.14	0.06	0.89	0.14
AMR	Jamaica	0.71	0.22	0.06	0.40	0.84	0.16
EMR	Jordan	0.91	0.05	0.04	0.26	0.98	0.14
EUR	Kazakhstan	0.61	0.34	0.05	0.63	0.97	0.15
AFR	Kenya	0.21	0.36	0.44	0.26	0.32	0.15
WPR	Kiribati	0.41	0.34	0.25	0.51	0.43	0.13
EUR	Kyrgyzstan	0.59	0.29	0.12	0.33	0.94	0.16
WPR	Lao People’s Democratic Republic	0.23	0.46	0.31	0.68	0.61	0.13
EUR	Latvia	0.87	0.12	0.01	0.15	0.85	0.44
EMR	Lebanon	0.99	0.01	0.00	0.11	0.95	0.14
AFR	Lesotho	0.23	0.52	0.25	0.07	0.34	0.14
AFR	Liberia	0.03	0.65	0.32	0.01	0.17	0.14
EMR	Libya	0.84	0.00	0.16	0.10	0.95	0.14
EUR	Lithuania	0.90	0.05	0.05	0.15	0.90	0.44
AFR	Madagascar	0.07	0.39	0.54	0.40	0.16	0.14
AFR	Malawi	0.07	0.57	0.36	0.10	0.50	0.14
WPR	Malaysia	0.94	0.04	0.02	0.52	0.94	0.13
SEAR	Maldives	0.40	0.58	0.02	0.42	0.93	0.17
AFR	Mali	0.15	0.46	0.39	0.02	0.28	0.14
WPR	Marshall Islands	0.02	0.93	0.05	0.50	0.77	0.13
AFR	Mauritania	0.29	0.19	0.52	0.01	0.26	0.14
AFR	Mauritius	1.00	0.00	0.00	0.14	0.92	0.14
AMR	Mexico	0.90	0.05	0.06	0.31	0.85	0.16
WPR	Micronesia	0.39	0.53	0.08	0.52	0.48	0.13
WPR	Mongolia	0.21	0.59	0.21	0.50	0.73	0.13
EUR	Montenegro	0.95	0.04	0.02	0.39	0.94	0.15
EMR	Morocco	0.62	0.19	0.19	0.02	0.82	0.14

Region[b]	Country	Proportion of the population: Piped water to premises	Other improved water source	Unimproved water source	Filtered or boiled in the household[c]	Improved sanitation	Practice of handwashing after potential contact with excreta[c]
AFR	Mozambique	0.07	0.33	0.60	0.06	0.19	0.14
SEAR	Myanmar	0.08	0.71	0.21	0.37	0.79	0.17
AFR	Namibia	0.48	0.37	0.15	0.11	0.38	0.14
WPR	Nauru	0.79	0.17	0.04	0.50	0.73	0.13
SEAR	Nepal	0.21	0.66	0.13	0.15	0.39	0.17
AMR	Nicaragua	0.67	0.20	0.13	0.28	0.59	0.16
AFR	Niger	0.09	0.38	0.53	0.08	0.12	0.14
AFR	Nigeria	0.05	0.52	0.43	0.05	0.33	0.14
WPR	Niue	0.98	0.00	0.01	0.54	0.88	0.13
EMR	Pakistan	0.36	0.52	0.12	0.06	0.48	0.14
WPR	Palau	0.96	0.00	0.04	0.51	0.89	0.13
AMR	Panama	0.93	0.01	0.06	0.31	0.76	0.16
WPR	Papua New Guinea	0.12	0.40	0.48	0.51	0.24	0.13
AMR	Paraguay	0.75	0.12	0.12	0.29	0.78	0.16
AMR	Peru	0.77	0.09	0.14	0.79	0.73	0.16
WPR	Philippines	0.45	0.47	0.08	0.27	0.77	0.13
EUR	Republic of Moldova	0.53	0.41	0.06	0.28	0.87	0.15
EUR	Romania	0.63	0.30	0.07	0.36	0.87	0.15
EURHI	Russian Federation	0.83	0.14	0.03	0.15	0.76	0.44
AFR	Rwanda	0.04	0.52	0.44	0.39	0.64	0.14
AMR	Saint Lucia	0.84	0.11	0.05	0.28	0.71	0.16
AMR	Saint Vincent and the Grenadines	0.85	0.10	0.04	0.30	0.77	0.16
WPR	Samoa	0.86	0.11	0.02	0.54	0.91	0.13
AFR	Sao Tome and Principe	0.33	0.47	0.19	0.02	0.30	0.14
AFR	Senegal	0.44	0.26	0.29	0.01	0.52	0.19
EUR	Serbia	0.89	0.10	0.01	0.38	0.98	0.15
AFR	Seychelles	0.93	0.03	0.04	0.14	0.90	0.14
AFR	Sierra Leone	0.05	0.47	0.48	0.01	0.14	0.14
WPR	Solomon Islands	0.26	0.57	0.17	0.52	0.30	0.13
EMR	Somalia	0.24	0.09	0.66	0.09	0.30	0.14
AFR	South Africa	0.70	0.19	0.11	0.13	0.78	0.14
EMR	South Sudan	0.15	0.44	0.41	0.08	0.33	0.14
SEAR	Sri Lanka	0.34	0.55	0.11	0.40	0.89	0.17
EMR	Sudan	0.27	0.32	0.41	0.04	0.26	0.14
AMR	Suriname	0.77	0.16	0.07	0.25	0.85	0.16
AFR	Swaziland	0.38	0.29	0.33	0.03	0.60	0.14
EMR	Syria	0.86	0.05	0.09	0.04	0.94	0.14
EUR	Tajikistan	0.48	0.22	0.31	0.74	0.95	0.15
SEAR	Thailand	0.52	0.43	0.05	0.24	0.97	0.25
EUR	The former Yugoslav Republic of Macedonia	0.91	0.07	0.01	0.12	0.93	0.15
SEAR	Timor-Leste	0.24	0.43	0.34	0.79	0.44	0.17
AFR	Togo	0.06	0.50	0.45	0.01	0.14	0.14
WPR	Tonga	0.79	0.20	0.01	0.54	0.83	0.13
EMR	Tunisia	0.81	0.13	0.07	0.08	0.90	0.14

Region[b]	Country	Proportion of the population: Piped water to premises	Other improved water source	Unimproved water source	Filtered or boiled in the household[c]	Improved sanitation	Practice of handwashing after potential contact with excreta[c]
EUR	Turkey	0.97	0.00	0.03	0.40	0.91	0.15
EUR	Turkmenistan	0.56	0.27	0.17	0.35	0.95	0.15
WPR	Tuvalu	0.97	0.00	0.03	0.53	0.83	0.13
AFR	Uganda	0.05	0.42	0.53	0.25	0.38	0.15
EUR	Ukraine	0.73	0.24	0.03	0.47	0.95	0.15
AFR	United Republic of Tanzania	0.09	0.37	0.54	0.28	0.14	0.05
AMRHI	Uruguay	0.99	0.01	0.00	0.17	0.99	0.49
EUR	Uzbekistan	0.55	0.36	0.10	0.91	0.95	0.15
WPR	Vanuatu	0.29	0.60	0.11	0.11	0.61	0.13
AMR	Venezuela	0.90	0.05	0.05	0.32	0.86	0.16
WPR	Viet Nam	0.26	0.66	0.08	0.89	0.75	0.13
EMR	Yemen	0.45	0.21	0.34	0.05	0.61	0.14
AFR	Zambia	0.14	0.45	0.41	0.14	0.46	0.14
AFR	Zimbabwe	0.34	0.41	0.25	0.14	0.49	0.14
Total LMIC		0.56	0.31	0.13	0.28	0.65	0.19

AFR: Africa; AMR: America; EMR: Eastern Mediterranean; EUR: Europe; SEAR: South East Asia; WPR: Western Pacific.

[a] Equatorial Guinea has been included in this analysis despite being classified as high-income country in 2012.

[b] World Bank Income classification, July 2012 (The World Bank 2012).

[c] Data based on limited country survey data, and modelled data provided for countries without survey information. These data should therefore be interpreted with caution, and provide indicative values only.

Annex Table 3. Diarrhoea burden attributable to inadequate water in LMICs for the year 2012, by region

Region	PAF	(95% CI)	Deaths	(95% CI)	DALYs	(95% CI)
Sub-Saharan Africa	0.38	(0.19–0.50)	229 316	(106 664–300 790)	17 587	(8 152–23 065)
Americas, LMI	0.26	(0.14–0.33)	6 441	(624–9 748)	522	(39–801)
Eastern Mediterranean, LMI	0.36	(0.19–0.46)	50 409	(22 498–66 604)	4 046	(1 784–5 351)
Europe, LMI	0.16	(0.10–0.26)	1 676	(196–2 606)	174	(19–271)
South-East Asia	0.32	(0.11–0.44)	207 773	(59 708–293 068)	10 748	(3 097–15 160)
Western Pacific, LMI	0.20	(0.09–0.27)	6 448	(2 005–9 469)	716	(198–1 081)
Total LMI	0.34	(0.16–0.45)	502 061	(217 119–671 945)	33 793	(14 930–44 871)

PAF: population-attributable fraction; LMI: low- and middle-income.
CI: confidence interval.
DALY: disability-adjusted life year.

Annex Table 4. Diarrhoea burden attributable to inadequate sanitation in LMICs for the year 2012, by region

Region	PAF	(95% CI)	Deaths	(95% CI)	DALYs	(95% CI)
Sub-Saharan Africa	0.21	(0.07–0.31)	126 294	(42 881–186 850)	9 694	(3 291–14 333)
Americas, LMI	0.09	(0.03–0.15)	2 370	(774–3 724)	188	(61–295)
Eastern Mediterranean, LMI	0.17	(0.06–0.26)	24 441	(8 339–36 809)	1 914	(651–2 887)
Europe, LMI	0.03	(0.01–0.06)	352	(107–597)	36	(11–61)
South-East Asia	0.19	(0.06–0.28)	123 279	(42 116–185 426)	6 376	(2 177–9 595)
Western Pacific, LMI	0.11	(0.04–0.17)	3 709	(1 171–5 954)	444	(136–737)
Total LMI	0.19	(0.07–0.29)	280 443	(95 699–417 482)	18 650	(6 380–27 769)

PAF: population-attributable fraction; LMI: low- and middle-income.
CI: confidence interval.
DALY: disability-adjusted life year.

Annex Table 5. Diarrhoea burden attributable to inadequate hand hygiene for the year 2012, by region

Region	PAF	(95% CI)	Deaths	(95% CI)	DALYs	(95% CI)
Sub-Saharan Africa	0.20	(0–0.61)	122 955	(0–365 911)	9 411	(0–28 006)
Americas, LMI	0.20	(0–0.60)	5 026	(0–15 013)	416	(0–1 243)
Eastern Mediterranean, LMI	0.21	(0–0.61)	28 699	(0–85 369)	2 314	(0–6 884)
Europe, LMI	0.19	(0–0.59)	1 972	(0–5 975)	202	(0–611)
South-East Asia	0.20	(0–0.60)	131 519	(0–392 018)	6 857	(0–20 444)
Western Pacific, LMI	0.21	(0–0.61)	6 690	(0–19 891)	758	(0–2 253)
Total	0.20	(0–0.60)	296 860	(0–885 355)	19 958	(0–59 491)

PAF: population-attributable fraction; LMI: low- and middle-income.
CI: confidence interval.
DALY: disability-adjusted life year.

Annex Table 6. Diarrhoea deaths attributable to the cluster of inadequate WASH and water and sanitation in LMICs for the year 2012, by region

	Inadequate water, sanitation and hand hygiene				Inadequate water and sanitation			
Region	PAF	(95% CI)	Deaths	(95% CI)	PAF	(95% CI)	Deaths	(95% CI)
Sub-Saharan Africa	0.61	(0.55–0.66)	367 605	(326 795–402 438)	0.51	(0.47–0.55)	307 493	(276 989–335 899)
Americas, LMI	0.46	(0.36–0.50)	11 519	(9 310–13 616)	0.32	(0.28–0.34)	8 125	(7 101–9 158)
Eastern Mediterranean, LMI	0.58	(0.47–0.66)	81 064	(65 359–94 707)	0.47	(0.40–0.53)	65 700	(55 266–75 876)
Europe, LMI	0.35	(0.28–0.46)	3 564	(2 462–4 678)	0.19	(0.19–0.27)	1 970	(1 654–2 280)
South-East Asia	0.56	(0.36–0.70)	363 904	(225 359–477 720)	0.45	(0.31–0.57)	291 763	(193 198–383 423)
Western Pacific, LMI	0.44	(0.31–0.54)	14 160	(10 035–18 009)	0.29	(0.23–0.33)	9 429	(7 519–11 242)
Total LMI	0.58	(0.48–0.65)	841 818	(699 059–963 626)	0.47	(0.40–0.53)	684 479	(580 456–780 463)

PAF: population-attributable fraction; LMI: low- and middle-income.
CI: confidence interval.

Annex Table 7. WHO regional country listings

Region	Low- and middle-income countries included in study
Africa (AFR)	Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Equatorial Guinea*, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, Swaziland, Togo, Uganda, United Republic of Tanzania, Zambia, Zimbabwe
Americas (AMR)	Antigua and Barbuda, Argentina, Belize, Bolivia (Plurinational State of), Brazil, Chile*, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Uruguay*, Venezuela
Eastern Mediterranean (EMR)	Afghanistan, Djibouti, Egypt, Iran (Islamic Republic of), Iraq, Jordan, Lebanon, Libya, Morocco, Pakistan, Somalia, South Sudan, Sudan, Syria, Tunisia, Yemen
Europe (EUR)	Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Georgia, Kazakhstan, Kyrgyzstan, Latvia*, Lithuania*, Montenegro, Republic of Moldova, Romania, Russian Federation*, Serbia, Tajikistan, The former Yugoslav Republic of Macedonia, Turkey, Turkmenistan, Ukraine, Uzbekistan
South-East Asia (SEAR)	Bangladesh, Bhutan, Democratic People's Republic of Korea, India, Indonesia, Maldives, Myanmar, Nepal, Sri Lanka, Thailand, Timor-Leste
Western Pacific (WPR)	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, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, Viet Nam

* Classified by the World Bank as a high-income economy in 2012.

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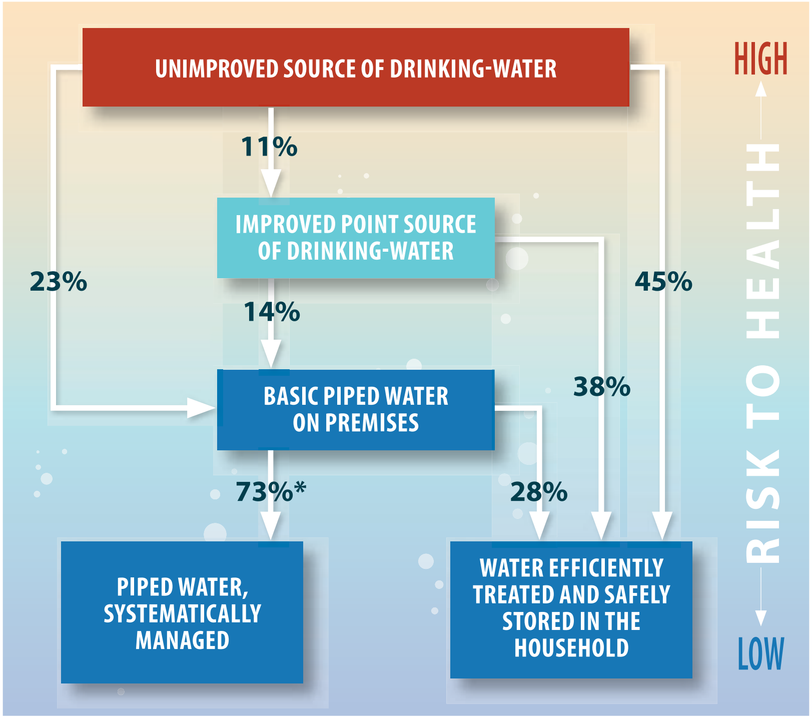
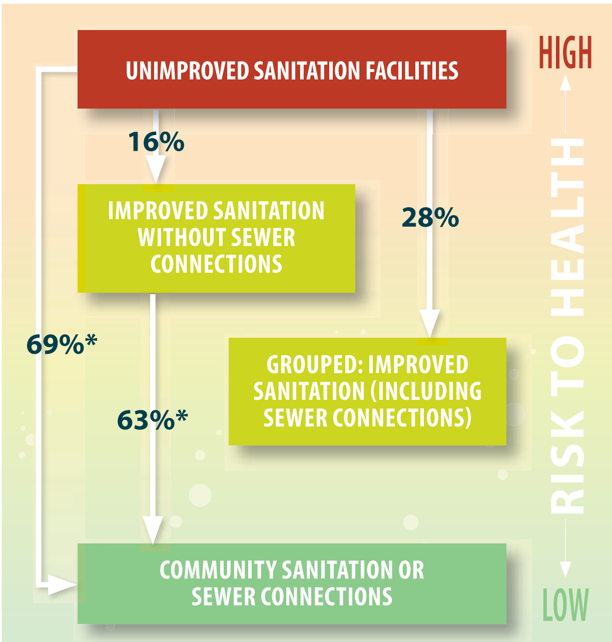
Drinking-water supply transitions and associated reductions in diarrhoeal disease risk



** These estimates are based on limited evidence and should therefore be considered as preliminary and have not been used in the estimation of disease burden.*

Sanitation transitions and associated reductions in diarrhoeal disease



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http://www.who.int/water_sanitation_health/gbd_poor_water/en/

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