SAFER WATER, BETTER HEALTH

World Health Organization

Safer water, better health. 2019 update

ISBN 978-92-4-151689-1

Suggested citation. Safer water, better health. 2019 update. Geneva: World Health Organization; 2019. Licence: CC BY-NC-SA 3.0 IGO.

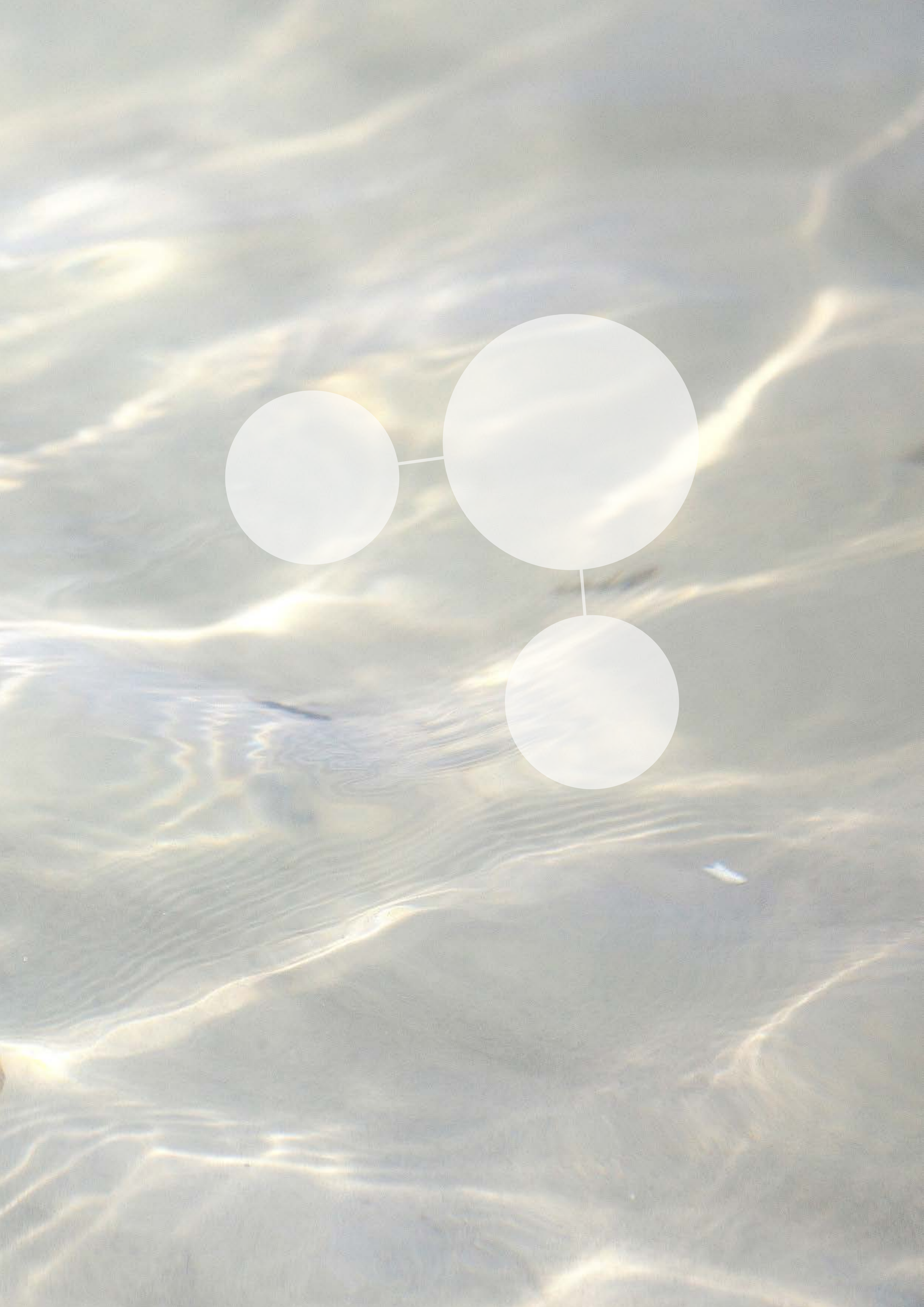
Photographs: Front cover: Mayer/Shutterstock, Figel/Shutterstock, wavebreakmedia/Shutterstock; iv: Kijja P44/Shutterstock; vi-vii: Mayer/Shutterstock; viii-ix: Blinkov/Shutterstock; x: gnomeandi/Shutterstock; 2-3: Rotenberg/Shutterstock; 4: Iurchenko/Shutterstock; 7: PiercarloAbate/Shutterstock; 9: Chichkareva/Shutterstock; 11: 249 Anurak/Shutterstock; 13: Warraich/Shutterstock; 15: Figel/Shutterstock; 17: I MAKE PHOTO 17/Shutterstock; 19: passion3/Shutterstock; 21: Lapaev/Shutterstock; 23: Birukov/Shutterstock; 25: Grigvovan/Shutterstock; 27: Bastidas/Shutterstock; 29: wavebreakmedia/Shutterstock; 31: Rustim Moosa/Shutterstock; 32: Nicolielo/Shutterstock; 35: Stanislav71/Shutterstock; 36: Chilvers/Shutterstock; 40: Iurchenko/Shutterstock; 42: Birukov/Shutterstock; 52: PaeJar/Shutterstock; 68: Kijja P44/Shutterstock; Back cover: Figel/Shutterstock.

Cataloguing-in-Publication (CIP) data. CIP data are available at http://apps.who.int/iris.

Printed in Switzerland

SAFER WATER, BETTER HEALTH

World Health Organization



Contents

Boy welcoming the rain. Millions of people worldwide face severe water shortages.

Acknowledgements

This report was coordinated by Richard Johnston and Annette Prüss-Ustün at WHO. Jennyfer Wolf, a WHO consultant, reviewed the evidence and wrote the first draft. Annette Prüss-Ustün estimated the burden of disease. The evidence and estimates for this update were reviewed in a report, "Preventing disease through healthy environments" *(1)*.

The authors thank the many experts who contributed to that document. Additional contributions were provided by Robert Bos and by Sophie Boisson and Jennifer de France at WHO. Alessandro Mannocchi's layout work is also greatly appreciated. This document is the second edition of one published in 2008 *(2)*.

Financial support was obtained from the United Kingdom Department for International Development (grant number: 204700-101).

Key findings

A large proportion of the overall disease burden, 3.3% of global deaths and 4.6% of global disability-adjusted life years (DALYs), was attributed to quantifiable effects of inadequate water, sanitation and hygiene (WASH) in 2016. This represents nearly 2 million preventable deaths and 123 million preventable DALYs annually. Children under 5 years of age are disproportionally affected by inadequate WASH: 13% of all deaths and 12% of all DALYs in this age group are related to inadequate WASH.

Sub-Saharan Africa remains the region with the largest disease burden from inadequate WASH: 53% of all WASH-attributable deaths and 60% of all WASH-attributable DALYs occur in this region, and nearly one fifth of all deaths of children under 5 years could be prevented with adequate WASH. This report presents estimates of the WASH-attributable burden of 12 major diseases, adverse health outcomes and injuries and evidence for links between WASH and another 14 conditions that have not yet been quantified because of data limitations. Not all the health effects of inadequate WASH on the diseases assessed could be quantified, such as the wider community risks of unsafe disposal or use of sewage.

The report also presents selected WASH interventions that have been shown to improve health and complements them with available cost–effectiveness analyses.

Marine pollution in Bali, Indonesia. Most marine debris is composed of plastics.

Because of a lack of drinking-water in homes, some women have to carry water over long distances, India.

Introduction

Ensuring the access of all people to sufficient, safe water and adequate sanitation and encouraging personal, domestic and community hygiene will improve the health and quality of life of millions of individuals. Adequate WASH is essential not only to reduce the large burden of disease from, for example diarrhoea, respiratory infections and malnutrition, but also for the control and elimination of many neglected tropical diseases, which affect over 1 billion people in 149 tropical and subtropical countries *(3, 4)*. Furthermore, cholera is still endemic in at least 47 countries, with an estimated 2.9 million cases and 95 000 deaths per year worldwide *(4–6)*.

Antimicrobial resistance (AMR) can have devastating consequences on health and the cost of treatment *(7)*. In communities, access to adequate WASH contributes to reducing the risk of infectious diseases and overuse of antibiotics. Health care facilities and pharmaceutical industries that do not adequately manage their waste also contribute to AMR, and lack of adequate WASH services in health care facilities increases the risks of patients, caretakers and health care workers for infection *(8)*.

Better management of water resources to reduce the transmission of vector-borne diseases, such as viral diseases carried by mosquitoes, and to make water bodies safe for recreational and other users can save many lives and also has direct and indirect economic benefits, from the level of households to national economies. The global importance of adequate WASH for development, poverty reduction and health is reflected in the Sustainable Development Goals (SDGs) *(9)*. SDG 6, "Ensure access to water and sanitation for all" is entirely devoted to improved WASH, and links to many other SDGs can be identified (Box 1).

Box 1. Sustainable Development Goals

Goal 6: Ensure access to water and sanitation for all

Targets:

6.1 By 2030, achieve universal and equitable access to safe and affordable drinking water for all.

6.2 By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations.

6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.

6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.

6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.

6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.

6.A By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies.

6.B Support and strengthen the participation of local communities in improving water and sanitation management.

Additionally, SDG 1, "End poverty in all its forms everywhere", includes a target for universal access to basic services; SDG 3, "Ensure healthy lives and promote well-being for all at all ages", includes a target for reducing the WASH-attributable disease burden; and SDG 4, "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all", includes a target on access to basic WASH in schools *(10, 11)*. Improving WASH also contributes to other SDGs, such as SDG 2, "End hunger, achieve food security and improved nutrition and promote sustainable agriculture"; SDG 5, "Achieve gender equality and empower all women and girls"; and SDG 11, "Make cities and human settlements inclusive, safe, resilient and sustainable" *(10)*.

Information on the disease burden attributable to inadequate WASH and approaches for prevention is a starting point for effective interventions. WHO recently estimated the disease burden (numbers of deaths and DALYs) from diarrhoeal disease, respiratory infections, malnutrition, schistosomiasis, malaria, soil-transmitted helminthiasis and trachoma attributable to inadequate WASH *(12)*. Previously, WHO made a comprehensive analysis of the environmental burden of disease and proposed effective interventions *(1)*. This updated version of "Safer water, better health" is based on those assessments.

WHO defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" *(13)*. This document summarizes recent evidence on the links between inadequate WASH, with a focus on water, and disease, adverse health outcomes and injuries. Many diseases and emerging issues such as AMR, however, have not been sufficiently quantified, and the disease burden in non-household settings could not be included (Table 1, and section on limitations). The evidence with regard to WASH and health is presented by disease, with effective interventions and cost–effectiveness analyses. The global health impacts provided are based mainly on rigorous assessments (comparative risk assessments, CRAs), complemented by analyses of more limited epidemiological data, information on disease transmission pathways and expert opinion.

Desalination plant, which turns salt water into drinkable water, United Arab Emirates.

Methods

For the purpose of this assessment, WASH conceptually encompasses drinking-water; water for personal hygiene; water systems; excreta and wastewater management; personal, domestic and agricultural hygiene; and water resources and related vector management. This assessment concentrates on the part of risk that is modifiable without impairing other ecosystem functions.

The fraction of disease attributable to WASH (the "population attributable fraction") that could be prevented by environmental improvement is the proportional reduction in deaths or disease that would occur if exposure to a risk were removed or reduced to an alternative (or counterfactual) exposure distribution. To estimate the comprehensive impacts of water-related risks on health worldwide, population attributable fractions were estimated or available fractions compiled for each disease to obtain the numbers of preventable deaths and the disease burden in DALYs, a combined measure of the years of life lost to premature mortality and to disability. Not all impacts on health may have been assessed. For each of the diseases and injuries covered in this report, the literature was systematically searched to identify the best evidence.

Four approaches were used to estimate the fractions of disease attributable to WASH-related risks, according to the availability of estimates, evidence on exposures and exposure–risk relations and information on disease transmission pathways. In order of priority, the following approaches were used:

Comparative risk assessment (CRA) generally provides estimates based on the strongest evidence and the most comprehensive data.

Calculations based on limited epidemiological data were performed if data on exposure or the exposure–response relation were not sufficient for CRA.

Certain diseases were attributed entirely to inadequate WASH according to **knowledge of their transmission pathways**.

Expert surveys were used when CRAs were not available and information on exposure and/or exposure–risk relations from limited epidemiological data were insufficient.

More detailed information on these approaches and further methods used are given in Annex 1.

Results

The population attributable fractions of inadequate WASH could be quantified for 12 major diseases, adverse health outcomes or injuries, and links to inadequate WASH are described for 14 additional diseases or adverse health outcomes (Table 1).

Table 1. Methods used for estimating the population attributable fraction of the disease burden for main disease groups

Disease or disease group	Comparative risk assessment	Calculation based on limited epidemiological data	Disease transmission pathway	Expert survey	No quantification
Diarrhoeal diseases	×[a]				
Respiratory infections	×[a]				
Soil-transmitted helminthiasis			×[a]		
Malaria		×[a]			
Trachoma			×[a]		
Schistosomiasis		×[a]			
Lymphatic filariasis				×	
Onchocerciasis				×	
Dengue				×	
Japanese encephalitis[b]				×	
Protein-energy malnutrition		×[a]			
Drowning	(×)			×	
Arsenicosis					×
Fluorosis					×
Legionellosis					×
Leptospirosis					×
Hepatitis A and hepatitis E					×
Methaemoglobinaemia					×
Cyanobacterial toxins					×
Lead poisoning					×
Scabies					×
Spinal injury					×
Poliomyelitis					×
Adverse neonatal conditions and maternal outcomes					×

×, estimate and method used; (×) estimate available, but expert survey for main risk factor–disease pairing not assessed

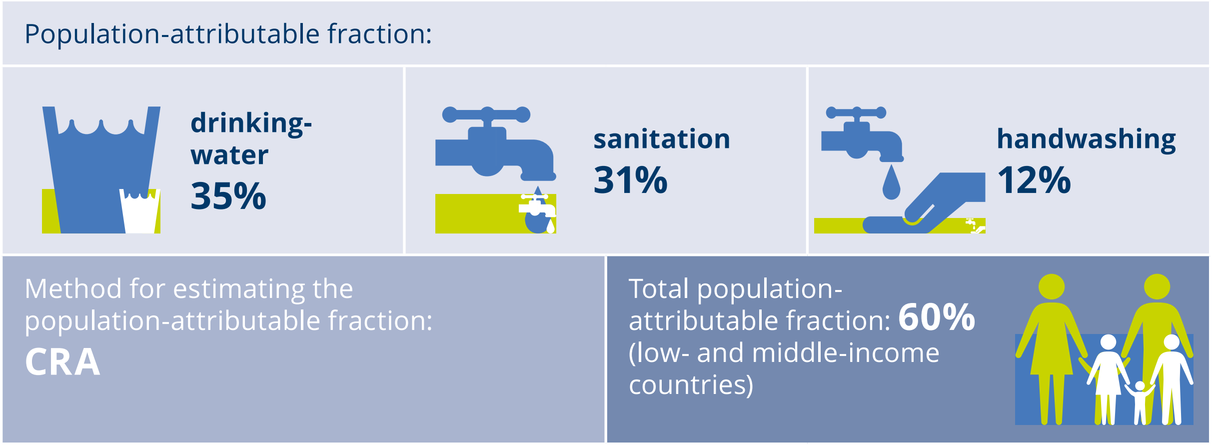
[a] Reference *12*

[b] Only the population attributable fraction could be estimated, not the proportion of attributable disease burden, because total disease estimates were lacking.

Other diseases and adverse health outcomes that are linked to inadequate WASH are not addressed in detail. These include amoebic meningoencephalitis and meningitis, reactive arthritis, inflammatory bowel disease, irritable bowel syndrome and Guillain-Barré syndrome due to infection with *Campylobacter jejuni (14, 15)*.

In the following sections, each of the diseases listed in Table 1 is described in detail with its link to inadequate WASH, followed by selected interventions and economic evaluations when available.

Diarrhoeal diseases



Diarrhoea can be efficiently prevented by ensuring adequate drinking-water, sanitation and hygiene *(16)***.**

Diarrhoeal diseases are among the main contributors to global child mortality, causing 8% of all deaths in children under 5 years *(17)*. Diarrhoeal diseases, including cholera, can be endemic, with constant transmission, or epidemic, such as during an outbreak *(18)*.

Diarrhoeal disease is transmitted mainly by the faecal–oral route and is most often caused by the ingestion of pathogens, especially in contaminated drinking-water, in contaminated food or from unclean hands. Transmission depends on the types of pathogen in the environment, local infrastructure (e.g. whether the population has access to appropriate WASH services) and behaviour. Better access to water and sanitation facilities, water quality and personal hygiene effectively reduce diarrhoea morbidity *(19)*. Although in 2015, 71% of the world's population used a safely managed drinking-water service,[1] only 39% were using a safely managed sanitation service, and 12% still practised open defaecation *(11)*; about one in four people did not have access to a handwashing facility with soap and water on the premises, and only 26% of potential faecal contacts (e.g. after toilet use) were followed by handwashing with soap *(21)*.

WHO recently estimated that 60% (54–65%) of all deaths due to diarrhoea in low- and middle-income countries are attributable to inadequate drinking-water (35%), sanitation (31%) and hygiene (12%), resulting in 829 000 deaths annually *(12)*. This estimate accounted only for the benefits of well-documented interventions, although additional benefits may be achieved, such as from continuous rather than intermittent availability of drinking-water. An additional burden of diarrhoea is due to aspects of food safety related to WASH (i.e. food contamination by unsafe water or lack of domestic hygiene). For high-income countries, only the fraction of diarrhoea attributable to hygiene has been estimated, which is 9% (5–12%) *(12)*.

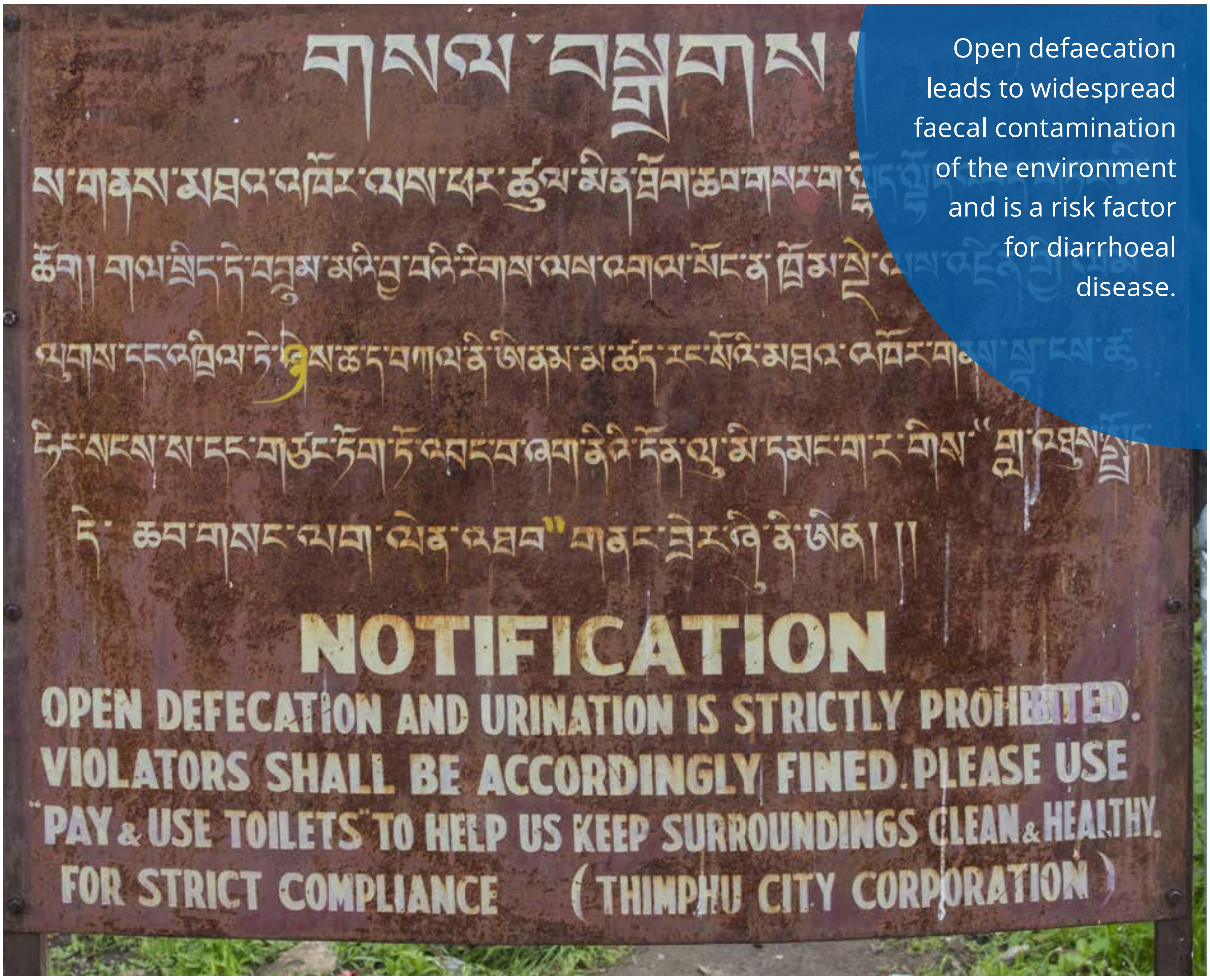
1 Safely managed drinking-water services include improved drinking-water facilities on premises, which provide continuous, uncontaminated drinking-water. Safely managed sanitation services include improved services that are not shared with other households and the excreta produced are either treated and disposed in situ, stored temporarily and then emptied and transported to treatment off-site, or transported through a sewer with wastewater and then treated off-site *(20)*.

Selected interventions:

- Interventions to improve access to or use of adequate WASH services effectively reduced the burden of diarrhoeal disease *(19)*. Similar results were obtained for people living with HIV/AIDS *(22)*.
- The prevalence of diarrhoea could be reduced by 61% by filtering and safely storing water from an unimproved source in the household, and a reduction of 75% could be obtained by using piped high-quality drinking-water as compared with drinking-water from an unimproved source *(19)*.

Economic evaluations:

- Interventions that improved the water supply, water quality and access to sanitation were cost–effective in most regions and were all cost–beneficial in low-income regions. An investment of US$ 1 in such programmes led to a return of US$ 5–6 *(23)*.
- Hygiene was promoted in six low-income countries at a cost of US$ 1.05–1.74 per person per year. The interventions were highly effective in reducing open defaecation and improving personal hygiene *(24)*.
- In China and India, behaviour change programmes to increase handwashing with soap were estimated to yield large economic gains due to decreases in diarrhoeal and respiratory infections *(25)*.



Open defaecation leads to widespread faecal contamination of the environment and is a risk factor for diarrhoeal disease.

Respiratory infections

Total population-attributable fraction:
hygiene and handwashing 13%

Method for estimating the population-attributable fraction:
CRA

Handwashing prevents transmission of respiratory infections, which cause nearly 900 000 deaths annually in children under 5 years *(17)*.

Lower respiratory infections are among the main causes of death among children under 5 years *(26)*. Respiratory infections are transmitted during close contact among people via droplets and hand-to-face contact *(27)*. Hand-washing with soap could therefore prevent transmission of respiratory infections *(28, 29)*. It is estimated that 13% of the overall burden of acute respiratory infections is due to inadequate hygiene, resulting in about 370 000 deaths in 2016 *(12)*.

Selected interventions:

- In England, a randomized, controlled, Internet-delivered handwashing intervention, comprising promotion, behaviour monitoring, tailored feedback and information about handwashing and health, significantly reduced the prevalence of respiratory infections in the general population *(30)*.
- A systematic review of the impact of handwashing interventions on respiratory infections indicated an overall reduction in risk of 16% in high-income settings *(28)*.
- In a recent systematic review of studies in low- and middle-income countries, three studies found that handwashing interventions reduced the prevalence of respiratory infections *(29)*.
- A Cochrane review concluded that transmission of viral respiratory disease can be reduced by frequent handwashing *(31)*.

Handwashing is effective in preventing respiratory infections.

Soil-transmitted helminthiasis

Total population-attributable fraction:
100% sanitation

Method for estimating the population-attributable fraction:
transmission pathway

Approximately 1.5 billion people worldwide are infected with soil-transmitted helminths *(32)***; this could be completely prevented with adequate WASH.**

Soil-transmitted helminthiases, such as ascariasis, trichuriasis and ancylostomiasis or necatoriasis (roundworm, whipworm and hookworm disease, respectively), are transmitted through soil contaminated with faeces. Intense infections affect the physical growth, cognitive development and nutritional status of children. Preventive administration of drugs has been used for control; however, reinfection occurs rapidly after treatment *(33)* if environmental conditions remain unchanged.

Transmission does not occur from person-to-person or from fresh faeces but only from soil contaminated with human excreta containing infectious eggs or larvae. Open defaecation, a daily practice of nearly 900 million people globally *(11)*, mainly in South Asia and sub-Saharan Africa, is the main cause. Use of wastewater and excreta in agriculture without adequate risk management may also result in disease transmission *(34)*.

Current recommendations for reducing morbidity due to intestinal nematode infections are to combine drug administration with improved sanitation and hygiene, with appropriate health education *(35–37)*.

The global mean fraction of the burden of soil-transmitted helminthiasis attributable to inadequate WASH is estimated from information on the transmission pathway to be 100% *(12)*.

Selected interventions:

- General sanitation reduced roundworm infection by 27%, whipworm infection by 20%, hookworm infection by 35% and infection with *S. stercoralis* by 52% *(38)*. An earlier review found that use of treated water reduced the likelihood of soil-transmitted helminthiasis by 54%, and soap use reduced it by 47%. Handwashing before eating and after defaecation also reduced infections *(35)*.

- A comprehensive programme to control schistosomiasis in Chinese villages, involving environmental management, provision of an improved domestic water supply and sanitation facilities and health education, reduced the rates of ascariasis from 27.6% to 3.8% and those of trichuriasis from 62.0% to 7.5% *(39)*.

Especially in areas where sanitation is poor, hookworm larvae can penetrate the skin of people walking barefoot.

Malaria

Population-attributable fraction:
80% water resource management

Method for estimating the population-attributable fraction:
calculation based on limited epidemiological data

Malaria, which takes the life of a child every 2 min *(40)*, can be prevented by modifying environments.

Malaria is the most important vector-borne disease globally. In 2016, there were 217 million malaria cases and 451 000 deaths, 90% of which were in sub-Saharan Africa *(40)*.

The larval stages of the anopheline mosquitoes that transmit malaria prefer clean, unpolluted, stagnant or slowly moving fresh water *(41)*. The clinical options for prevention are limited for local populations (rather than incidental visitors to malarial areas), and the agents are increasingly resistant to curative drugs. Vector control is therefore an important component of sustainable malaria reduction strategies *(42)*.

The measures for preventing the vector include environmental management and modification of water bodies in an integrated vector management strategy. Environmental management is non-toxic, relatively easy to do, cost–effective and sustainable *(43–45)*. Measures should be adapted on the basis of local vector ecology and biology. Transmission of malaria can be interrupted or reduced by limiting vector habitats, mainly by eliminating stagnant water, modifying the contours of reservoirs, canals or lake shores and improving the management of irrigation schemes. In urban environments, vector control measures include management of drains, gutters and wastewater and maintenance of water supply and sanitation areas.

The choice of irrigation method, e.g. drip irrigation or intermittent or alternate wet and dry irrigation, can also reduce the vector population. It has been estimated that 80% (67–87%) of the global malaria burden could be prevented by environmental management, including water resource management *(1)*.

Selected interventions:

- A meta-analysis of studies of environmental management to reduce malaria, with water resource management as the main component, showed that environmental manipulation and modification of human habitation reduced the risk by 88.0% (81.7–92.1%) and 79.5% (67.4–87.2%), respectively *(46)*. The results of a Cochrane review of studies on mosquito larval source management are consistent, although few of the studies were rigorously conducted *(47)*.

Economic evaluations:

- A review of studies on environmental management interventions for malaria control in Africa south of the Sahara indicated that malaria-related mortality, morbidity and incidence were reduced by 70–95% within 3–5 years, and the costs per death and malaria attack averted were US$ 858 and US$ 22.20, respectively. Environmental management would become more cost–effective in the longer term, with much lower maintenance costs, for an estimated US$ 22–92 per DALY averted *(45)*.

Transmission of malaria can be interrupted or reduced by eliminating stagnant water bodies.

Trachoma

Population-attributable fraction:

100% WASH

Method for estimating the population-attributable fraction:

transmission pathway

Appropriate hygiene and fly control prevent trachoma, which irreversibly impairs the vision of 1.9 million people worldwide *(48)*.

Trachoma is a chronic contagious eye disease caused by *Chlamydia trachomatis*; it is the main infectious cause of blindness globally. Trachoma is a significant public health problem in rural communities in many low-income countries *(49)*. Worldwide, 190 million people in 41 countries live in areas endemic for trachoma *(48)*.

Transmission is closely related to hygiene, including mechanical transmission by eye-seeking flies, probably person-to-person contact and via fomites, particularly clothing used to wipe children's faces *(50)*. Risk factors for trachoma include poor access to domestic water supplies, limited access to and use of latrines or toilets, crowding and a large number of flies *(49)*. Trachoma-transmitting flies can be controlled by removing human faeces (the medium on which the females oviposit) from the environment. Transmission is also controlled by improving access to and use of sanitation, especially ending open defaecation, and hygiene, especially facial cleanliness. Although the evidence is of limited quality, it supports the effectiveness of several environmental control measures *(38, 51–56)*.

Globally, the mean fraction of trachoma disease burden attributable to inadequate WASH is estimated to be 100% on the basis of information on the transmission pathways *(1)*.

Selected interventions:

- A systematic review and meta-analysis showed that sanitation was associated with 30–38% lower odds for active trachoma *(38)*.
- A randomized controlled trial in the Gambia showed that latrine provision significantly reduced the populations of the main fly vector (*Musca sorbens*) for trachoma transmission by 30% and subsequently reduced trachoma prevalence *(57)*.
- In a randomized trial in communities in the United Republic of Tanzania, intensive face-washing promotion reduced the odds of severe trachoma by 38% *(53)*.
- In a randomized controlled trial in the Gambia, fly control decreased the number of flies by around 75%. After 3 months of fly control, the number of trachoma cases in intervention villages was reduced by 75% *(54)*.

Hygiene, especially face hygiene, reduces the spread of trachoma.

Schistosomiasis

Population-attributable fraction:
43% WASH

Method for estimating the population-attributable fraction:
calculation based on limited epidemiological data

Schistosomiasis transmission involves a water cycle and can be prevented by better management of excreta *(58)*.

Schistosomiasis is caused by infection with parasitic worms that live in the veins that drain the intestines or the urinary tract. Damage to intestinal or urogenital tissues results from the large quantities of eggs produced by flukes, which work their way through these tissues, and from the associated immune reaction of the host. Left untreated, the disease can lead to long-term, irreversible health effects, including liver and kidney damage, infertility or bladder cancer *(50, 58)*.

Schistosoma flukes have a complex life cycle, which includes obligatory passage through species of aquatic or amphibious snails. Transmission occurs through direct human contact with water containing free-swimming larval forms that have been shed by the intermediate host snails and penetrate the human skin. Water contaminated by the excreta (faeces or urine) of infected humans may contain schistosome eggs *(58)*.

Current understanding of schistosomiasis transmission indicates that the disease burden is 100% attributable to risk factors associated with the environment, mainly lack of adequate sanitation, and ecological conditions that favour propagation of intermediate host snails *(50)*. Contact with contaminated water, such as during swimming, washing laundry, fishing or farming in irrigated fields, and poor hygiene (urinating or defaecating in or close to water bodies) can increase the risks. Systematic reviews indicate that adequate water supplies are associated with 47% lower odds of infection with schistosomes and adequate sanitation with 39% lower odds of infection with *S. mansoni* and 31% lower odds of infection with *S. haematobium (38, 59)*.

The global mean fraction of the disease burden due to schistosomiasis attributable to inadequate WASH is estimated to be 43% (40–46%) *(1)*.

Selected interventions:

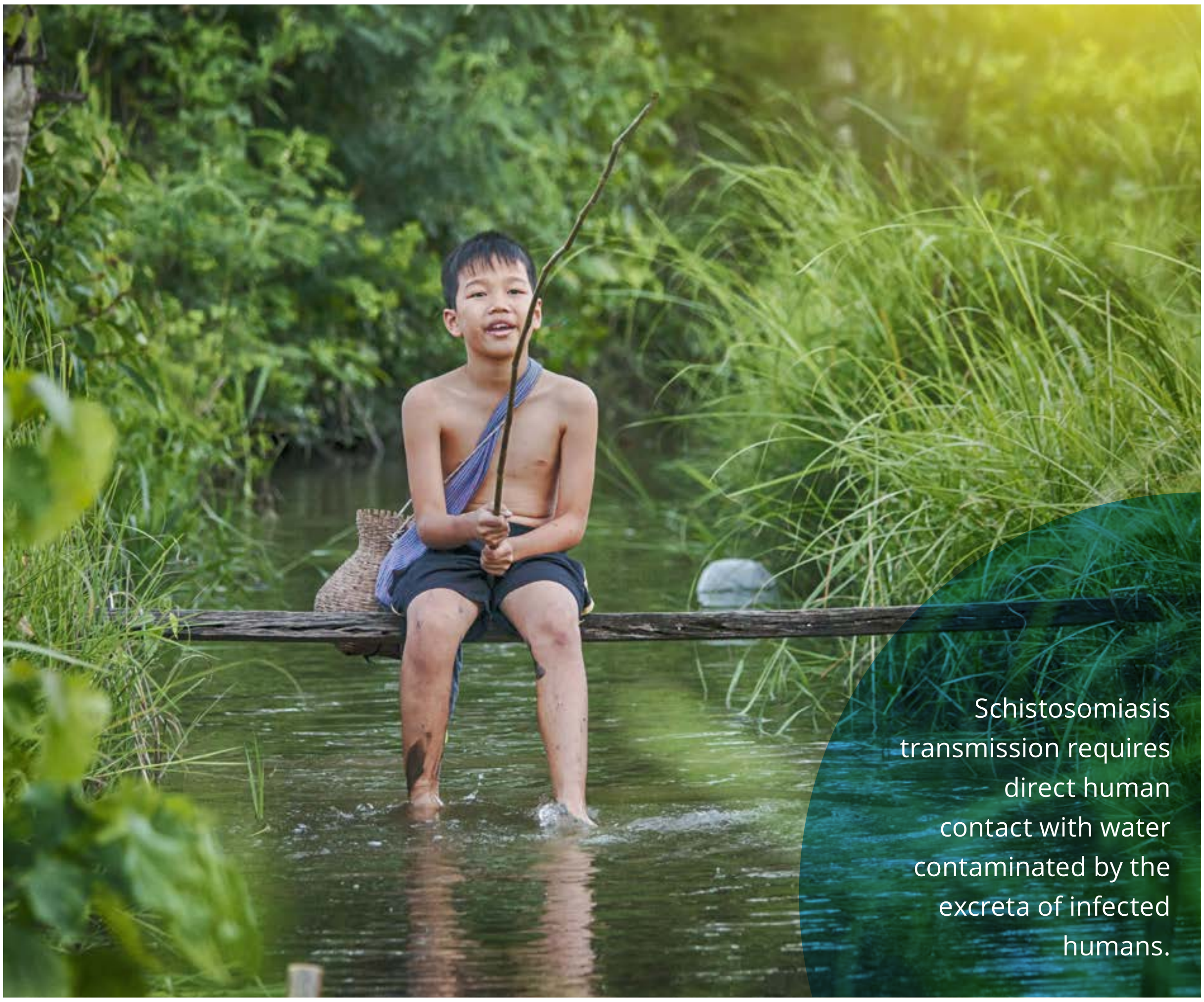
- Environmental management, with water management as a crucial component, integrated into agricultural activities and water resources development has been shown to be effective in snail control *(60, 61)*. This strategy achieved interruption of transmission in most counties in China and eradication of the disease in Japan *(62, 63)*.
- In China, a comprehensive *S. japonicum* control programme comprised environmental modification for the management of water resources, health education to reduce human contact with infected water, installation of a water supply and sanitation facilities and preventive chemotherapy. The prevalence in eight villages decreased over 3 years from 9% to 3%, infections in livestock were completely eliminated, and the area infested with infected snails was reduced by over 90% *(64)*.

- Another comprehensive schistosomiasis control programme in Chinese villages involved removing cattle from snail-infested grasslands and providing farmers with mechanized equipment, a domestic water supply, sanitation facilities and health education. The initiative reduced *Schistosoma* infection rates in humans from 11.3% and 4.0% to 0.7% and 0.9% in the two intervention villages, respectively, and the percentage of sites with infected snails dropped from 2.2% and 0.3% to 0.1% and 0%, respectively *(65)*.

- Rehabilitation of the Mushandike irrigation scheme in Zimbabwe in the 1980s comprised self-draining hydraulic structures and carefully sloped irrigation and drainage canals to prevent snail infestation, elimination of high-risk infrastructure such as duckbill weirs (a hydrological structure in a water course), management of night storage ponds and distribution of latrines in a grid pattern in fields to avoid contamination of water bodies. This led to low schistosomiasis prevalence rates after 10 years, while control areas without environmental measures maintained consistently higher rates *(66)*.

Economic evaluations:

- In China, comprehensive schistosomiasis control programmes with environmental management for snail control were shown to be cost–effective *(67–69)*. Environmental modification to eliminate snail habitats in the Dez irrigation scheme in the Islamic Republic of Iran was also cost–effective *(70, 71)*.



Schistosomiasis transmission requires direct human contact with water contaminated by the excreta of infected humans.

Lymphatic filariasis

Population-attributable fraction:

67% WASH

Method for estimating the population-attributable fraction:

expert survey

Management of drains and other water bodies can reduce proliferation of the mosquito vectors that transmit lymphatic filariasis, which affects over 100 million people worldwide *(72)*.

Lymphatic filariasis is an infectious disease caused by parasitic roundworms. It is endemic in at least 52 countries and is a cause of severe disability when untreated *(72, 73)*. Adult worms lodge in lymphatic vessels, where they affect the immune system and cause abnormal swelling of the extremities or of the scrotum. The infection can lead to severe disability in later life.

Infection occurs mainly in South-East Asia and Africa but also in other tropical areas. Lymphatic filariasis is transmitted by various types of mosquito, including *Culex*, which is widespread in urban and semi-urban areas, *Anopheles*, found mainly in rural areas, and *Aedes*, mainly on endemic islands in the Pacific Ocean *(72)*.

The main strategy recommended by WHO for interrupting transmission of lymphatic filariasis is annual mass drug distribution to entire populations living in endemic areas for several years *(72)*. This strategy has been effective in several settings; however, the long-term sustainability of the benefits of mass drug administration may require altering the environmental conditions that facilitate transmission *(74)*.

Environmental vector control includes management and modification of water bodies to facilitate and sustain interruption of transmission *(75)*. It was found, for example, that the vast majority of mosquito breeding habitats in Dar es Salaam were of human origin; drains, especially those with stagnant water and vegetation, constituted the majority of aquatic habitats *(76)*. Sufficient clean water also plays an important role in managing morbidity and preventing further disability *(77)*. Globally, the mean fraction of the disease burden due to lymphatic filariasis attributable to inadequate WASH is estimated to be 67% (39–89%) *(1)*.

Selected interventions:

- In Zanzibar, United Republic of Tanzania, and in Tirukoilur, Tamil Nadu, India, drug treatment alone and combined with application of floating layers of polystyrene beads on water containers prevented resurgence of filarial infection *(78, 79)*.

Clogged drains can be breeding places for the mosquitoes that are the vectors for lymphatic filariasis, malaria and dengue.

Onchocerciasis

Population-attributable fraction: **10% water resource projects and deforestation**	Method for estimating the population-attributable fraction: **expert survey**

There is no vaccine or medication to prevent onchocerciasis, and vector control is one of the main means for prevention *(80)***.**

Onchocerciasis is caused by a parasitic filarial worm and is the second most important cause of blindness due to infection, after trachoma. More than 99% of infected people live in 31 African countries; there are also foci in Latin America and Yemen. The disease is transmitted by blackflies. The symptoms include severe itching, disfiguring skin conditions and visual impairment, which may lead to permanent blindness *(80)*.

Blackflies breed in fast-flowing rivers and streams *(81)* and take blood meals from animals and humans. High densities of blackflies make fertile river valleys practically uninhabitable because of biting. The WHO/World Bank/UNDP Onchocerciasis Control Programme eliminated the disease from a number of West African countries between 1974 and 2002 by systematic aerial application of insecticides in rivers upstream from breeding places, followed by mass administration of ivermectin. Colombia, Ecuador, Mexico and Guatemala eliminated the disease in 2013, 2014, 2015 and 2016, respectively *(80)*. Large programmes for onchocerciasis control and elimination in Africa and the Americas have considerably reduced disease transmission and morbidity and reduced the number of people requiring ivermectin *(80)*.

Vector control involves environmental management of river systems downstream from water resource projects, particularly dams. Strategies include building dams with a double spillway, "drowning" breeding places in the reservoir area and changing the hydrology downstream of the dam *(82)*.

Globally, the mean fraction of the burden of onchocerciasis attributable to water resource projects and deforestation is estimated to be 10% (7–13%) *(1)*.

Fast-flowing rivers and streams offer breeding places for blackflies, the disease vector that transmits onchocerciasis, Kenya.

Dengue

Population-attributable fraction:

95% water and waste management

Method for estimating the population-attributable fraction:

expert survey

Dengue poses a threat to around half the world's population but could be nearly entirely prevented by adequate water and waste management *(83)*.

Dengue fever is the most rapidly spreading mosquito-borne viral disease in the world. Infected people show flu-like symptoms, especially painful joints; severe dengue has potentially deadly complications, particularly in children. About 390 million cases of dengue infection are estimated to occur annually *(84)*. In another study, it was estimated that 3900 million people in 128 countries are at risk of infection with dengue viruses *(85)*. Member States in three WHO regions reported 3.2 million dengue cases in 2015, an increase of 1 million cases over that in 2010 *(83)*. There is no specific treatment for dengue fever.

Rapid urbanization, unreliable drinking-water supplies, increased population mobility and global trade are determinants of the disease *(86)*. The vector breeds in clean, man-made and sometimes natural water bodies close to human dwellings. Strategies for preventing dengue fever comprise environmental management and modification to reduce the density of the mosquito vector population by source reduction and minimizing human–vector contact. They include the provision of reliable piped water to eliminate household water storage, disposal or mosquito-proofing of water holdings and water containers, introducing larvivorous species (fish or tiny crustacean copepods) into drinking-water containers, solid waste management and well-enforced regulations for urban building design *(83, 87, 88)*.

The global mean fraction of the disease burden due to dengue fever attributable to inappropriate water and waste management is estimated to be 95% (89–100%) *(13)*.

Selected interventions:

- A systematic review and meta-analysis of studies of the effectiveness of interventions for dengue vector control (biological control, chemical control, environmental management and integrated vector management) showed that integrated vector management, a combination of environmental management with either chemical or biological control, was the most effective. It reduced the number of infested houses by 83%, infested water containers by 88% and infested containers per 100 houses inspected by 67% *(89)*.

Economic evaluations:

- Integrated vector management in Santiago de Cuba was more efficient and effective than routine (mainly chemical) dengue vector control. The average cost-effectiveness ratio was US$ 831 per vector focus reduction with integrated vector management and US$ 2466 with routine vector control *(90)*.

Dengue can be prevented by eliminating stagnant water holdings, such as from outdoor rubbish dumps, Kolkata, India.

Japanese encephalitis

Population-attributable fraction:

95% agricultural practices, personal protection

Method for estimating the population-attributable fraction:

expert survey

Changing agricultural practices can reduce transmission of Japanese encephalitis, a severe, life-threatening disease that frequently leads to permanent disability *(91)***.**

Japanese encephalitis virus is the leading cause of viral encephalitis in South, South-East and East Asia. The annual incidence of clinical disease varies among and within countries, ranging from < 10 to > 100 per 100 000 population. A review of the literature resulted in an annual estimate of nearly 68 000 clinical cases of Japanese encephalitis globally, with up to 20 400 deaths *(92)*. Japanese encephalitis primarily affects children. Although symptomatic disease is rare, the case fatality rate may be as high as 30% *(91)*. Of patients who survive, 30–50% suffer severe long-term neurological sequelae. Most cases are reported in China and India *(93)*.

The Japanese encephalitis virus breeds mainly in irrigated rice production systems in rural or peri-urban areas, where the mosquito vectors of the virus prefer to breed. The natural hosts of the virus are birds living in the aquatic environment, and pigs are the main amplifying host.

Although Japanese encephalitis is a vaccine-preventable disease, many countries have limited capacity to deliver costly vaccination programmes in rural areas. Environmental interventions can significantly reduce transmission of the disease *(81, 94, 95)*, including management of irrigated rice fields.

The mean fraction of the disease burden due to Japanese encephalitis that is attributable to agricultural practices and inadequate personal protection is estimated to be 95% (90–99%) *(1)*.

Peasant tilling the soil in a paddy field, Guizhou, China.

Protein–energy malnutrition

Population-attributable fraction:

16% WASH

Method for estimating the population-attributable fraction:

calculation based on limited epidemiological data

About 45% of all child deaths are linked to malnutrition *(95)*, which can result in recurrent diarrhoea and other infectious diseases due to inadequate WASH.

Protein–energy malnutrition occurs when the body's requirements for protein or energy are unmet as a result of either under-consumption or poor absorption and use of nutrients *(97)*. Globally in 2016, 155 million children under 5 years of age were stunted (low height for age), 52 million were wasted (low weight for height), and 17 million were severely wasted *(96)*. Stunted, wasted and underweight children are at greater risk of death from acute respiratory illnesses, diarrhoea, measles and other infectious diseases. Stunting has significant long-term consequences on health and functional outcomes, including poor motor and cognitive development and poor educational outcomes *(98)*.

Individual nutritional status depends on food intake, general health and the physical environment, and poor WASH plays an important role in all three aspects. Recurrent infectious diseases such as diarrhoea can impair nutritional status *(99–102)*. Giardiasis, which is commonly transmitted through water or food contaminated with water or waste, also leads to malabsorption and therefore to a higher risk of malnutrition *(103, 104)*. There is also increasing evidence for a link between living in unhygienic conditions and an intestinal disorder referred to as "environmental enteric dysfunction", which has been associated with stunting *(102, 105–107)*. The evidence from studies on WASH interventions and nutritional status is, however, controversial *(108–112)*. Indirect impacts include increased spending of household income on water from vendors when adequate services are not available, such as in informal settlements, which may reduce spending on food, contributing to malnutrition *(113)*. Fetching water from a distant source may use up a person's energy *(114)*, also contributing to undernutrition. Greater water scarcity is likely to reduce food security further and possibly aggravate malnutrition *(115, 116)*.

When the 60% fraction of the diarrhoeal disease burden attributable to WASH *(12)* is combined with the estimate that 25% (8–38%) of stunting is attributable to frequent diarrhoea *(98)*, 16% (15–17%) of malnutrition can be attributed to inadequate WASH. This estimate is based on a number of assumptions and is therefore only a rough estimate. Furthermore, it does not account for the other possible impacts of the environment on malnutrition and may be an underestimate of the effect of the environment on malnutrition.

Selected interventions:

- A systematic review and meta-analysis of studies on interventions to improve water quality, water supplies, sanitation and hygiene practices provides suggestive evidence that they can improve nutritional status in children. None of the studies included in the analysis was of high quality, which increases the uncertainty of the estimate *(108)*.

Recurrent diarrhoea, often due to inadequate WASH, can lead to and aggravate malnutrition.

Drowning

Population-attributable fraction: **11% occupational risks**	Method for estimating the population-attributable fraction: **CRA**
Total population-attributable fraction: **73% safety of home and community environments, occupational risks**	Method for estimating the population-attributable fraction: **expert survey**

Every year, 322 000 people die by drowning *(17)*. **The number could be reduced by increasing community and occupational safety around water bodies and water supplies, in waterway transport, by mitigating climate change and by adaptation strategies.**

An estimated 322 000 people drowned in 2016, although this may be a significant underestimate. Drowning is the leading cause of injury death among children under 5 years. The risk factors for drowning include the absence of physical barriers, particularly close to dwellings, and inadequate child supervision. Recreational environments may present a risk of drowning because of inadequate safety measures or equipment in swimming pools and other recreational water bodies *(117, 118)* or for tourists who are unfamiliar with local risks and features. Uncovered and unprotected water supplies and the absence of safe water crossings also constitute risks *(117, 119)*.

Occupations that pose an increased risk include fishing. Transport on overcrowded or unsafe vessels that have no safety equipment or insufficiently trained personnel is also a risk factor *(119, 120)*. Drowning often occurs during natural events such as floods, torrential rains and tsunamis, and climate change may increase the frequency or amplitude of such events *(121)*. Climate change mitigation and adaptation measures could therefore prevent the adverse impacts of floods.

Other strategies to prevent drowning include improved community infrastructure, public awareness and appropriate policies and legislation *(119)*. Community action to improve infrastructure could include ensuring safe water systems, such as drainage systems and flood control, fencing around pools and other standing water, creating and maintaining safe water zones for recreation, covering wells and cisterns and emptying water containers and baths *(119, 122, 123)*. Public awareness can be raised about the particular risk of children. Dangerous areas could be signposted and rescue equipment pre-positioned, with lifeguards. Individual and community education on the risk of drowning, teaching school-age children to swim and water survival skills and teaching safe rescue and resuscitation are further measures to prevent drowning *(119)*.

Regulations to prevent drowning should cover boating, shipping and ferries, including systems to ensure vessel safety, the availability of flotation devices, avoiding overcrowding and appropriate travel routes and rules. Other regulations could be for pool fencing and prohibition of alcohol use while boating or swimming. Occupational safety measures might include the wearing of personal flotation devices and guard rails, for example on commercial fishing vessels *(124)*. National water safety plans, with the involvement of other sectors, could ensure systematic, sound preventive action *(119)*.

Drowning rates have decreased significantly in developed countries during the past decade, coinciding with interventions and legislation for recreational environments and education. In Italy, for example, the rate of drowning was reduced by 64% in less than three decades *(125)*. It was estimated that 54% (24–79%) of drownings were attributable to the environment or to occupation in high-income countries and 74% (44–95%) in low- and middle-income countries, where recreational safety, water transport safety and flood control are less developed.

Selected interventions:

- After a surveillance system was established in an area in Thailand at high risk for drowning, the risk was about six times lower than in an area without surveillance *(126)*.
- An intervention to prevent drowning of children aged 4–12 years in Bangladesh that comprised swimming lessons, more supervision, awareness of risks and water safety and safe rescue skills decreased the risk by more than 90%. Collective supervision of children aged 1–5 years in child-care centres reduced the rate by more than 80%. Both interventions were evaluated as highly cost-effective *(127)*.
- Pool fencing reduces the risk of drowning or near-drowning by about 73% (84–53%). Fencing that encloses only the pool is more effective than fencing that encloses an entire property, including the pool *(122)*.

Teaching children how to swim is an important means of preventing drowning.

Other diseases

The following diseases are linked to inadequate WASH, but there are no global estimates of the effects on population health.

Arsenicosis

Arsenic contamination of drinking-water is a major public health problem in many countries *(128)*.

Arsenicosis results from chronic exposure to elevated levels of arsenic, mainly by drinking contaminated groundwater or using it for irrigation and food preparation *(128, 129)*. Other routes of exposure are in the workplace and cigarette smoking. Skin alterations such as colour and hard patches, skin, bladder and lung cancer and diseases of the blood vessels in the legs and feet are consequences of prolonged exposure. Chronic exposure has also been linked to developmental effects, diabetes, pulmonary disease and cardiovascular disease *(128, 129)*.

Contamination of drinking-water with arsenic (above the WHO guideline value of 10 µg/L) is a problem that affects millions of people, including 39 million people in Bangladesh and some 20 million people in China *(128, 130)*. In Bangladesh, about 43 000 deaths per year were estimated to be due to arsenic *(128)*. A prospective study in a highly affected area of Bangladesh attributed more than 20% of all deaths to arsenic *(131)*.

In areas where arsenic occurs in high concentrations in drinking-water, safe water should be provided for drinking, food preparation and irrigation of food crops. If possible, households should change to low-arsenic, microbiologically safe sources, such as rainwater or treated surface water. The arsenic concentration in water should be measured regularly and the information provided to the community, for instance by painting high-arsenic and low-arsenic water sources in different colours. Both centralized and household techniques for removing arsenic are available, such as oxidation, coagulation, flocculation, adsorptive ion exchange and membrane processes. Appropriate techniques should be selected, and the removed arsenic must be disposed of safely. The community should be involved, appropriately educated about disease risks and mitigation and monitored for early signs of arsenic poisoning *(128, 132)*.

As arsenic absorption through the skin is minimal, arsenic-contaminated water can be used for bathing and washing *(128, 129)*.

Selected interventions:

- In Bangladesh, interventions that included testing water for arsenic and education about arsenic awareness, reduced exposure and motivated people to switch to safe drinking-water sources *(133–137)*. Techniques for removing arsenic such as a filter or a flocculant-disinfectant reduced arsenic contamination of drinking-water; however, compliance was problematic *(138–140)*.

- In Taiwan (China), after installation of a tap-water supply in an area in which drinking-water was previously taken from groundwater wells containing high levels of arsenic, the mortality rates from kidney, bladder and lung cancer and ischaemic heart disease decreased gradually over 30 years *(141–145)*.

Fluorosis

Fluoride intake has both beneficial and deleterious health effects, depending on the level of intake *(146)***.**

Fluoride reduces the incidence of dental caries, and provision of drinking-water with adequate fluoride can therefore prevent this adverse effect. Excessive intake of fluoride by consumption of fluoride-rich groundwater and foods can, however, lead to fluorosis of the teeth and bones, ranging from staining and pitting of the teeth to damaged enamel and stiffness and pains in the joints to changed bone structure and calcified ligaments *(15)*. Fluorosis affects millions of people worldwide, although mild stages of the disease prevail *(147)*.

Various means are available to reduce excess fluoride in drinking-water, including provision of water containing fluoride below the threshold value of 1.5 mg/L; de-fluoridation of water used for drinking and cooking by various techniques, with adequate disposal of the resulting sludge; promotion of breastfeeding in areas with high fluoride intake; and monitoring of overall exposure to fluoride *(15, 132, 146)*.

Selected interventions:

- In Estonia, reduction of the high fluoride content of public water supplies by reverse osmosis and by drilling new wells reduced exposure by 82% *(148)*.
- In Ethiopia, a behaviour change programme increased consumption of fluoride-filtered drinking-water *(149)*.
- In China and India, provision of safe drinking-water to populations in areas with high levels of fluoride reduced dental and skeletal fluorosis *(150, 151)*.

Dental fluorosis with staining and pitting.

Legionellosis

Legionellosis is a waterborne, potentially fatal form of pneumonia *(152)***.**

Legionellosis, which ranges in intensity from mild febrile illness to a serious, potentially fatal form of pneumonia known as Legionnaires' disease, is caused by exposure to bacteria of the species *Legionella (152)*. The number of new cases of Legionnaires' disease is unknown, and the disease is substantially underdiagnosed and under-reported. It is estimated that Legionnaires' disease accounts for 2–9% of cases of community-acquired pneumonia *(153)*. The pathogen is found worldwide in various natural and artificial aquatic environments *(153)* and lives and grows in water of 20–50 °C. It is transmitted by inhalation of contaminated aerosols from e.g. air-conditioning cooling towers, hot and cold water systems, humidifiers and whirlpool spas *(152)*.

Measures to limit the growth of *Legionella* and dissemination of aerosols can reduce the occurrence of legionellosis. They include maintenance, cleaning and disinfection of devices, application of biocides such as chlorine and water temperatures < 20 °C or > 60 °C *(152)*.

Leptospirosis

Leptospirosis can be transmitted by water contaminated with urine from infected animals *(15)***.**

Leptospirosis, caused by bacteria of the *Leptospira* species, affects both humans and animals worldwide. The consequences of infection may be mild or severe and even result in death due to organ dysfunction. It has been estimated that > 1 million new cases, 59 000 deaths and 2.9 million DALYs are lost due to leptospirosis annually, mainly in resource-poor countries *(154, 155)*. Humans are infected mainly by direct contact with the urine of infected animals, such as rodents, insectivores, dogs, cattle, pigs and horses, or by contact with or ingestion of urine-contaminated water or other environmental media *(15)*.

Various common events and activities have been associated with outbreaks of leptospirosis, including flooding, swimming, farming and drinking contaminated water *(156)*. Interventions for the prevention of leptospirosis should be based on the specific eco-epidemiological and cultural setting and may include rodent control, human and animal vaccination, antibiotic prophylaxis, personal protection such as gloves and goggles, refraining from contact with infected animals and from swimming in contaminated water, provision of safe drinking-water and awareness-raising among doctors, veterinarians, groups at risk and the general population *(156, 157)*.

Hepatitis A and hepatitis E

Measures for preventing hepatitis A and E include safe water supplies, appropriate sanitation, hygiene education and food hygiene *(158, 159)*.

Hepatitis A and E viruses cause liver diseases that can lead to severe disease and death. Infections are usually self-limiting, with low mortality; however, the rate of mortality from hepatitis E can be as high as 20–25% in pregnant women *(158, 160)*. In countries with poor sanitation and hygiene, 90% of children have been infected with hepatitis A virus before the age of 10 *(159)*. An estimated 20 million people are infected with hepatitis E virus every year. Hepatitis A and E infections occur worldwide, but the risk is much higher in low-income settings *(158, 159)*.

Hepatitis A and E infections are predominantly transmitted by the faecal–oral route, upon ingestion of food or water contaminated with faeces from an infected person. Contaminated water supplies and inadequate sanitation can cause large epidemics. Hepatitis E virus can also be transmitted from animals (e.g. swine) to humans *(161)*. Hepatitis A and E are prevented by vaccination, safe water supplies, appropriate sanitation and education about hygiene, especially hand-washing and food safety *(158, 159)*.

Cyanobacterial toxins

Cyanobacterial poisoning occurs after contact with contaminated recreational or drinking-water *(15)*.

Cyanobacteria, also called blue-green algae, occur worldwide in water used for recreation or drinking. They grow in calm, warm, nutrient-rich waters. Some species produce toxins that can harm humans and animals. The effects range from skin irritation, nausea with vomiting and diarrhoea to seizures, liver damage, neurotoxicity, tumour promotion and occasionally death *(15, 162)*. Furthermore, cyanobacteria can have major impacts on aquatic ecosystems *(163)*. It has been estimated that the cost of eutrophication of fresh water in the USA was > US$ 2.2 billion per year *(164)*.

The extent of toxin-producing cyanobacterial growth has increased in recent decades, and it is likely that climate change and increasing water temperatures will increase growth in the future *(165)*. Interventions include reducing the nutrient load of lakes and reservoirs through better management of wastewater and reducing run-off of fertilizers from agriculture and other sources *(162)*. Further measures are increasing awareness and educating health care and water supply personnel and the general public about the risks associated with drinking, bathing or water sports in cyanobacteria-contaminated water; where necessary, water can be treated to remove cyanobacteria and their toxins. Water safety plans are recommended for assessment and management of risks associated with cyanobacteria *(162)*.

Selected interventions:

- In 2011, a "Harmful algal bloom response strategy" was released in Ohio, USA, which included thresholds for cyanotoxins in recreational and drinking-water, signposts at lakes to inform the public about the health risks associated with exposure to cyanotoxins in water, monitoring of public drinking-water supplies and strategies to decrease the input of nutrients into lakes *(163)*.

Lead poisoning

Exposure to lead in contaminated drinking-water is estimated to cause over 500 000 deaths annually *(166)*.

People are exposed to lead mainly in air, water, food, soil or dust. Since enactment of legislation that reduced its use in fuel and paints, the levels in air, soil and dust have decreased; however, it is still found in drinking-water from lead in household plumbing systems such as pipes, solder, fittings and service connections. Excess lead intake can result in neurodevelopmental effects, the most vulnerable groups being fetuses, infants and children; it can also cause renal disease, hypertension and anaemia. No level of lead is considered safe. The most important measure for ensuring safe drinking-water is removal of lead-containing plumbing and fittings. When this is not immediately possible, all practical measures should be taken to reduce total exposure to lead, e.g. flushing of pipes, raising the pH and drinking lead-free water *(15, 167, 168)*.

Selected interventions:

- Environmental interventions (removing lead pipes or raising the pH of drinking-water) and combined environmental and educational interventions (provision of filtered water, identification and removal of lead sources) reduced blood lead levels *(169)*.
- The lead concentrations in the environment in the USA, including drinking-water, have been considerably reduced since the 1970s, and blood lead levels in children have decreased significantly *(170)*.

Scabies

Scabies is estimated to affect more than 200 million people. Personal hygiene is an important preventive measure *(171)*.

Scabies is one of the commonest skin diseases, affecting millions of people worldwide *(171)*. It is caused by person-to-person contact and is due to infestation with a mite that burrows into the skin and lays eggs, causing intense itching. Scratching frequently causes bacterial infection, leading to aggravated skin problems, and can even cause septicaemia, heart disease and chronic kidney disease *(171)*. Scabies is controlled with drugs, preferably by treating whole households and possibly mass administration *(171)*. Personal hygiene is an important preventive measure, for which an adequate water supply is a prerequisite *(172)*.

Spinal injury

Spinal injuries are frequently related to water, for example in recreational water activities and in carrying water over long distances *(173)***.**

Spinal injury may lead to loss of sensation or paralysis of the legs, arms or the whole body. Every year, 250 000–500 000 people have a spinal cord injury *(174)*. Spinal injuries can occur during recreational water activities, such as diving into shallow water *(173)*, and 9% of traumatic spine injuries are thought to be water-related in Australia and 3–6% in the USA *(175)*. Young to middle-aged men were shown to be at particular risk for water-related spinal injuries *(176, 177)*. The spine may also be injured by carrying water over long distances *(173)*.

Prevention of water-related spinal injuries includes education about the hazards of and safe behaviour during water sports, supervision and instructions, access to rapid emergency treatment and appropriate water supplies so that water does not have to be carried over long distances *(173)*.

Young men jumping into shallow water – a typical risk situation for spinal injuries.

Poliomyelitis

Polio is a highly infectious disease that is transmitted via the faecal–oral route or contaminated water or food *(178)***.**

Polio is a highly infectious viral disease, which damages the nervous system, can lead to paralysis and mainly affects children < 5 years of age. Polio eradication campaigns resulted in a decrease in the number of reported cases from 350 000 in 1988 to 33 in 2018; however, remaining areas of ongoing polio transmission could potentially result in 200 000 new cases every year *(178)*.

Inadequate drinking-water, sanitation and hygiene can facilitate the spread of polio. The virus is transmitted mainly directly from person to person by the faecal–oral route but also in contaminated water or food. As there is no cure for polio, prevention of the disease by vaccination is crucial *(178)*.

Neonatal conditions and maternal outcomes

Appropriate WASH is crucial for safe child delivery, maternal health and prevention of infections *(179)***.**

Approximately 830 women die every day from preventable causes during pregnancy and childbirth *(180)*. One in four health care facilities lacks basic water services, and one in five has no sanitation. Nearly 900 million people attend health care facilities that have no water, and 1.5 billion people attend health care facilities with no toilet *(10)*. Poor WASH has been associated with various adverse maternal and perinatal health outcomes *(179)* and with increased maternal mortality *(181)*. In low-resource settings, there are many more neonatal health care-associated infections than in higher-income settings *(182)*. Neonatal sepsis and other severe infections are estimated to cause 430 000 deaths per year, mainly in low-resource settings *(183)*. Poor WASH also favours undernutrition, resulting in greater susceptibility to infectious diseases, which are associated with poor fetal development and complications of pregnancy *(179)*.

Poor sanitary conditions in health care settings prevail in many low- and middle-income countries. Outside toilets at a hospital in Ethiopia.

Other diseases

Many other diseases are related to WASH. Appropriate WASH is important for the control and care of most neglected tropical diseases *(184)*. A few other diseases are described below.

About 89 million people live in the 13 countries endemic for **yaws**, and, in many countries previously endemic for yaws, the current status of the disease is not known. Yaws is a chronic infectious disease that affects the skin, bones and cartilage and which can cause chronic deformities, disfigurement and disability. About 75–80% of yaws cases occur in children < 15 years. Poor hygiene and socio-economic conditions and crowding facilitate yaws transmission *(185)*.

Dracunculiasis is a parasitic disease of which there were only 30 human cases in 2017. The number of cases has fallen by more than 99% due to global eradication initiatives since 1989. Transmission occurs exclusively by drinking stagnant water, such as surface water, contaminated with parasite-infected water fleas. There is no vaccine or specific medication against the disease. Measures against transmission include preventing contamination of drinking-water by advising patients not to wade in water, access to improved drinking-water sources and filtering water from open water bodies before drinking *(186)*.

More than 200 000 new cases of **leprosy** were officially reported in 2016. Leprosy is a chronic infectious disease that mainly affects the skin, peripheral nerves, eyes and upper respiratory tract, where it can cause progressive and permanent damage if left untreated *(187)*. Appropriate WASH is especially important for morbidity management and disability prevention, e.g. for washing open wounds and soaking affected limbs *(184, 188)*.

In 2016, 42% of children < 5 years and 40% of pregnant women were **anaemic**, defined as a decreased number of red blood cells or haemoglobin in the blood *(17)*. Some anaemia is WASH-related, as it can result from WASH-related adverse health outcomes such as malnutrition or infections such as malaria, hookworm infection and schistosomiasis.

Tinea or dermatophytosis (also called "ringworm"), a fungal infection of the skin, can be prevented by good personal hygiene, which requires adequate quantities of water *(189)*.

Various **mosquito-borne diseases**, such as yellow fever, chikungunya and Zika virus disease, can be considered water-related, as disease transmission depends on the proximity of mosquito breeding sites, which require the presence of water, to human habitations. Preventive measures include vector control by reducing the number of water containers, such as buckets, drums, flower pots, old tyres and gutters, that offer a habitat for mosquito breeding *(190–192)*.

Summary

Worldwide, 1.9 million deaths and 123 million DALYs could have been prevented in 2016 with adequate WASH (Table 2). The WASH-attributable disease burden amounts to 3.3% of global deaths and 4.6% of global DALYs (Fig. 1). Among children under 5 years, WASH-attributable deaths represent 13% of deaths and 12% of DALYs. The WASH-attributable disease burden is shown by disease, for regions or individual countries and for WHO regions in Annex 1.

Table 2. Disease burden due to inadequate WASH, 2016

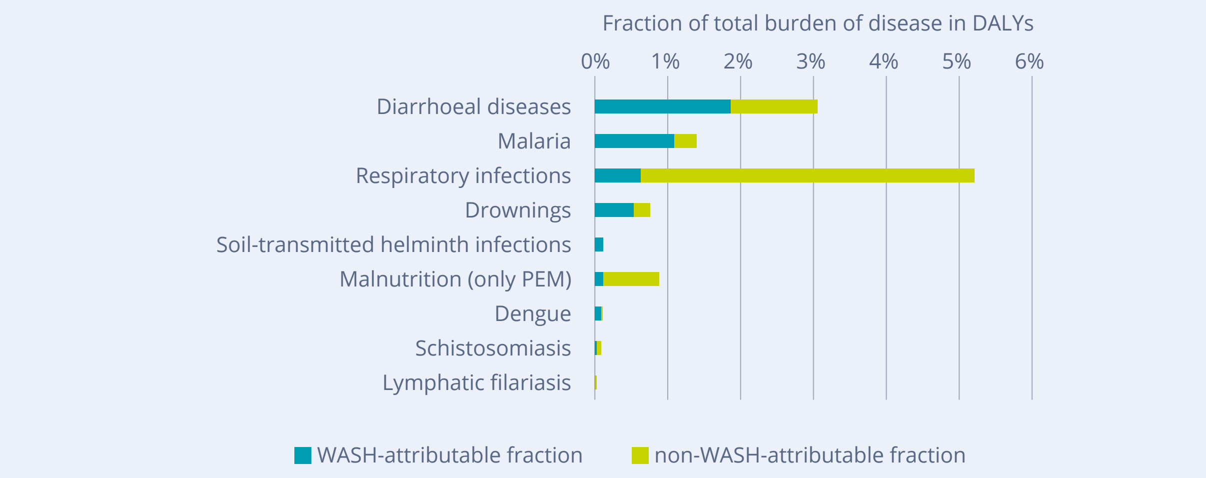
Disease	Deaths	DALYs (thousands)	Population-attributable fraction
Diarrhoeal diseases	828 651	49 774	0.60
Soil-transmitted helminthiasis	6 248	3 431	1
Acute respiratory infections	370 370	17 308	0.13
Malnutrition[a]	28 194	2 996	0.16
Trachoma	< 10	244	1
Schistosomiasis	10 405	1 096	0.43
Lymphatic filariasis	< 10	782	0.67
Subtotal drinking-water, sanitation and hygiene	*1 243 869*	*75 630*	*NA*
Malaria	354 924	29 708	0.80
Dengue	38 315	2 936	0.95
Onchocerciasis	< 10	96	0.10
Subtotal water resource management	*393 239*	*32 740*	*NA*
Drownings	233 890	14 723	0.73 (0.74 for LMIC, 0.54 for HIC)
Subtotal safety of water environments	*233 890*	*14 723*	*NA*
Total inadequate water, sanitation and hygiene	**1 870 998**	**123 094**	**NA**

LMIC, low- and middle-income countries; HIC, high-income countries; DALYs, disability-adjusted life years; NA, not applicable

Disease burden estimates are for LMICs; diarrhoea, acute respiratory infections and drowning include disease burden in high-income countries.

[a] Includes disease burden of protein–energy malnutrition and consequences in children < 5 years only.

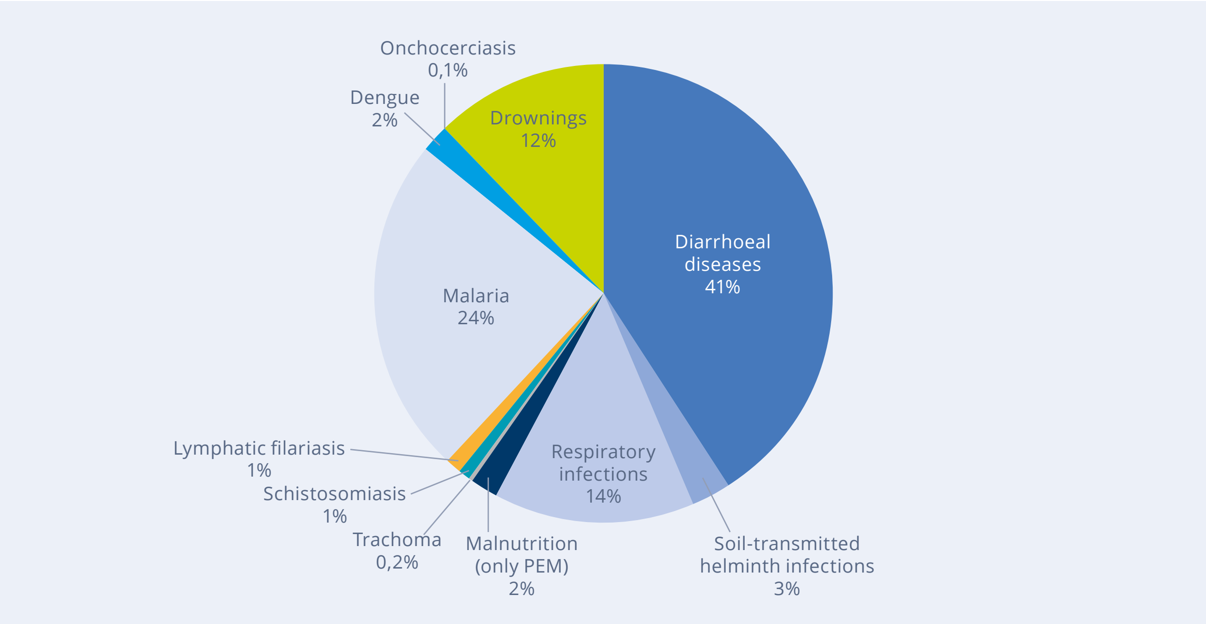
Fig. 1. WASH-related diseases that make the greatest contributions to the global disease burden, 2016



DALY, disability-adjusted life year (years of life lost to premature mortality and to disability); PEM, protein–energy malnutrition

The WASH-attributable disease burden is due mainly to inadequate drinking-water, sanitation and hygiene (62%). Inadequate water resource management contributes 26% and unsafe water environments 12% to the WASH-attributable burden of disease (in DALYs, Fig. 2). Most of the WASH-attributable disease burden is due to infectious, parasitic and nutritional causes (88%). Only 12% of disease burden is due to injuries (i.e. drowning).

Fig. 2. Contribution of diseases to the WASH-attributable disease burden (in DALYs), 2016



DALY, disability-adjusted life year (years of life lost to premature mortality and to disability); PEM, protein–energy malnutrition

The fraction of WASH-attributable disease in the total disease burden shows considerable regional discrepancy and is highest in sub-Saharan Africa, where 12% of the total disease burden in total and 17% of the total disease burden in children can be attributed to inadequate WASH.

Sustainable Development Goal 6 includes universal, equitable access to safe, affordable drinking-water for all.

Conclusions

Nearly 2 million deaths and more than 120 million DALYs could have been prevented in 2016 with adequate WASH, including adequate drinking-water, sanitation and hygiene, adequate water resource management and safe water bodies. Concrete action has been proposed in this document, with examples of effective interventions for improving health and analyses of their cost–effectiveness. Box 2 lists selected WHO resources for guiding national and international approaches to achieving adequate WASH.

Box 2. Selected WHO resources for guiding national and international approaches to achieving adequate WASH

Water safety planning is a comprehensive approach to risk assessment and risk management that encompasses all steps in a drinking-water supply chain, from catchment to consumer. The WHO guidelines for drinking-water quality note that such plans are the most effective means of ensuring the consistent safety of a drinking-water supply. They are being implemented in many countries worldwide *(193–195)*.

WHO guidelines for safe recreational water environments include international norms for recreational water use and health *(196)*, comprising control, monitoring and management of health risks. The risks include drowning and injury, exposure to cold, heat and sunlight and water quality, especially water contaminated by sewage but also exposure to free-living pathogenic microorganisms in recreational waters, contaminated beach sand, algae and their products, chemical and physical agents and dangerous aquatic organisms.

WHO guidelines for drinking-water quality *(15)* are the authoritative basis for setting national regulations and standards for water safety to ensure public health.

WHO guidelines on sanitation and health *(197)* summarize the evidence on the links between sanitation and health and offer evidence-informed guidance for international, national and local sanitation policies and programmes. The guidelines also define the role of health authorities in sanitation policy and programming to ensure that health risks are identified and managed effectively.

WHO guidelines for safe use of wastewater, excreta and greywater *(34)* propose a flexible approach to risk assessment and risk management based on health targets established at a realistic level for local conditions. The approach should be accompanied by strict monitoring.

Sanitation safety planning is a step-by-step risk-based approach to implementation of the WHO guidelines for safe use of wastewater, excreta and greywater. Risk assessment and risk management are used to prevent exposure to excreta along the sanitation chain from the household to final use or disposal *(198)*.

Limitations

The strength of the evidence for links between WASH and various health outcomes compiled and analysed for this assessment varies by risk factor and disease, and some of the conclusions are based on more assumptions than others. Comparative risk assessment methods were used to estimate 65% of WASH-attributable deaths and 55% of DALYs, requiring detailed data on exposures and exposure–response relations. For some diseases, approximate epidemiological estimates or expert surveys were used to estimate the population attributable fractions of inadequate WASH, because the evidence was more limited.

The plausible relation of many diseases to inadequate WASH (Table 1) has not yet been quantified and is therefore not reflected in the overall WASH-attributable disease burden. Additionally, the burden of waterborne disease outbreaks, flooding and droughts and the disease burden of certain populations such as refugees, internally displaced people and the homeless and in certain settings such as health care facilities, schools, workplaces and other public places were not considered. Many health care facilities lack even basic water and sanitation services *(8)*. Health-care associated infections affect hundreds of millions of patients every year, especially in low-income countries *(182)*. Worldwide in 2016, 19% of schools had no drinking-water service, 23% had no sanitation services, and 36% had no hygiene service *(199)*. Inadequate WASH and untreated wastewater from households, intensive livestock raising and industry are important environmental drivers of AMR, an increasingly serious threat to global public health (Box 3), which was also not considered in this analysis.

Box 3. WASH and antimicrobial resistance (AMR)

AMR is present when micro-organisms such as bacteria that cause infection survive exposure to antimicrobial drugs that would normally kill them or stop their growth *(5)*. It has been estimated that 700 000 people die due to AMR annually and that this number will increase to 10 million by 2050 *(5)*.

There are several important links between WASH and AMR. Adequate WASH is crucial in preventing the spread of bacteria, thereby reducing the need for antimicrobial treatment *(200)*. Furthermore, antimicrobial agents, their residues, antimicrobial-resistant bacteria and AMR genes are present in human and animal waste. Wastewater is often discharged untreated into the environment or is used in food-crop irrigation and can contaminate drinking-water sources *(201)*. Adequate WASH can thereby reduce AMR in several ways.

In conclusion, our estimates of the disease burden attributable to inadequate WASH remain conservative. More comprehensive evidence, both on exposure and the effectiveness of interventions, is required to establish exposure–response relations between inadequate WASH and a greater number of health outcomes, which will allow more precise, comprehensive estimates of the associated disease burden.

Slum in Bihar, India

References

1. Prüss-Ustün A, Wolf J, Corvalán C, Bos R, Neira M. Preventing disease through healthy environments: a global assessment of the environmental burden of disease from environmental risks. Geneva: World Health Organization; 2016 (http://www.who.int/quantifying_ehimpacts/publications/preventing-disease/en/, accessed May 2019).
2. Prüss-Üstün A, Bos R, Gore F, Bartram J. Safer water, better health. Costs, benefits and sustainability of interventions to protect and promote health. Geneva: World Health Organization; 2008 (https://apps.who.int/iris/bitstream/handle/10665/43840/9789241596435_eng.pdf?sequence=1, accessed May 2019).
3. Health in 2015 from MDGs to SDGs. Geneva: World Health Organization; 2015 (https://apps.who.int/iris/bitstream/handle/10665/200009/9789241565110_eng.pdf?sequence=1, accessed May 2019).
4. WHO water, sanitation and hygiene strategy 2018–2025. Geneva: World Health Organization; 2018 (https://apps.who.int/iris/bitstream/handle/10665/274273/WHO-CED-PHE-WSH-18.03-eng.pdf, accessed May 2019).
5. Ali M, Nelson AR, Lopez AL, Sack DA. Updated global burden of cholera in endemic countries. PLoS Negl Trop Dis. 2015;9(6):e0003832.
6. Global Task Force on Cholera Control. Ending cholera: a global roadmap to 2030. World Health Organization; 2017 (https://www.who.int/cholera/publications/global-roadmap.pdf, accessed May 2019).
7. O'Neill J. Tackling drug-resistant infections globally: final report and recommendations. London: Wellcome Trust, Department of Health; 2016 (https://amr-review.org/sites/default/files/160525_Final%20paper_with%20cover.pdf, accessed May 2019).
8. WHO, UNICEF. Water, sanitation and hygiene in health care facilities. Global baseline report 2019. Geneva: UNICEF; 2019.
9. About the Sustainable Development Goals. New York City (NY): United Nations; 2019 (http://www.un.org/sustainabledevelopment/sustainable-development-goals/, accessed May 2019).
10. Transforming our world: the 2030 Agenda for Sustainable Development. United Nations General Assembly resolution A/RES/70/1. New York City (NY): United Nations; 2015 (http://www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/70/1, accessed May 2019).
11. WHO, UNICEF. Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines. Geneva: World Health Organization; 2017 (https://apps.who.int/iris/bitstream/handle/10665/258617/9789241512893-eng.pdf?sequence=1&isAllowed=y, accessed May 2019).
12. Prüss-Ustün A, Wolf J, Bartram J, Clasen T, Cumming O, Freeman MC, et al. Burden of disease from inadequate water, sanitation and hygiene behaviours for selected adverse health outcomes: an updated analysis with a focus on low- and middle-income countries. Int J Hyg Environ Health. 2019;222(5):765–77.
13. WHO Constitution. Geneva: World Health Organization; 1946 (http://apps.who.int/gb/bd/PDF/bd48/basic-documents-48th-edition-en.pdf#page=7, accessed May 2019).
14. The global view of campylobacteriosis: report of expert consultation, Utrecht, Netherlands, 9–11 July 2012. Geneva: World Health Organization; 2013 (https://apps.who.int/iris/bitstream/handle/10665/80751/9789241564601_eng.pdf?sequence=1, accessed May 2019).
15. Guidelines for drinking-water quality, fourth edition incorporating the first addendum. Geneva: World Health Organization; 2017 (https://apps.who.int/iris/bitstream/handle/10665/254637/9789241549950-eng.pdf?sequence=1, accessed May 2019).
16. Preventing diarrhoea through better water, sanitation and hygiene: exposures and impacts in low- and middle-income countries. Geneva: World Health Organization; 2014 (http://apps.who.int/iris/bitstream/10665/150112/1/9789241564823_eng.pdf, accessed May 2019).
17. Global Health Observatory (GHO) data. Geneva: World Health Organization; 2018 (http://www.who.int/gho/en/, accessed May 2019); Maternal Child Epidemiology Estimates; https://www.who.int/healthinfo/global_burden_disease/estimates/en/index2.html
18. Cholera: fact sheet. 2019 (https://www.who.int/news-room/fact-sheets/detail/cholera, accessed May 2019).
19. Wolf J, Hunter PR, Freeman MC, Cumming O, Clasen T, Bartram J, et al. Impact of drinking water, sanitation and hand washing with soap on childhood diarrhoeal disease: updated meta-analysis and meta-regression. Trop Med Int Health. 2018;23(5):508–25.
20. WHO, UNICEF. Joint monitoring programme for water supply, sanitation and hygiene. Geneva, New York City (NY); 2019 (https://washdata.org/, accessed May 2019).

21. Wolf J, Johnston R, Freeman MC, Ram PK, Slaymaker T, Laurenz E, et al. Handwashing with soap after potential faecal contact: global, regional and country estimates for handwashing with soap after potential faecal contact. Int J Epidemiol. 2019; https://doi.org/10.1093/ije/dyy253.

22. Peletz R, Mahin T, Elliott M, Harris MS, Chan KS, Cohen MS, et al. Water, sanitation, and hygiene interventions to improve health among people living with HIV/AIDS: a systematic review. AIDS. 2013;27(16):2593–601.

23. Haller L, Hutton G, Bartram J. Estimating the costs and health benefits of water and sanitation improvements at global level. J Water Health. 2007;5(4):467–80.

24. Sijbesma C, Christoffers T. The value of hygiene promotion: cost-effectiveness analysis of interventions in developing countries. Health Policy Plan. 2009;24(6):418–27.

25. Townsend J, Greenland K, Curtis V. Costs of diarrhoea and acute respiratory infection attributable to not handwashing: the cases of India and China. Trop Med Int Health. 2017;22(1):74–81.

26. Causes of child mortality, 2017. Global Health Observatory (GHO) data. Geneva: World Health Organization; 2018 (http://www.who.int/gho/child_health/mortality/causes/en/, accessed May 2019).

27. Pneumonia: fact sheet. Geneva: World Health Organization; 2016 (http://www.who.int/mediacentre/factsheets/fs331/en/, accessed May 2019).

28. Rabie T, Curtis V. Handwashing and risk of respiratory infections: a quantitative systematic review. Trop Med Int Health. 2006;11(3):258–67.

29. Mbakaya BC, Lee PH, Lee RL. Hand hygiene intervention strategies to reduce diarrhoea and respiratory infections among schoolchildren in developing countries: a systematic review. Int J Environ Res Public Health. 2017;14(4):371.

30. Little P, Stuart B, Hobbs FDR, Moore M, Barnett J, Popoola D, et al. An internet-delivered handwashing intervention to modify influenza-like illness and respiratory infection transmission (PRIMIT): a primary care randomised trial. Lancet. 2015;386(10004):1631–9.

31. Jefferson T, Del Mar CB, Dooley L, Ferroni E, Al-Ansary LA, Bawazeer GA, et al. Physical interventions to interrupt or reduce the spread of respiratory viruses. Cochrane Database Syst Rev. 2011;(7):CD006207.

32. Soil-transmitted helminth infections: fact sheet. Geneva: World Health Organization; 2018 (http://www.who.int/news-room/fact-sheets/detail/soil-transmitted-helminth-infections, accessed May 2019).

33. Jia TW, Melville S, Utzinger J, King CH, Zhou XN. Soil-transmitted helminth reinfection after drug treatment: a systematic review and meta-analysis. PLoS Negl Trop Dis. 2012;6(5):e1621.

34. Guidelines for the safe use of wastewater, excreta and greywater in agriculture and aquaculture (volumes 1–4). Geneva: World Health Organization; 2006.

35. Strunz EC, Addiss DG, Stocks ME, Ogden S, Utzinger J, Freeman MC. Water, sanitation, hygiene, and soil-transmitted helminth infection: a systematic review and meta-analysis. PLoS Med. 2014;11(3):e1001620.

36. Ziegelbauer K, Speich B, Mäusezahl D, Bos R, Keiser J, Utzinger J. Effect of sanitation on soil-transmitted helminth infection: systematic review and meta-analysis. PLoS Med. 2012;9(1):e1001162.

37. Soil-transmitted helminthiases: eliminating soil-transmitted helminthiases as a public health problem in children: progress report 2001–2010 and strategic plan 2011–2020. Geneva: World Health Organization; 2012 (http://apps.who.int/iris/bitstream/10665/44804/1/9789241503129_eng.pdf, accessed May 2019).

38. Freeman MC, Garn JV, Sclar GD, Boisson S, Medlicott K, Alexander KT, et al. The impact of sanitation on infectious disease and nutritional status: a systematic review and meta-analysis. Int J Hyg Environ Health. 2017;220(6):928–49.

39. Wang LD, Guo JG, Wu XH, Chen HG, Wang TP, Zhu SP, et al. China's new strategy to block *Schistosoma japonicum* transmission: experiences and impact beyond schistosomiasis. Trop Med Int Health. 2009;14(12):1475–83.

40. Malaria: fact sheet. Geneva: World Health Organization; 2019 (http://www.who.int/news-room/fact-sheets/detail/malaria, accessed May 2019).

41. Muir DA. Anopheline mosquitoes: vector reproduction, life cycle and biotope. In: Malaria, Principles and practices of malariology. New York: Churchill Livingstone; 1988.

42. Karunamoorthi K. Vector control: a cornerstone in the malaria elimination campaign. Clin Microbiol Infect. 2011;17(11):1608–16.

43. Ault SK. Environmental management: a re-emerging vector control strategy. Am J Trop Med Hyg. 1993;50(6 Suppl):35–49.

44. Bos R, Mills A. Financial and economic aspects of environmental management for vector control. Parasitol Today. 1987;3(5):160–3.

45. Utzinger J, Tozan Y, Singer BH. Efficacy and cost-effectiveness of environmental management for malaria control. Trop Med Int Health. 2001;6(9):677–87.

46. Keiser J, Singer BH, Utzinger J. Reducing the burden of malaria in different eco-epidemiological settings with environmental management: a systematic review. Lancet Infect Dis. 2005;5(11):695–708.

47. Tusting LS, Thwing J, Sinclair D, Fillinger U, Gimnig J, Bonner KE, et al. Mosquito larval source management for controlling malaria. Cochrane Database Syst Rev. 2013;8: CD008923.

48. Trachoma: fact sheet. Geneva: World Health Organization; 2018 (http://www.who.int/news-room/fact-sheets/detail/trachoma, accessed May 2019).

49. Hu VH, Harding-Esch EM, Burton MJ, Bailey RL, Kadimpeul J, Mabey DCW. Epidemiology and control of trachoma: systematic review. Trop Med Int Health. 2010;15(6):673–91.

50. Heymann DL. Control of communicable diseases manual. Washington DC: American Public Health Association; 2008.

51. Sutter EE, Ballard RC. Community participation in the control of trachoma in Gazankulu. Soc Sci Med. 1983;17(22):1813–7.

52. Esrey SA, Potash JB, Roberts L, Shiff C. Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis, and trachoma. Bull World Health Organ. 1991;69(5):609.

53. West S, Muñoz B, Lynch M, Kayongoya A, Chilangwa Z, Mmbaga BBO, et al. Impact of face-washing on trachoma in Kongwa, Tanzania. Lancet. 1995;345(8943):155–8.

54. Emerson PM, Lindsay SW, Walraven GE, Faal H, Bøgh C, Lowe K, et al. Effect of fly control on trachoma and diarrhoea. Lancet. 1999;353(9162):1401–3.

55. Emerson PM, Cairncross S, Bailey RL, Mabey DCW. Review of the evidence base for the "F"and "E" components of the SAFE strategy for trachoma control. Trop Med Int Health. 2000;5(8):515–27.

56. Prüss A, Mariotti SP. Preventing trachoma through environmental sanitation: a review of the evidence base. Bull World Health Organ. 2000;78(2):267–73.

57. Emerson PM, Lindsay SW, Alexander N, Bah M, Dibba SM, Faal HB, et al. Role of flies and provision of latrines in trachoma control: cluster-randomised controlled trial. Lancet. 2004;363(9415):1093–8.

58. Schistosomiasis: fact sheet. Geneva: World Health Organization; 2018 (http://www.who.int/news-room/fact-sheets/detail/schistosomiasis, accessed May 2019).

59. Grimes JE, Croll D, Harrison WE, Utzinger J, Freeman MC, Templeton MR. The relationship between water, sanitation and schistosomiasis: a systematic review and meta-analysis. PLoS Negl Trop Dis. 2014;8(12):e3296.

60. Liu Q, Tian LG, Xiao SH, Qi Z, Steinmann P, Mak TK, et al. Harnessing the wealth of Chinese scientific literature: schistosomiasis research and control in China. Emerg Themes Epidemiol. 2008;5:19.

61. Zhou YB, Yang MX, Yihuo W, Liu G, Wang H, Wei JG, et al. Effect of habitat fragmentation on the schistosome-transmitting snail *Oncomelania hupensis* in a mountainous area of China. Trans R Soc Trop Med Hyg. 2011;105(4):189–96.

62. Ebisawa I. Epidemiology and eradication of *Schistosomiasis japonica* in Japan. J Travel Med. 1998;5(1):33–5.

63. Zhou XN, Wang LY, Chen MG, Wu XH, Jiang QW, Chen XY, et al. The public health significance and control of schistosomiasis in China – then and now. Acta Trop. 2005;96(2–3):97–105.

64. Hong Q, Yang K, Huang Y, Sun L, Yang G, Gao Y, et al. Effectiveness of a comprehensive schistosomiasis japonica control program in Jiangsu Province, China, from 2005 to 2008. Acta Trop. 2011;120(Suppl 1):S151–7.

65. Wang LD, Chen HG, Guo JG, Zeng XJ, Hong XL, Xiong JJ, et al. A strategy to control transmission of *Schistosoma japonicum* in China. N Engl J Med. 2009;360(2):121–8.

66. Chimbari MJ. Enhancing schistosomiasis control strategy for Zimbabwe: building on past experiences. J Parasitol Res. 2012;353768 (http://dx.doi.org/10.1155/2012/353768, accessed May 2019).

67. Lin DD, Zeng XJ, Chen HG, Hong XL, Tao B, Li YF, et al. [Cost-effectiveness and cost-benefit analysis on the integrated schistosomiasis control strategies with emphasis on infection source in Poyang Lake region]. Zhongguo Ji Sheng Chong Xue Yu Ji Sheng Chong Bing Za Zhi. 2009;27(4):297–302.

68. Yu Q, Zhao GM, Hong XL, Lutz EA, Guo JG. Impact and cost-effectiveness of a comprehensive schistosomiasis japonica control program in the Poyang Lake region of China. Int J Environ Res Public Health. 2013;10(12):6409–21.

69. Zhou XN, Wang LY, Chen MG, Wang TP, Guo JG, Wu XH, et al. An economic evaluation of the national schistosomiasis control programme in China from 1992 to 2000. Acta Trop. 2005;96(2):255–65.

70. Jobin WR. Long-term cost-effectiveness of environmental management for schistosomiasis control in water resources development. Geneva: World Health Organization; 1986.

71. Oomen JMV, de Wolf J, Jobin WR. Health and Irrigation. Wageningen: International Institute for Land Reclamation and Improvement; 1994 (Report No. 45).

72. Lymphatic filariasis: fact sheet. Geneva: World Health Organization; 2018 (http://www.who.int/news-room/fact-sheets/detail/lymphatic-filariasis, accessed May 2019).

73. Ichimori K, King JD, Engels D, Yajima A, Mikhailov A, Lammie P, et al. Global Programme to Eliminate Lymphatic Filariasis: the processes underlying programme success. PLoS Negl Trop Dis. 2014;8(12):e3328.

74. Prichard RK, Basáñez M-G, Boatin BA, McCarthy JS, García HH, Yang GJ, et al. A research agenda for helminth diseases of humans: intervention for control and elimination. PLoS Negl Trop Dis. 2012;6(4):e1549.

75. Lymphatic filariasis: a handbook of practical entomology for national lymphatic filariasis elimination programmes. Geneva: World Health Organization; 2013.

76. Castro MC, Kanamori S, Kannady K, Mkude S, Killeen GF, Fillinger U. The importance of drains for the larval development of lymphatic filariasis and malaria vectors in Dar es Salaam, United Republic of Tanzania. PLoS Negl Trop Dis. 2010;4(5):e693.

77. Lymphatic filariasis: managing morbidity and preventing disability: an aide-mémoire for national programme managers. Geneva: World Health Organization; 2013.

78. Curtis CF, Malecela-Lazaro M, Reuben R, Maxwell CA. Use of floating layers of polystyrene beads to control populations of the filaria vector *Culex quinquefasciatus*. Ann Trop Med Parasitol. 2002;96:S97–104.

79. Sunish IP, Rajendran R, Mani TR, Munirathinam A, Dash AP, Tyagi BK. Vector control complements mass drug administration against Bancroftian filariasis in Tirukoilur, India. Bull World Health Organ. 2007;85(2):138–45.

80. Onchocerciasis (river blindness): fact sheet. Geneva: World Health Organization; 2018 (http://www.who.int/news-room/fact-sheets/detail/onchocerciasis, accessed May 2019).

81. Rozendaal JA. Vector control. Methods for use by individuals and communities. Geneva: World Health Organization; 1997.

82. Jobin W. Prediction of health hazards in tropical reservoirs and evaluation of low-cost methods for disease prevention. Beijing: UNHYDRO; 2004 (https://pdfs.semanticscholar.org/0e3e/12a917c5f8e18332ec106e38f75a01743af1.pdf, accessed May 2019).

83. Dengue and severe dengue: fact sheet. Geneva: World Health Organization; 2018 (http://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue, accessed May 2019).

84. Bhatt S, Gething PW, Brady OJ, Messina JP, Farlow AW, Moyes CL, et al. The global distribution and burden of dengue. Nature. 2013;496(7446):504–7.

85. Brady OJ, Gething PW, Bhatt S, Messina JP, Brownstein JS, Hoen AG, et al. Refining the global spatial limits of dengue virus transmission by evidence-based consensus. PLoS Negl Trop Dis. 2012;6(8):e1760.

86. Global strategy for dengue prevention and control 2012–2020. Geneva: World Health Organization; 2012.

87. Kay BH, Nam VS, Van Tien T, Yen NT, Phong TV, Diep VTB, et al. Control of *Aedes* vectors of dengue in three provinces of Vietnam by use of *Mesocyclops* (Copepoda) and community-based methods validated by entomologic, clinical, and serological surveillance. Am J Trop Med Hyg. 2002;66(1):40–8.

88. WHO, Special Programme for Research and Training in Tropical Diseases. Dengue guidelines for diagnosis, treatment, prevention and control: new edition. Geneva: World Health Organization; 2009:147 (http://www.who.int/rpc/guidelines/9789241547871/en/, accessed May 2019).

89. Erlanger TE, Keiser J, Utzinger J. Effect of dengue vector control interventions on entomological parameters in developing countries: a systematic review and meta-analysis. Med Vet Entomol. 2008;22(3):203–21.

90. Baly A, Toledo ME, Vanlerberghe V, Ceballos E, Reyes A, Sanchez I, et al. Cost-effectiveness of a community-based approach intertwined with a vertical *Aedes* control program. Am J Trop Med Hyg. 2009;81(1):88–93.

91. Japanese encephalitis: fact sheet. Geneva: World Health Organization; 2015 (https://www.who.int/news-room/fact-sheets/detail/japanese-encephalitis, accessed May 2019).

92. Campbell GL, Hills SL, Fischer M, Jacobson JA, Hoke CH, Hombach JM, et al. Estimated global incidence of Japanese encephalitis: a systematic review. Bull World Health Organ. 2011;89(10):766–74E.

93. Tarantola A, Goutard F, Newton P, de Lamballerie X, Lortholary O, Cappelle J, et al. Estimating the burden of Japanese encephalitis virus and other encephalitides in countries of the Mekong region. PLoS Negl Trop Dis. 2014;8(1):e2533.

94. Keiser J, Maltese MF, Erlanger TE, Bos R, Tanner M, Singer BH, et al. Effect of irrigated rice agriculture on Japanese encephalitis, including challenges and opportunities for integrated vector management. Acta Trop. 2005;95(1):40–57.

95. Erlanger TE, Weiss S, Keiser J, Utzinger J, Wiedenmayer K. Past, present, and future of Japanese encephalitis. Emerg Infect Dis. 2009;15(1):1–7.

96. Malnutrition: fact sheet. Geneva: World Health Organization; 2018 (http://www.who.int/news-room/fact-sheets/detail/malnutrition, accessed May 2019).

97. WHO, UNICEF, USAID. Improving nutrition outcomes with better water, sanitation and hygiene: Practical solutions for policies and programmes. Geneva: World Health Organization; 2015.

98. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, De Onis M, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet. 2013;382(9890):427–51.

99. Checkley W, Buckley G, Gilman RH, Assis AM, Guerrant RL, Morris SS, et al. Multi-country analysis of the effects of diarrhoea on childhood stunting. Int J Epidemiol. 2008;37(4):816–30.

100. Dewey KG, Mayers DR. Early child growth: how do nutrition and infection interact? Matern Child Nutr. 2011;7:129–42.

101. Kotloff KL, Nataro JP, Blackwelder WC, Nasrin D, Farag TH, Panchalingam S, et al. Burden and aetiology of diarrhoeal disease in infants and young children in developing countries (the Global Enteric Multicenter Study, GEMS): a prospective, case-control study. Lancet. 2013;382(9888):209–22.

102. Ngure FM, Reid BM, Humphrey JH, Mbuya MN, Pelto G, Stoltzfus RJ. Water, sanitation, and hygiene (WASH), environmental enteropathy, nutrition, and early child development: making the links. Ann NY Acad Sci. 2014;1308(1):118–28.

103. Escobedo AA, Almirall P, J Robertson LJ, Franco RM, Hanevik K, Morch K, et al. Giardiasis: the ever-present threat of a neglected disease. Infect Disord Drug Targets. 2010;10(5):329–48.

104. Halliez MC, Buret AG. Extra-intestinal and long term consequences of *Giardia duodenalis* infections. World J Gastroenterol. 2013;19(47):8974–85.

105. Lin A, Arnold BF, Afreen S, Goto R, Huda T, Haque R, et al. Household environmental conditions are associated with enteropathy and impaired growth in rural Bangladesh. Am J Trop Med Hyg. 2013; 89(1):130–7.

106. Keusch GT, Denno DM, Black RE, Duggan C, Guerrant RL, Lavery JV, et al. Environmental enteric dysfunction: pathogenesis, diagnosis, and clinical consequences. Clin Infect Dis. 2014;59(Suppl 4):S207–12.

107. Prendergast A, Kelly P. Enteropathies in the developing world: neglected effects on global health. Am J Trop Med Hyg. 2012;86(5):756–63.

108. Dangour AD, Watson L, Cumming O, Boisson S, Che Y, Velleman Y, et al. Interventions to improve water quality and supply, sanitation and hygiene practices, and their effects on the nutritional status of children. Cochrane Database Syst Rev. 2013;(8):CD009382.

109. Ikeda N, Irie Y, Shibuya K. Determinants of reduced child stunting in Cambodia: analysis of pooled data from three Demographic and Health Surveys. Bull World Health Organ. 2013;91(5):341–9.

110. Humphrey JH, Mbuya MN, Nitozini R, Moulton LH, Stoltzfus RJ, Tavengwa NV, et al. Independent and combined effects of improved water, sanitation, and hygiene, and improved complementary feeding, on child stunting and anaemia in rural Zimbabwe: a cluster-randomised trial. Lancet Glob Health. 2019;7:e132–47.

111. Luby SP, Rahman M, Arnold BF, Unicomb L, Ashraf S, Winch PJ, et al. Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Bangladesh: a cluster randomised controlled trial. Lancet Glob Health. 2018;6(3):e302–15.

112. Null C, Stewart CP, Pickering AJ, Dentz HN, Arnold BF, Arnold CD, et al. Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Kenya: a cluster-randomised controlled trial. Lancet Glob Health. 2018;6(3):e316–29.

113. Cairncross S, Kinnear J. Elasticity of demand for water in Khartoum, Sudan. Soc Sci Med. 1992;34(2):183–9.

114. Chikava W, Annegarn HJ. Human and physical energy cycles in a subsistence village in South Africa. J Energy South Afr. 2013;24(2):67–75.

115. Wheeler T, von Braun J. Climate change impacts on global food security. Science. 2013;341(6145):508–13.

116. Climate change and hunger. Rome: World Food Programme; 2009.

117. Global Health Observatory. Geneva: World Health Organization; 2016 (https://www.who.int/gho/en/, accessed June 2019).

118. Modell JH. Prevention of needless deaths from drowning. South Med J. 2010;103(7):650–3.

119. Global report on drowning. Preventing a leading killer. Geneva: World Health Organization; 2014 (https://apps.who.int/iris/bitstream/handle/10665/143893/9789241564786_eng.pdf?sequence=1, accessed May 2019).

120. Facts about injuries – drowning. Geneva: World Health Organization; 2010 (https://www.who.int/violence_injury_prevention/publications/other_injury/en/drowning_factsheet.pdf, accessed May 2019).

121. Hales S, Kovats S, Lloyd S, Campbell-Lendrum D, editors. Quantitative risk assessment of the potential effects of climate change on health. Geneva: World Health Organization; 2014 (https://apps.who.int/iris/bitstream/handle/10665/134014/9789241507691_eng.pdf?sequence=1&isAllowed=y, accessed May 2019).

122. Thompson DC, Rivara F. Pool fencing for preventing drowning in children. Cochrane Database Syst Rev. 1998;(1):CD001047.

123. Iqbal A, Shirin T, Ahmed T, Ahmed S, Islam N, Sobhan A, et al. Childhood mortality due to drowning in rural Matlab of Bangladesh: magnitude of the problem and proposed solutions. J Health Popul Nutr. 2007;3:370–6.

124. Preventing drownings of commercial fishermen. Washington DC: National Institute for Occupational Safety and Health; 1994 (Report No. 94-107).

125. Giustini M, Ade P, Taggi F, Funari E. [Accidents in recreational waters]. Ann Ist Sup Sanit. 2002;39(1):69–76.

126. Sansiritaweesook G, Muangsom N, Kanato M, Ratanasiri A. Effectiveness of community participation in a surveillance system initiative to prevent drowning in Thailand. Asia Pac J Public Health. 2015;27(2):2677–89.

127. Rahman F, Bose S, Linnan M, Rahman A, Mashreky S, Haaland B, et al. Cost-effectiveness of an injury and drowning prevention program in Bangladesh. Pediatrics. 2012;130(6):e1621–8.

128. Arsenic: fact sheet. Geneva: World Health Organization; 2018 (http://www.who.int/news-room/fact-sheets/detail/arsenic, accessed May 2019).

129. Arsenic in drinking-water: background document for development of WHO guidelines for drinking-water quality. Geneva: World Health Organization; 2011 (https://www.who.int/water_sanitation_health/dwq/chemicals/arsenic.pdf?ua=1, accessed May 2019).

130. Huang L, Wu H, van der Kuijp TJ. The health effects of exposure to arsenic-contaminated drinking water: a review by global geographical distribution. Int J Environ Health Res. 2015;25(4):432–52.

131. Argos M, Kalra T, Rathouz PJ, Chen Y, Pierce B, Parvez F, et al. Arsenic exposure from drinking water, and all-cause and chronic-disease mortalities in Bangladesh (HEALS): a prospective cohort study. Lancet. 2010;376(9737):252–8.

132. Johnson CA, Bretzler A, editors. Geogenic contamination handbook: addressing arsenic and fluoride in drinking water. Dübendorf: Swiss Federal Institute of Aquatic Science and Technology (Eawag); 2017 (https://www.eawag.ch/fileadmin/Domain1/Forschung/Menschen/Trinkwasser/Wrq/Handbook/geogenic-contamination-handbook.pdf, accessed May 2019).

133. George CM, van Geen A, Slavkovich V, Singha A, Levy D, Islam T, et al. A cluster-based randomized controlled trial promoting community participation in arsenic mitigation efforts in Bangladesh. Environ Health. 2012;11(41):1–10.

134. Inauen J, Mosler HJ. Developing and testing theory-based and evidence-based interventions to promote switching to arsenic-safe wells in Bangladesh. J Health Psychol. 2014;19(12):1483–98.

135. George CM, Factor-Litvak P, Khan K, Islam T, Singha A, Moon-Howard J, et al. Approaches to increase arsenic awareness in Bangladesh. An evaluation of an arsenic education program. Health Educ Behav. 2012;40(3):331–8.

136. Hadi A. Fighting arsenic at the grassroots: experience of BRAC's community awareness initiative in Bangladesh. Health Policy Plan. 2003;18(1):93–100.

137. Hanchett S, Nahar Q, Van Agthoven A, Geers C, Rezvi MFJ. Increasing awareness of arsenic in Bangladesh: lessons from a public education programme. Health Policy Plan. 2002;17(4):393–401.

138. Shafiquzzaman M, Azam MS, Mishima I, Nakajima J. Technical and social evaluation of arsenic mitigation in rural Bangladesh. J Health Popul Nutr. 2009;674–83.

139. Norton DM, Rahman M, Shane AL, Hossain Z, Kulick RM, Bhuiyan MI, et al. Flocculant-disinfectant point-of-use water treatment for reducing arsenic exposure in rural Bangladesh. Int J Environ Health Res. 2009;19(1):17–29.

140. Milton AH, Smith W, Dear K, Ng J, Sim M, Ranmuthugala G, et al. A randomised intervention trial to assess two arsenic mitigation options in Bangladesh. J Environ Sci Health Part A. 2007;42(12):1897–908.

141. Yang CY, Chiu HF, Wu TN, Chuang HY, Ho SC. Reduction in kidney cancer mortality following installation of a tap water supply system in an arsenic-endemic area of Taiwan. Arch Environ Health Int J. 2004;59(9):484–8.

142. Chiu HF, Yang CY. Decreasing trend in renal disease mortality after cessation from arsenic exposure in a previous arseniasis-endemic area in southwestern Taiwan. J Toxicol Environ Health A. 2005;68(5):319–27.

143. Yang CY, Chiu HF, Chang CC, Ho SC, Wu TN. Bladder cancer mortality reduction after installation of a tap-water supply system in an arsenious-endemic area in southwestern Taiwan. Environ Res. 2005;98(1):127–32.

144. Chiu HF, Ho SC, Yang CY. Lung cancer mortality reduction after installation of tap-water supply system in an arseniasis-endemic area in southwestern Taiwan. Lung Cancer. 2004;46(3):265–70.

145. Chang CC, Ho SC, Tsai SS, Yang CY. Ischemic heart disease mortality reduction in an arseniasis-endemic area in southwestern Taiwan after a switch in the tap-water supply system. J Toxicol Environ Health. 2004;67(17):1353–61.

146. Exposure to inadequate or excess fluoride: a major public health concern. Geneva: World Health Organization; 2010 (http://www.who.int/ipcs/features/fluoride.pdf, accessed May 2019).

147. Khairnar MR, Dodamani AS, Jadhav HC, Naik RG, Deshmukh MA. Mitigation of fluorosis – a review. J Clin Diagn Res. 2015;9(6):ZE05.

148. Indermitte E, Saava A, Karro E. Reducing exposure to high fluoride drinking water in Estonia – a countrywide study. Int J Environ Res Public Health. 2014;11(3):3132–42.

149. Huber AC, Tobias R, Mosler HJ. Evidence-based tailoring of behavior-change campaigns: increasing fluoride-free water consumption in rural Ethiopia with persuasion. Appl Psychol Health Well-being. 2014;6(1):96–118.

150. Wang C, Gao Y, Wang W, Zhao L, Zhang W, Han H, et al. A national cross-sectional study on effects of fluoride-safe water supply on the prevalence of fluorosis in China. BMJ Open. 2012;2(5):e001564.

151. Majumdar KK. Health impact of supplying safe drinking water containing fluoride below permissible level on fluorosis patients in a fluoride-endemic rural area of West Bengal. Indian J Public Health. 2011;55(4):303.

152. Legionellosis: fact sheet. Geneva: World Health Organization; 2018 (http://www.who.int/news-room/fact-sheets/detail/legionellosis, accessed May 2019).

153. Cunha BA, Burillo A, Bouza E. Legionnaires' disease. Lancet. 2016;387(10016):376–85.

154. Costa F, Hagan JE, Calcagno J, Kane M, Torgerson P, Martinez-Silveira MS, et al. Global morbidity and mortality of leptospirosis: a systematic review. PLoS Negl Trop Dis. 2015;9(9):e0003898.

155. Torgerson PR, Hagan JE, Costa F, Calcagno J, Kane M, Martinez-Silveira MS, et al. Global burden of leptospirosis: estimated in terms of disability adjusted life years. PLoS Negl Trop Dis. 2015;9(10):e0004122.

156. Wynwood SJ, Graham GC, Weier SL, Collet TA, McKay DB, Craig SB. Leptospirosis from water sources. Pathog Glob Health. 2014;108(7):334–8.

157. Water related diseases: leptospirosis. Geneva: World Health Organization; 2019 (http://www.who.int/water_sanitation_health/diseases-risks/diseases/leptospirosis/en/, accessed May 2019).

158. Hepatitis E: fact sheet. Geneva: World Health Organization; 2019 (http://www.who.int/news-room/fact-sheets/detail/hepatitis-e, accessed May 2019).

159. Hepatitis A: fact sheet. Geneva: World Health Organization; 2019 (http://www.who.int/news-room/fact-sheets/detail/hepatitis-a, accessed May 2019).

160. Pérez-Gracia MT, García M, Suay B, Mateos-Lindemann ML. Current knowledge on hepatitis E. J Clin Transl Hepatol. 2015;3(2):117.

161. Yugo DM, Meng XJ. Hepatitis E virus: foodborne, waterborne and zoonotic transmission. Int J Environ Res Public Health. 2013;10(10):4507–33.

162. Management of cyanobacteria in drinking-water supplies: information for regulators and water suppliers (WHO/FWC/WSH/15.03). Geneva: World Health Organization; 2015 (https://apps.who.int/iris/bitstream/handle/10665/153970/WHO_FWC_WSH_15.03_eng.pdf?sequence=1, accessed May 2019).

163. Cheung MY, Liang S, Lee J. Toxin-producing cyanobacteria in freshwater: a review of the problems, impact on drinking water safety, and efforts for protecting public health. J Microbiol. 2013;51(1):1–10.

164. Dodds WK, Bouska WW, Eitzmann JL, Pilger TJ, Pitts KL, Riley AJ, et al. Eutrophication of US freshwaters: analysis of potential economic damages. Environ Sci Technol. 2008;43(1):12–9.

165. Elliott JA. Is the future blue-green? A review of the current model predictions of how climate change could affect pelagic freshwater cyanobacteria. Water Res. 2012;46(5):1364–71.

166. GBD compare Viz hub. Seattle (WA): Institute for Health Metrics and Evaluation; 2017 (http://vizhub.healthdata.org/gbd-compare, accessed May 2019).

167. Lead in drinking-water: background document for development of WHO guidelines for drinking-water quality. Geneva: World Health Organization; 2011 (http://www.who.int/water_sanitation_health/water-quality/guidelines/chemicals/lead.pdf, accessed May 2019).

168. Lead poisoning and health: fact sheet. Geneva: World Health Organization; 2018 (http://www.who.int/news-room/fact-sheets/detail/lead-poisoning-and-health, accessed May 2019).

169. Pfadenhauer LM, Burns J, Rohwer A, Rehfuess EA. Effectiveness of interventions to reduce exposure to lead through consumer products and drinking water: a systematic review. Environ Res. 2016;147:525–36.

170. Brown MJ, Margolis S. Lead in drinking water and human blood lead levels in the United States. Morbid Mortal Wkly Rep. 2012;61(Suppl 4):1–9.

171. Scabies. Geneva: World Health Organization; 2019 (https://www.who.int/neglected_diseases/diseases/scabies/en/, accessed May 2019).

172. Water-related diseases: scabies. Geneva: World Health Organization; 2001 (http://www.who.int/water_sanitation_health/diseases-risks/diseases/scabies/en/, accessed May 2019).

173. Water-related diseases: spinal injury. Geneva: World Health Organization; 2001 (http://www.who.int/water_sanitation_health/diseases/spinal/en/, accessed May 2019).

174. Spinal cord injury: fact sheet. Geneva: World Health Organization; 2013 (http://www.who.int/mediacentre/factsheets/fs384/en/, accessed May 2019).

175. Lee BB, Cripps RA, Fitzharris M, Wing PC. The global map for traumatic spinal cord injury epidemiology: update 2011, global incidence rate. Spinal Cord. 2014;52(2):110–6.

176. Vlok AJ, Petersen I, Dunn RN, Stander J. Shallow-water spinal injuries: devastating but preventable. South Afr Med J. 2010;100(10):682.

177. Chang SK, Tominaga GT, Wong JH, Weldon EJ, Kaan KT. Risk factors for water sports-related cervical spine injuries. J Trauma Acute Care Surg. 2006;60(5):1041–6.

178. Poliomyelitis: fact sheet. Geneva: World Health Organization; 2019 (http://www.who.int/news-room/fact-sheets/detail/poliomyelitis, accessed May 2019).

179. Campbell OMR, Benova L, Gon G, Afsana K, Cumming O. Getting the basic rights – the role of water, sanitation and hygiene in maternal and reproductive health: a conceptual framework. Trop Med Int Health. 2015;20(3):252–67.

180. Maternal mortality: fact sheet. Geneva: World Health Organization; 2018 (http://www.who.int/news-room/fact-sheets/detail/maternal-mortality, accessed May 2019).

181. Benova L, Cumming O, Campbell OM. Systematic review and meta-analysis: association between water and sanitation environment and maternal mortality. Trop Med Int Health. 2014;19(4):368–87.

182. Allegranzi B, Nejad SB, Combescure C, Graafmans W, Attar H, Donaldson L, et al. Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis. Lancet. 2011;377(9761):228–41.

183. Oza S, Lawn JE, Hogan DR, Mathers C, Cousens SN. Neonatal cause-of-death estimates for the early and late neonatal periods for 194 countries: 2000–2013. Bull World Health Organ. 2014;93:19–28.

184. Neglected Tropical Disease NGO Network, WHO. WASH and Health working together: a "how-to" guide for neglected tropical disease programmes. Geneva: World Health Organization; 2018 (https://apps.who.int/iris/bitstream/handle/10665/279913/9789241515009-eng.pdf?ua=1, accessed May 2019).

185. Yaws: fact sheet. Geneva: World Health Organization; 2018 (http://www.who.int/news-room/fact-sheets/detail/yaws, accessed May 2019).

186. Dracunculiasis (guinea-worm disease): fact sheet. Geneva: World Health Organization; 2018 (http://www.who.int/news-room/fact-sheets/detail/dracunculiasis-(guinea-worm-disease), accessed May 2019).

187. Leprosy: fact sheet. Geneva: World Health Organization; 2018 (http://www.who.int/news-room/fact-sheets/detail/leprosy, accessed May 2019).

188. Garsed C, Waite R. The importance of water, sanitation and hygiene for lymphatic filariasis and leprosy care and inclusion. Briefing note. London: The Leprosy Mission, Water Aid; 2015 (https://www.leprosymission.org.uk/documents/WASH_in_LF_and_leprosy_self-care_briefing_note_2.pdf, accessed May 2019).

189. Water-related diseases: ringworm (tinea). Geneva: World Health Organization; 2001 (http://www.who.int/water_sanitation_health/diseases-risks/diseases/ringworm/en/, accessed May 2019).

190. Chikungunya: fact sheet. Geneva: World Health Organization; 2017 (http://www.who.int/news-room/fact-sheets/detail/chikungunya, accessed May 2019).

191. Zika virus: fact sheet. Geneva: World Health Organization; 2018 (http://www.who.int/news-room/fact-sheets/detail/zika-virus, accessed May 2019).

192. Yellow fever: fact sheet. Geneva: World Health Organization. 2018 (http://www.who.int/news-room/fact-sheets/detail/yellow-fever, accessed May 2019).

193. WHO, International Water Association. Water safety plan manual: step-by-step risk management for drinking-water suppliers. Geneva: World Health Organization; 2009 (https://www.who.int/water_sanitation_health/publications/publication_9789241562638/en, accessed May 2019).

194. Bartram J, Corrales L, Davison A, Deere D, Drury D, Gordon B, et al. Water safety planning for small community water supplies: step-by-step risk management guidance for drinking-water supplies in small communities. Geneva: World Health Organization; 2012 (https://www.who.int/water_sanitation_health/publications/small-comm-water_supplies/en/, accessed May 2019).

195. Water safety planning. Geneva: World Health Organization; 2016 (https://www.who.int/water_sanitation_health/water-quality/safety-planning/en/).

196. Recreational, or bathing, waters. Geneva: World Health Organization; 2016 (http://www.who.int/water_sanitation_health/bathing/en/).

197. Guidelines on sanitation and health. Geneva: World Health Organization; 2018 (http://www.who.int/water_sanitation_health/sanitation-waste/sanitation/sanitation-guidelines/en/, accessed May 2019).

198. Sanitation safety planning. Manual for safe use and disposal of wastewater, greywater and excreta. Geneva: World Health Organization; 2015 (https://www.who.int/water_sanitation_health/publications/ssp-manual/en/).

199. UNICEF, WHO. Drinking water, sanitation and hygiene in schools: global baseline report 2018. New York City (NY): UNICEF; 2018 (https://www.who.int/water_sanitation_health/publications/jmp-wash-in-schools-en.pdf, accessed May 2019).

200. Bürgmann H, Frigon DH, Gaze WM, Manaia C, Pruden A, Singer AC, et al. Water and sanitation: an essential battlefront in the war on antimicrobial resistance. FEMS Microbiol Ecol. 2018;94(9).

201. Antimicrobial resistance: an emerging water, sanitation and hygiene issue. Geneva: World Health Organization; 2014 (http://www.who.int/water_sanitation_health/publications/antimicrobial-resistance/en/, accessed May 2019).

202. Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 2012;380(9859):2224–60.

203. Ezzati M, Lopez AD, Rodgers A, Vander Hoorn S, Murray CJ, the Comparative Risk Assessment Collaborating Group. Selected major risk factors and global and regional burden of disease. Lancet. 2002;360(9343):1347–60.

Annex 1. Estimating the burden of disease attributable to inadequate WASH

What is meant by the population attributable fraction of a risk factor?

The population attributable fraction is the proportional reduction in death or disease that would occur if exposure to a risk were removed or reduced to an alternative (or counterfactual) exposure distribution. In this study, risks from inadequate WASH were considered to be reduced to the minimum exposure distributions (or counterfactual distributions) that are currently achieved in certain population groups with the necessary technology and infrastructure.

For each risk factor (e.g. inadequate drinking-water, sanitation and hygiene separately), the population attributable fraction can be estimated by comparing current distributions of exposure to the risk factor with a counterfactual risk distribution by country and, if possible, for each exposure level, sex and age group:

$$PAF = \frac{\sum_{i=1}^{n} p_i (RR_i - 1)}{\sum_{i=1}^{n} p_i (RR_i - 1) + 1} \quad \text{(eq. 1)}$$

where p_i and RR_i are the proportion of the exposed population and the relative risk at exposure level i, respectively, and n is the total number of exposure levels.

A first step is to establish a realistic minimum exposure level. The simplest case of an alternative distribution of exposure to the risk factor is that in which the exposure can be reduced to zero, but this is not always achievable in practice. Therefore, the analysis addressed by how much the disease burden would decrease if exposure to a risk factor were reduced, not to zero, but to some achievable level (the counterfactual or baseline level).

Exposure to drinking-water, sanitation and hygiene is related by similar mechanisms and policy interventions. Equation 2 is generally used for estimating the burden attributable to an interlinked cluster of risk factors *(1)* (relevant for the diarrhoea and schistosomiasis burden):

$$PAF = 1 - \prod_{r=1}^{R} (1 - PAF_r) \quad \text{(eq. 2)}$$

where r is the individual risk factor and R the total number of risk factors accounted for in the cluster.

Estimating the population attributable fraction

To estimate the comprehensive health impacts of WASH-related risks worldwide, CRAs were compiled for each disease, complemented with information on the disease transmission pathway, approximate epidemiological estimates and surveys of expert opinion. For each of the diseases and injuries plausibly related to inadequate WASH and listed in the WHO Global Health Observatory for 2016 *(2)*, the literature was systematically searched to identify the best evidence of population health impacts of WASH-related risks.

Four approaches were used to obtain estimates of the fractions of disease attributable to WASH-related risks, according to the estimates available and the type and amount of evidence available on exposure and exposure–risk relations.

Comparative risk assessment
When available, CRA methods were used. These methods comprise: detailed population exposure data; an alternative (counterfactual) exposure distribution to which WASH-related risks could be reduced; and matching exposure–risk relations for the global population. For each disease, these data were combined into population attributable fractions. Furthermore, a set of basic criteria was used for selection of exposure–disease pairings, to define alternative (counterfactual) exposure distribution and for selection of exposure and exposure–risk data. The methods are described in detail elsewhere *(1, 3–5)*.

Disease transmission pathway
In certain cases, a disease is transmitted via a pathway that necessarily implicates WASH, and is therefore modifiable. Soil-transmitted helminthiasis, for example, requires the presence of inadequately disposed human excreta in the environment and is therefore entirely attributable to WASH.

Calculations based on limited epidemiological data
When limited exposure or exposure–response information was available, population attributable fractions were estimated on the basis of more assumptions and extrapolations and, presumably, weaker evidence.

Expert survey
When neither CRA at global level nor sufficient data were available to make approximate calculations of population attributable fractions, three or more experts were consulted to provide estimates for one or more disease or injury. The experts were selected on the basis of their publication record, preferably international, in the area of the disease or the relevant WASH-related risk factor. The experts were provided with abstracts of references from the systematic reviews and an initial estimate based on pooled estimates from the literature. CRA results often provided partial results for a disease and a corresponding attributable risk. The experts were asked to provide a best estimate of the fraction of disease in the global population attributable to the reasonably modifiable environment, with 95% confidence intervals. The experts were encouraged to provide estimates by age, sex and region.

For diseases for which the attributable burden was estimated by CRA, no additional risk factor was considered from any other assessment method for estimating the overall population attributable fraction.

Estimates of the burden of disease attributable to inadequate WASH

To calculate the fraction of disease attributable to a risk factor for any defined population, compiled or estimated population attributable fractions were multiplied by the corresponding WHO disease statistics *(6)*, by disease or injury, country, sex and age group, for deaths and DALYs. The following equations were used:

$$AM = PAF \times M \qquad \text{(eq. 3)}$$

and

$$AB(DALYs) = PAF \times B(DALYs) \qquad \text{(eq. 4)}$$

Where *AM* = attributable mortality, *PAF* = population attributable fraction, *M* = mortality, *AB (DALYs)* = attributable burden in DALYs and *B (DALYs)* = burden of disease in DALYs, for each disease or injury, country, sex and age group, where relevant. Further details are given elsewhere *(7, 8)*.

WHO regional groupings

WHO African Region:
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, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, São Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, South Sudan, Togo, Uganda, United Republic of Tanzania, Zambia, Zimbabwe.

WHO Region of the Americas:
Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia (Plurinational State of), Brazil, Canada, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, United States of America, Uruguay, Venezuela (Bolivarian Republic of).

WHO South-East Asia Region:
Bangladesh, Bhutan, Democratic People's Republic of Korea, India, Indonesia, Maldives, Myanmar, Nepal, Sri Lanka, Thailand, Timor-Leste.

WHO European Region:
Albania, Andorra, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Malta, Monaco, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Republic of Moldova, Romania, Russian Federation, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tajikistan, Turkey, Turkmenistan, Ukraine, United Kingdom of Great Britain and Northern Ireland, Uzbekistan.

WHO Eastern Mediterranean Region:
Afghanistan, Bahrain, Djibouti, Egypt, Iran (Islamic Republic of), Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Pakistan, Qatar, Saudi Arabia, Somalia, Sudan, Syrian Arab Republic, Tunisia, United Arab Emirates, Yemen.

WHO Western Pacific Region:
Australia, Brunei Darussalam, Cambodia, China, Cook Islands, Fiji, Japan, Kiribati, Lao People's Democratic Republic, Malaysia, Marshall Islands, Micronesia (Federated States of), Mongolia, Nauru, New Zealand, Niue, Palau, Papua New Guinea, Philippines, Republic of Korea, Samoa, Singapore, Solomon Islands, Tonga, Tuvalu, Vanuatu, Viet Nam.

Deaths (thousands) attributable to inadequate WASH (selected), by WHO region, 2016

WHO region						WASH-attributable deaths (000)													
		Population (000)	*Total deaths (000)*	*Total WASH-related deaths (000)*	*% of total deaths*	Diarrhoeal diseases	Soil-transmitted helminths infections	Respiratory infections	Protein-energy malnutrition (only PEM)	Trachoma	Schistosomiasis	Lymphatic filariasis	*Subtotal drinking-water sanitation and hygiene*	Malaria	Dengue	Onchocerciasis	*Subtotal water resource management*	Drowning	*Subtotal safety of water environments*
African	**Males**	*508 849*	*4 640*	*518.7*	*11.2*	230.5	2.0	71.6	12.7	0.0	5.0	0.0	*321.8*	161.1	0.1	0.0	*161.3*	35.6	*35.6*
	Females	*511 071*	*4 205*	*473.9*	*11.3*	208.8	2.7	64.5	10.8	0.0	4.7	0.0	*291.4*	163.3	0.3	0.0	*163.6*	18.8	*18.8*
	Children 0–4 years	*164 016*	*2 733*	*505.6*	*18.5*	172.1	3.4	68.2	23.4	0.0	0.1	0.0	*267.3*	220.8	0.2	0.0	*221.0*	17.3	*17.3*
	Both sexes	*1 019 920*	*8 845*	*992.6*	*11.2*	439.2	4.8	136.1	23.4	0.0	9.7	0.0	*613.2*	324.5	0.4	0.0	*324.9*	54.5	*54.5*
Americas	**Males**	*490 695*	*3 690*	*36.1*	*1.0*	5.4	0.0	16.1	0.3	0.0	0.0	0.0	*21.8*	0.2	1.0	0.0	*1.2*	13.1	*13.1*
	Females	*501 334*	*3 185*	*25.0*	*0.8*	5.4	0.0	15.8	0.2	0.0	0.0	0.0	*21.5*	0.2	0.9	0.0	*1.1*	2.5	*2.5*
	Children 0–4 years	*74 744*	*215*	*8.2*	*3.8*	3.4	0.0	2.4	0.5	0.0	0.0	0.0	*6.4*	0.1	0.3	0.0	*0.4*	1.5	*1.5*
	Both sexes	*992 028*	*6 876*	*61.1*	*0.9*	10.8	0.1	31.9	0.5	0.0	0.1	0.0	*43.3*	0.3	1.9	0.0	*2.3*	15.6	*15.6*
Eastern Medi-terranean	**Males**	*342 557*	*2 261*	*61.5*	*2.7*	30.6	0.1	15.2	0.8	0.0	0.3	0.0	*47.0*	3.0	0.6	0.0	*3.6*	10.9	*10.9*
	Females	*321 779*	*1 877*	*63.6*	*3.4*	38.3	0.1	13.5	0.8	0.0	0.3	0.0	*53.0*	3.5	0.6	0.0	*4.0*	6.6	*6.6*
	Children 0–4 years	*81 746*	*879*	*71.9*	*8.2*	43.6	0.2	17.4	1.6	0.0	0.0	0.0	*62.8*	2.0	0.3	0.0	*2.3*	6.8	*6.8*
	Both sexes	*664 335*	*4 138*	*125.2*	*3.0*	68.9	0.2	28.7	1.6	0.0	0.6	0.0	*100.0*	6.5	1.1	0.0	*7.6*	17.5	*17.5*
European	**Males**	*444 247*	*4 644*	*27.1*	*0.6*	1.2	0.0	12.9	0.0	0.0	0.0	0.0	*14.1*	0.0	0.0	0.0	*0.0*	13.0	*13.0*
	Females	*471 918*	*4 571*	*15.5*	*0.3*	1.5	0.0	11.0	0.0	0.0	0.0	0.0	*12.5*	0.0	0.0	0.0	*0.0*	3.0	*3.0*
	Children 0–4 years	*56 610*	*108*	*3.1*	*2.9*	1.0	0.0	1.3	0.0	0.0	0.0	0.0	*2.3*	0.0	0.0	0.0	*0.0*	0.8	*0.8*
	Both sexes	*916 166*	*9 215*	*42.6*	*0.5*	2.7	0.0	23.9	0.0	0.0	0.0	0.0	*26.6*	0.0	0.0	0.0	*0.0*	16.0	*16.0*

WHO region		*Population (000)*	*Total deaths (000)*	*Total WASH-related deaths (000)*	*% of total deaths*	WASH-attributable deaths (000)													
						Diarrhoeal diseases	**Soil-transmitted helminths infections**	**Respiratory infections**	**Protein-energy malnutrition (only PEM)**	**Trachoma**	**Schistosomiasis**	**Lymphatic filariasis**	***Subtotal drinking-water sanitation and hygiene***	**Malaria**	**Dengue**	**Onchocerciasis**	***Subtotal water resource management***	**Drowning**	***Subtotal safety of water environments***
South-East Asian	**Males**	*997 199*	*7 545*	*250.7*	*3.3*	130.9	0.4	43.6	0.9	0.0	0.0	0.0	*175.8*	9.3	16.4	0.0	*25.7*	49.2	*49.2*
	Females	*950 433*	*6 274*	*267.0*	*4.3*	164.2	0.5	50.7	1.5	0.0	0.0	0.0	*216.8*	11.9	14.9	0.0	*26.8*	23.4	*23.4*
	Children 0–4 years	*174 760*	*1 407*	*121.9*	*8.7*	70.9	0.4	25.3	2.4	0.0	0.0	0.0	*98.9*	5.3	4.0	0.0	*9.3*	13.7	*13.7*
	Both sexes	*1 947 631*	*13 819*	*517.7*	*3.7*	295.1	0.9	94.3	2.4	0.0	0.0	0.0	*392.7*	21.1	31.3	0.0	*52.4*	72.6	*72.6*
Western Pacific	**Males**	*964 712*	*7 451*	*73.0*	*1.0*	6.4	0.1	29.0	0.1	0.0	0.0	0.0	*35.7*	1.2	1.8	0.0	*3.0*	34.2	*34.2*
	Females	*925 076*	*6 328*	*58.8*	*0.9*	5.6	0.1	26.5	0.1	0.0	0.0	0.0	*32.3*	1.3	1.8	0.0	*3.1*	23.5	*23.5*
	Children 0–4 years	*121 999*	*313*	*22.2*	*7.1*	6.1	0.2	5.9	0.3	0.0	0.0	0.0	*12.5*	1.3	1.9	0.0	*3.2*	6.5	*6.5*
	Both sexes	*1 889 788*	*13 779*	*131.8*	*1.0*	12.0	0.2	55.5	0.3	0.0	0.1	0.0	*68.0*	2.5	3.6	0.0	*6.1*	57.7	*57.7*
All	**Males**	*3 748 257*	*30 231*	*967.1*	*3.2*	405.0	2.7	188.4	14.8	0.0	5.4	0.0	616.3	174.8	19.9	0.0	194.7	156.1	156.1
	Females	*3 681 611*	*26 441*	*903.9*	*3.4*	423.7	3.6	181.9	13.4	0.0	5.0	0.0	627.5	180.1	18.5	0.0	198.5	77.8	77.8
	Children 0–4 years	*673 875*	*5 655*	*732.9*	*13.0*	297.0	4.2	120.6	28.2	0.0	0.1	0.0	450.2	229.5	6.7	0.0	236.2	46.6	46.6
	Both sexes	*7 429 869*	*56 672*	*1871.0*	*3.3*	828.7	6.2	370.4	28.2	0.0	10.4	0.0	1243.9	354.9	38.3	0.0	393.2	233.9	233.9

DALYs (thousands) attributable to inadequate WASH, by region, 2016

WHO region						WASH-attributable DALYs (000)													
		Population ('000)	*Total DALYs (000)*	*Total WASH-related DALYs (000)*	*% of total DALYs*	Diarrhoeal diseases	Soil-transmitted helminth infections	Respiratory infections	Malnutrition (only PEM)	Trachoma	Schistosomiasis	Lymphatic filariasis	*Subtotal drinking-water, sanitation and hygiene*	Malaria	Dengue	Onchocerciasis	*Subtotal water resource*	Drowning	*Subtotal safety of water environments*
African	**Males**	*508 849*	*315 473*	*38 866*	*12.3*	15 306	521	4 607	1 196	17	511	378	*22 536*	13 654	42	52	*13 748*	2 581	*2 581*
	Females	*511 071*	*283 142*	*34 969*	*12.4*	13 148	627	4 151	1 015	24	519	67	*19 551*	*13 916*	55	44	*14 015*	1 403	*1 403*
	Children 0–4 years	*164 016*	*257 277*	*44 256*	*17.2*	16 043	391	3 847	2 212	0	12	0	*22 505*	*20 172*	28	0	*20 200*	1 552	*1 552*
	Both sexes	*1 019 920*	*598 615*	*73 835*	*12.3*	28 453	1 148	8 758	2 212	40	1 030	445	*42 087*	*27 570*	97	96	*27 764*	3 984	*3 984*
Americas	**Males**	*490 695*	*157 394*	*1 956*	*1.2*	426	134	450	30	5	4	13	*1 062*	*13*	94	0	*107*	788	*788*
	Females	*501 334*	*129 478*	*1 229*	*0.9*	398	159	361	24	6	5	4	*958*	13	97	0	*110*	162	*162*
	Children 0–4 years	*74 744*	*21 972*	*1 088*	*4.9*	409	20	431	54	0	0	0	*915*	12	30	0	*42*	131	*131*
	Both sexes	*992 028*	*286 872*	*3 185*	*1.1*	823	293	811	54	11	9	18	*2 020*	25	191	0	*216*	949	*949*
Eastern Medi-terranean	**Males**	*342 557*	*135 761*	*4 714*	*3.5*	2 430	75	1 004	95	15	23	2	*3 644*	216	57	0	*272*	798	*798*
	Females	*321 779*	*116 483*	*4 833*	*4.1*	2 836	82	953	92	19	19	0	*4 002*	248	57	0	*305*	525	*525*
	Children 0–4 years	*81 746*	*83 971*	*6 214*	*7.4*	4 145	26	1 032	187	0	2	0	*5 392*	181	33	0	*214*	608	*608*
	Both sexes	*664 335*	*252 244*	*9 547*	*3.8*	5 266	157	1 957	187	34	42	2	*7 646*	464	113	0	*577*	1 323	*1 323*
European	**Males**	*444 247*	*161 120*	*1 143*	*0.7*	121	3	350	4	0	0	0	*478*	*0*	0	0	*0*	665	*665*
	Females	*471 918*	*139 297*	*494*	*0.4*	115	4	219	3	0	0	0	*341*	0	0	0	*0*	154	*154*
	Children 0–4 years	*56 610*	*11 444*	*743*	*6.5*	126	1	538	7	0	0	0	*671*	0	0	0	*0*	72	*72*
	Both sexes	*916 166*	*300 416*	*1 638*	*0.5*	236	7	569	7	0	0	0	*819*	0	0	0	*0*	818	*818*

WHO region		*Population ('000)*	*Total DALYs (000)*	*Total WASH-related DALYs (000)*	*% of total DALYs*	**WASH-attributable DALYs (000)**													
						Diarrhoeal diseases	Soil-transmitted helminth infections	Respiratory infections	Malnutrition (only PEM)	Trachoma	Schistosomiasis	Lymphatic filariasis	*Subtotal drinking-water, sanitation and hygiene*	Malaria	Dengue	Onchocerciasis	*Subtotal water resource*	Drowning	*Subtotal safety of water environments*
South-East Asian	**Males**	*997 199*	*381 325*	*14 287*	*3.7*	6 442	569	1 806	234	57	0	242	*9 350*	628	1 158	0	*1 786*	3 151	*3 151*
	Females	*950 433*	*331 197*	*13 869*	*4.2*	7 539	628	1 969	264	76	0	44	*10 521*	830	1 012	0	*1 842*	1 506	*1 506*
	Children 0–4 years	*174 760*	*138 290*	*11 218*	*8.1*	6 638	105	1 859	499	0	0	0	*9 101*	483	403	0	*886*	1 231	*1 231*
	Both sexes	*1 947 631*	*712 522*	*28 155*	*4.0*	13 981	1 196	3 775	499	133	0	286	*19 871*	1 458	2 170	0	*3 628*	4 657	*4 657*
Western Pacific	**Males**	*964 712*	*274 492*	*3 900*	*1.4*	573	294	800	20	10	7	25	*1 730*	91	178	0	*269*	1 901	*1 901*
	Females	*925 076*	*235 952*	*2 834*	*1.2*	441	335	638	17	15	7	6	*1 459*	99	187	0	*285*	1 090	*1 090*
	Children 0–4 years	*121 999*	*31 012*	*2 679*	*8.6*	604	42	1 118	37	0	0	0	*1 802*	114	177	0	*291*	586	*586*
	Both sexes	*1 889 788*	*510 444*	*6 734*	*1.3*	1 014	628	1 438	37	25	14	31	*3 188*	190	365	0	*555*	2 991	*2 991*
All	**Males**	*3 748 257*	*1425 564*	*64 866*	*4.6*	25 297	1 597	9 017	1 580	104	546	660	*38 800*	14 602	1 528	52	*16 182*	9 883	*9 883*
	Females	*3 681 611*	*1235 550*	*58 228*	*4.7*	24 477	1 834	8 292	1 416	140	550	122	*36 831*	15 105	1 408	44	*16 557*	4 840	*4 840*
	Children 0–4 years	*673 875*	*543 967*	*66 198*	*12.2*	27 964	586	8 826	2 996	0	14	0	*40 385*	20 962	671	0	*21 633*	4 180	*4 180*
	Both sexes	*7 429 869*	*2661 114*	*123 094*	*4.6*	49 774	3 431	17 308	2 996	244	1 096	782	*75 631*	29 708	2 936	96	*32 740*	14 723	*14 723*

Deaths attributable to water, sanitation and hygiene from selected diseases related to SDG 3.9.2, by cause and country, 2016

		WASH-attributable deaths				
Country	Population (000)	Diarrhoeal diseases	Soil-transmitted helminth infections	Protein–energy malnutrition	Total from selected diseases (related to SDG 3.9.2)	SDG 3.9.2, Mortality rate attributed to WASH (for selected diseases, per 100,000 population)
Afghanistan	34 656	4 703	50	72	4 824	13.9
Albania	2 926	5	0	0	5	0.2
Algeria	40 606	749	2	7	758	1.9
Angola	28 813	13 274	77	715	14 065	48.8
Antigua and Barbuda	101	0	0	0	0	0.1
Argentina	43 847	156	0	3	159	0.4
Armenia	2 925	5	0	0	5	0.2
Australia	24 126	23	0	0	23	0.1
Austria	8 712	11	0	0	11	0.1
Azerbaijan	9 725	108	0	1	109	1.1
Bahamas	391	0	0	0	0	0.1
Bahrain	1 425	1	0	0	1	0.0
Bangladesh	162 952	19 084	55	245	19 384	11.9
Barbados	285	0	0	0	0	0.2
Belarus	9 480	5	0	0	5	0.1
Belgium	11 358	32	0	0	32	0.3
Belize	367	3	0	0	4	1.0
Benin	10 872	5 985	78	431	6 494	59.7
Bhutan	798	31	0	0	32	3.9
Bolivia (Plurinational State of)	10 888	554	6	48	607	5.6
Bosnia and Herzegovina	3 517	3	0	0	3	0.1
Botswana	2 250	257	0	7	265	11.8
Brazil	207 653	2 098	19	58	2 175	1.0
Brunei Darussalam	423	0	0	0	0	0.0
Bulgaria	7 131	9	0	0	9	0.1
Burkina Faso	18 646	8 689	70	498	9 256	49.6
Burundi	10 524	6 369	48	466	6 883	65.4
Cambodia	15 762	906	4	13	923	5.9
Cameroon	23 439	9 866	261	457	10 583	45.2
Canada	36 290	133	0	0	133	0.4
Cape Verde	540	22	0	0	22	4.1
Central African Republic	4 595	3 577	49	147	3 773	82.1
Chad	14 453	13 889	82	632	14 603	101.0
Chile	17 910	36	0	0	36	0.2
China	1 411 415	3 593	35	51	3 680	0.3
Colombia	48 653	315	12	39	366	0.8
Comoros	796	386	1	16	404	50.7
Congo	5 126	1 867	12	105	1 984	38.7
Costa Rica	4 857	41	1	0	42	0.9
Côte d'Ivoire	23 696	10 273	279	622	11 174	47.2
Croatia	4 213	5	0	0	5	0.1
Cuba	11 476	117	1	0	118	1.0
Cyprus	1 170	3	0	0	3	0.3
Czech Republic	10 611	19	0	0	19	0.2
Democratic People's Republic of Korea	25 369	201	2	4	208	0.8
Democratic Republic of the Congo	78 736	42 621	753	3 675	47 050	59.8
Denmark	5 712	17	0	0	17	0.3
Djibouti	942	281	0	13	295	31.3
Dominican Republic	10 649	224	0	10	235	2.2
Ecuador	16 385	91	2	9	102	0.6
Egypt	95 689	1 854	4	58	1 916	2.0
El Salvador	6 345	123	1	3	127	2.0

Country	Population (000)	WASH-attributable deaths: Diarrhoeal diseases	Soil-transmitted helminth infections	Protein–energy malnutrition	Total from selected diseases (related to SDG 3.9.2)	SDG 3.9.2, Mortality rate attributed to WASH (for selected diseases, per 100,000 population)
Equatorial Guinea	1 221	250	6	17	272	22.3
Eritrea	4 955	2 178	4	75	2 258	45.6
Estonia	1 312	0	0	0	0	0.0
Eswatini	1 343	349	2	24	375	27.9
Ethiopia	102 403	42 924	195	1 595	44 713	43.7
Fiji	899	25	0	0	26	2.9
Finland	5 503	2	0	0	2	0.0
France	64 721	172	0	0	172	0.3
Gabon	1 980	388	3	16	407	20.6
Gambia	2 039	555	2	47	605	29.7
Georgia	3 925	7	0	0	7	0.2
Germany	81 915	480	0	0	480	0.6
Ghana	28 207	4 786	39	488	5 313	18.8
Greece	11 184	4	0	0	4	0.0
Grenada	107	0	0	0	0	0.3
Guatemala	16 582	963	13	68	1 044	6.3
Guinea	12 396	5 144	136	253	5 533	44.6
Guinea-Bissau	1 816	609	8	23	640	35.3
Guyana	773	27	0	1	28	3.6
Haiti	10 847	2 436	14	130	2 581	23.8
Honduras	9 113	319	3	8	330	3.6
Hungary	9 753	23	0	0	23	0.2
Iceland	332	0	0	0	0	0.1
India	1 324 171	243 551	529	2 007	246 088	18.6
Indonesia	261 115	18 193	179	55	18 426	7.1
Iran (Islamic Republic of)	80 277	784	1	5	790	1.0
Iraq	37 203	1 109	1	19	1 129	3.0
Ireland	4 726	4	0	0	4	0.1
Israel	8 192	20	0	0	20	0.2
Italy	59 430	82	0	0	82	0.1
Jamaica	2 881	17	0	1	18	0.6
Japan	127 749	213	0	0	213	0.2
Jordan	9 456	58	0	1	59	0.6
Kazakhstan	17 988	68	0	0	69	0.4
Kenya	48 462	24 192	33	566	24 790	51.2
Kiribati	114	18	0	1	19	16.7
Kuwait	4 053	1	0	0	1	0.0
Kyrgyzstan	5 956	46	0	0	46	0.8
Lao People's Democratic Republic	6 758	612	92	18	721	10.7
Latvia	1 971	0	0	0	0	0.0
Lebanon	6 007	47	0	0	47	0.8
Lesotho	2 204	944	2	31	978	44.4
Liberia	4 614	1 835	25	56	1 917	41.5
Libya	6 293	36	0	0	37	0.6
Lithuania	2 908	2	0	0	2	0.1
Luxembourg	576	0	0	0	0	0.0
Madagascar	24 895	7 071	84	371	7 526	30.2
Malawi	18 092	4 750	15	353	5 118	28.3
Malaysia	31 187	127	4	0	131	0.4
Maldives	428	1	0	0	1	0.3
Mali	17 995	12 069	30	627	12 726	70.7
Malta	429	0	0	0	0	0.0
Mauritania	4 301	1 575	2	82	1 659	38.6
Mauritius	1 262	7	0	0	7	0.6
Mexico	127 540	1 279	8	59	1 346	1.1
Micronesia (Federated States of)	105	4	0	0	4	3.6
Mongolia	3 027	32	0	0	32	1.1

		WASH-attributable deaths				
Country	Population (000)	Diarrhoeal diseases	Soil-transmitted helminth infections	Protein–energy malnutrition	Total from selected diseases (related to SDG 3.9.2)	SDG 3.9.2, Mortality rate attributed to WASH (for selected diseases, per 100,000 population)
Montenegro	629	0	0	0	0	0.0
Morocco	35 277	661	1	9	671	1.9
Mozambique	28 829	7 537	126	302	7 965	27.6
Myanmar	52 885	6 035	100	55	6 191	11.7
Namibia	2 480	426	0	28	454	18.3
Nepal	28 983	5 711	11	25	5 747	19.8
Netherlands	16 987	41	0	0	41	0.2
New Zealand	4 661	7	0	0	7	0.1
Nicaragua	6 150	126	2	10	138	2.2
Niger	20 673	13 628	66	945	14 640	70.8
Nigeria	185 990	119 879	1 721	6 041	127 641	68.6
Norway	5 255	11	0	0	11	0.2
Oman	4 425	2	0	0	2	0.0
Pakistan	193 203	37 382	70	395	37 847	19.6
Panama	4 034	72	1	4	76	1.9
Papua New Guinea	8 085	1 267	28	24	1 319	16.3
Paraguay	6 725	93	1	4	98	1.5
Peru	31 774	375	5	24	404	1.3
Philippines	103 320	4 113	48	171	4 332	4.2
Poland	38 224	35	0	0	35	0.1
Portugal	10 372	16	0	0	16	0.2
Qatar	2 570	0	0	0	0	0.0
Republic of Korea	50 792	64	0	0	64	0.1
Republic of Moldova	4 060	4	0	0	4	0.1
Romania	19 778	71	0	0	72	0.4
Russian Federation	143 965	150	0	1	151	0.1
Rwanda	11 918	2 164	14	128	2 306	19.3
Saint Lucia	178	1	0	0	1	0.6
Saint Vincent and the Grenadines	110	1	0	0	1	1.3
Samoa	195	3	0	0	3	1.5
Sao Tome and Principe	200	21	0	2	23	11.4
Saudi Arabia	32 276	29	0	0	29	0.1
Senegal	15 412	3 509	14	156	3 679	23.9
Serbia	8 820	65	0	0	65	0.7
Seychelles	94	0	0	0	0	0.2
Sierra Leone	7 396	5 596	113	304	6 013	81.3
Singapore	5 622	4	0	0	4	0.1
Slovakia	5 444	2	0	0	2	0.0
Slovenia	2 078	0	0	0	0	0.0
Solomon Islands	599	36	0	1	37	6.2
Somalia	14 318	11 756	48	591	12 396	86.6
South Africa	56 015	7 243	5	409	7 657	13.7
South Sudan	12 231	7 510	34	196	7 740	63.3
Spain	46 348	70	0	0	70	0.2
Sri Lanka	20 798	245	2	0	248	1.2
Sudan	39 579	6 637	57	163	6 856	17.3
Suriname	558	11	0	0	11	2.0
Sweden	9 838	21	0	0	21	0.2
Switzerland	8 402	12	0	0	12	0.1
Syrian Arab Republic	18 430	669	1	6	676	3.7
Tajikistan	8 735	227	1	9	236	2.7
Thailand	68 864	1 895	10	0	1 905	2.8
The former Yugoslav Republic of Macedonia	2 081	1	0	0	2	0.1
Timor-Leste	1 269	121	3	2	126	9.9
Togo	7 606	2 985	35	146	3 167	41.6
Tonga	107	1	0	0	2	1.4
Trinidad and Tobago	1 365	2	0	0	2	0.1

Country	Population (000)	WASH-attributable deaths				
		Diarrhoeal diseases	Soil-transmitted helminth infections	Protein–energy malnutrition	Total from selected diseases (related to SDG 3.9.2)	SDG 3.9.2, Mortality rate attributed to WASH (for selected diseases, per 100,000 population)
Tunisia	11 403	114	0	1	116	1.0
Turkey	79 512	230	1	4	235	0.3
Turkmenistan	5 663	224	0	1	225	4.0
Uganda	41 488	12 414	106	573	13 093	31.6
Ukraine	44 439	116	0	3	119	0.3
United Arab Emirates	9 270	3	0	0	3	0.0
United Kingdom	65 789	130	0	0	130	0.2
United Republic of Tanzania	55 572	20 043	192	1 107	21 342	38.4
United States of America	322 180	746	0	0	746	0.2
Uruguay	3 444	12	0	0	12	0.4
Uzbekistan	31 447	137	0	1	139	0.4
Vanuatu	270	27	0	1	28	10.4
Venezuela (Bolivarian Republic of)	31 568	417	9	13	439	1.4
Viet Nam	94 569	898	26	0	924	1.0
Yemen	27 584	2 779	8	28	2 814	10.2
Zambia	16 591	5 330	35	428	5 793	34.9
Zimbabwe	16 150	3 472	17	476	3 965	24.6

DALYs attributable to water, sanitation and hygiene from selected diseases related to SDG 3.9.2, by cause and country, 2016

		WASH-attributable DALYs				
Country	**Population (000)**	**Diarrhoeal diseases**	**Soil-transmitted helminthiasis**	**Protein–energy malnutrition**	**Total from selected diseases (related to SDG 3.9.2)**	**DALY rate attributed to WASH (for selected diseases, per 100,000 population)**
Afghanistan	34 656	455 218	28 958	9 780	493 957	1 425
Albania	2 926	920	1	104	1 025	35
Algeria	40 606	72 917	723	2 013	75 652	186
Angola	28 813	984 781	25 658	67 800	1 078 239	3 742
Antigua and Barbuda	101	11	0	0	11	11
Argentina	43 847	12 252	4 434	338	17 025	39
Armenia	2 925	1 321	12	48	1 381	47
Australia	24 126	540	0	0	540	2
Austria	8 712	360	0	0	360	4
Azerbaijan	9 725	12 677	67	308	13 053	134
Bahamas	391	48	0	0	48	12
Bahrain	1 425	109	0	0	109	8
Bangladesh	162 952	855 637	281 438	30 906	1 167 980	717
Barbados	285	38	0	0	38	13
Belarus	9 480	2 040	0	53	2 093	22
Belgium	11 358	693	0	0	693	6
Belize	367	373	46	21	439	120
Benin	10 872	408 771	8 870	41 511	459 152	4 223
Bhutan	798	2 488	89	41	2 619	328
Bolivia (Plurinational State of)	10 888	47 013	7 247	4 458	58 718	539
Bosnia and Herzegovina	3 517	841	0	55	897	26
Botswana	2 250	13 565	2 093	769	16 427	730
Brazil	207 653	208 756	71 765	10 103	290 624	140
Brunei Darussalam	423	10	0	0	10	2
Bulgaria	7 131	1 966	0	63	2 029	28
Burkina Faso	18 646	551 164	9 442	47 986	608 592	3 264
Burundi	10 524	419 210	15 399	42 727	477 337	4 536
Cambodia	15 762	61 964	506	2 070	64 540	409
Cameroon	23 439	690 500	43 367	42 788	776 655	3 313
Canada	36 290	2 166	0	0	2 166	6
Cape Verde	540	1 317	4	57	1 378	255
Central African Republic	4 595	228 497	11 478	13 743	253 718	5 522
Chad	14 453	1 022 814	18 824	59 852	1 101 490	7 621
Chile	17 910	1 036	0	0	1 036	6
China	1 411 415	379 173	254 996	9 393	643 561	46
Colombia	48 653	32 185	46 171	3 695	82 051	169
Comoros	796	22 103	1 282	1 542	24 926	3 133
Congo	5 126	100 255	8 494	9 838	118 587	2 314
Costa Rica	4 857	3 062	2 760	30	5 852	120
Côte d'Ivoire	23 696	739 311	43 228	57 962	840 501	3 547
Croatia	4 213	301	0	0	301	7
Cuba	11 476	6 865	9 715	64	16 644	145
Cyprus	1 170	64	0	0	64	5
Czech Republic	10 611	956	0	0	956	9
Democratic People's Republic of Korea	25 369	28 382	2 531	658	31 571	124
Democratic Republic of the Congo	78 736	3 102 853	159 148	343 781	3 605 781	4 580
Denmark	5 712	347	0	0	347	6
Djibouti	942	16 115	297	1 433	17 845	1 894
Dominican Republic	10 649	18 943	65	1 011	20 020	188
Ecuador	16 385	14 157	18 615	903	33 675	206
Egypt	95 689	175 169	18 031	9 052	202 253	211
El Salvador	6 345	8 860	1 957	327	11 143	176
Equatorial Guinea	1 221	18 147	2 001	1 547	21 695	1 776

Country	Population (000)	WASH-attributable DALYs				
		Diarrhoeal diseases	Soil-transmitted helminthiasis	Protein–energy malnutrition	Total from selected diseases (related to SDG 3.9.2)	DALY rate attributed to WASH (for selected diseases, per 100,000 population)
Eritrea	4 955	113 961	727	7 438	122 126	2 465
Estonia	1 312	130	0	0	130	10
Eswatini	1 343	23 703	3 707	2 180	29 590	2 203
Ethiopia	102 403	2 522 490	77 750	154 839	2 755 079	2 690
Fiji	899	1 394	1 755	45	3 194	355
Finland	5 503	208	0	0	208	4
France	64 721	3 578	0	0	3 578	6
Gabon	1 980	20 663	3 219	1 559	25 440	1 285
Gambia	2 039	39 580	462	4 502	44 545	2 185
Georgia	3 925	1 436	16	61	1 513	39
Germany	81 915	8 130	0	0	8 130	10
Ghana	28 207	327 219	7 064	46 373	380 656	1 350
Greece	11 184	231	0	0	231	2
Grenada	107	92	69	3	164	153
Guatemala	16 582	64 421	35 020	6 305	105 746	638
Guinea	12 396	348 011	24 433	23 988	396 432	3 198
Guinea-Bissau	1 816	44 421	1 289	2 184	47 894	2 638
Guyana	773	1 839	106	148	2 093	271
Haiti	10 847	173 983	1 720	12 395	188 098	1 734
Honduras	9 113	20 757	9 771	767	31 296	343
Hungary	9 753	958	0	0	958	10
Iceland	332	11	0	0	11	3
India	1 324 171	11 731 606	668 242	437 983	12 837 831	969
Indonesia	261 115	733 979	105 366	17 234	856 580	328
Iran (Islamic Republic of)	80 277	91 415	849	2 902	95 165	119
Iraq	37 203	114 169	86	5 230	119 485	321
Ireland	4 726	154	0	0	154	3
Israel	8 192	423	0	0	423	5
Italy	59 430	1 517	0	0	1 517	3
Jamaica	2 881	1 296	1 966	95	3 357	117
Japan	127 749	3 853	0	0	3 853	3
Jordan	9 456	7 104	1 589	204	8 898	94
Kazakhstan	17 988	9 008	4 304	309	13 622	76
Kenya	48 462	1 205 099	11 588	53 365	1 270 053	2 621
Kiribati	114	1 051	35	116	1 201	1 050
Kuwait	4 053	316	0	0	316	8
Kyrgyzstan	5 956	5 589	1 693	93	7 376	124
Lao People's Democratic Republic	6 758	51 036	14 526	1 883	67 445	998
Latvia	1 971	156	0	0	156	8
Lebanon	6 007	3 969	19	69	4 056	68
Lesotho	2 204	54 072	4 167	2 907	61 147	2 775
Liberia	4 614	110 450	8 045	5 445	123 941	2 686
Libya	6 293	5 398	55	140	5 593	89
Lithuania	2 908	286	0	0	286	10
Luxembourg	576	16	0	0	16	3
Madagascar	24 895	437 527	34 900	41 466	513 893	2 064
Malawi	18 092	266 265	3 244	32 548	302 058	1 670
Malaysia	31 187	13 931	66 828	367	81 126	260
Maldives	428	165	1	10	177	41
Mali	17 995	767 504	6 689	58 556	832 749	4 628
Malta	429	5	0	0	5	1
Mauritania	4 301	101 940	499	7 647	110 086	2 560
Mauritius	1 262	858	5	37	900	71
Mexico	127 540	77 868	31 515	7 895	117 277	92
Micronesia (Federated States of)	105	304	99	17	420	401
Mongolia	3 027	3 962	12	75	4 049	134
Montenegro	629	91	0	5	97	15

Country	Population (000)	WASH-attributable DALYs				
		Diarrhoeal diseases	Soil-transmitted helminthiasis	Protein–energy malnutrition	Total from selected diseases (related to SDG 3.9.2)	DALY rate attributed to WASH (for selected diseases, per 100,000 population)
Morocco	35 277	57 280	1 289	1 465	60 035	170
Mozambique	28 829	538 356	53 703	28 814	620 873	2 154
Myanmar	52 885	332 236	46 552	6 122	384 910	728
Namibia	2 480	26 292	1 727	2 700	30 719	1 239
Nepal	28 983	201 321	48 129	4 586	254 037	877
Netherlands	16 987	1 066	0	0	1 066	6
New Zealand	4 661	173	0	0	173	4
Nicaragua	6 150	11 194	534	963	12 690	206
Niger	20 673	938 916	6 618	89 664	1 035 198	5 007
Nigeria	185 990	7 786 133	280 594	563 525	8 630 252	4 640
Norway	5 255	237	0	0	237	5
Oman	4 425	495	0	0	495	11
Pakistan	193 203	2 560 918	61 098	54 326	2 676 343	1 385
Panama	4 034	6 446	267	377	7 090	176
Papua New Guinea	8 085	72 217	35 958	3 163	111 338	1 377
Paraguay	6 725	12 160	1 728	465	14 352	213
Peru	31 774	32 311	10 985	2 329	45 625	144
Philippines	103 320	336 297	126 446	18 617	481 360	466
Poland	38 224	2 698	0	0	2 698	7
Portugal	10 372	337	0	0	337	3
Qatar	2 570	94	0	0	94	4
Republic of Korea	50 792	1 197	0	0	1 197	2
Republic of Moldova	4 060	970	0	36	1 006	25
Romania	19 778	7 092	1	126	7 220	37
Russian Federation	143 965	44 845	0	1 741	46 586	32
Rwanda	11 918	126 834	21 395	11 931	160 160	1 344
Saint Lucia	178	160	138	3	301	169
Saint Vincent and the Grenadines	110	120	66	3	188	172
Samoa	195	275	11	15	301	154
Sao Tome and Principe	200	1 625	285	175	2 084	1 043
Saudi Arabia	32 276	3 246	0	0	3 246	10
Senegal	15 412	216 202	2 721	14 829	233 752	1 517
Serbia	8 820	3 199	0	81	3 280	37
Seychelles	94	13	0	0	13	13
Sierra Leone	7 396	356 254	14 492	28 307	399 053	5 395
Singapore	5 622	105	0	0	105	2
Slovakia	5 444	378	0	0	378	7
Slovenia	2 078	127	0	0	127	6
Solomon Islands	599	2 663	1 063	139	3 865	645
Somalia	14 318	886 677	17 829	54 542	959 048	6 698
South Africa	56 015	401 044	72 563	39 051	512 659	915
South Sudan	12 231	456 635	7 001	22 339	485 976	3 973
Spain	46 348	1 515	0	0	1 515	3
Sri Lanka	20 798	14 104	5 117	681	19 902	96
Sudan	39 579	551 580	16 613	18 039	586 232	1 481
Suriname	558	672	119	39	831	149
Sweden	9 838	487	0	0	487	5
Switzerland	8 402	349	0	0	349	4
Syrian Arab Republic	18 430	67 230	3 909	1 504	72 643	394
Tajikistan	8 735	21 527	276	1 117	22 919	262
Thailand	68 864	70 734	38 400	903	110 036	160
The former Yugoslav Republic of Macedonia	2 081	581	1	23	605	29
Timor-Leste	1 269	10 581	523	285	11 389	898
Togo	7 606	188 818	4 061	13 795	206 674	2 717
Tonga	107	135	20	10	165	154
Trinidad and Tobago	1 365	127	0	0	127	9
Tunisia	11 403	8 665	181	242	9 089	80

		WASH-attributable DALYs				
Country	Population (000)	Diarrhoeal diseases	Soil-transmitted helminthiasis	Protein–energy malnutrition	Total from selected diseases (related to SDG 3.9.2)	DALY rate attributed to WASH (for selected diseases, per 100,000 population)
Turkey	79 512	35 211	639	663	36 513	46
Turkmenistan	5 663	22 566	53	180	22 799	403
Uganda	41 488	861 660	23 528	53 757	938 945	2 263
Ukraine	44 439	20 503	0	804	21 307	48
United Arab Emirates	9 270	760	0	0	760	8
United Kingdom	65 789	3 047	0	0	3 047	5
United Republic of Tanzania	55 572	1 189 064	77 760	102 702	1 369 527	2 464
United States of America	322 180	20 835	0	0	20 835	6
Uruguay	3 444	265	0	0	265	8
Uzbekistan	31 447	14 853	114	498	15 465	49
Vanuatu	270	2 158	662	73	2 893	1 070
Venezuela (Bolivarian Republic of)	31 568	42 785	36 536	1 345	80 666	256
Viet Nam	94 569	81 844	125 221	1 244	208 309	220
Yemen	27 584	258 601	6 485	5 420	270 505	981
Zambia	16 591	350 341	23 145	39 865	413 352	2 491
Zimbabwe	16 150	255 164	20 714	43 441	319 319	1 977

This comprehensive global review highlights the importance of adequate water, sanitation and hygiene (WASH) for human health. Many diseases are caused by pathogens that are ingested with drinking-water, which circulate due to improper treatment and disposal of excreta and which are propagated by inadequate hand-washing and lack of hygiene facilities. Diarrhoeal diseases and respiratory infections are the main diseases that follow these pathways. Inadequate management of water resources, such as ponds, standing water in waste or containers and poorly maintained drains, causes diseases that are propagated by vectors such as mosquitoes. Young children are the most vulnerable to inadequate WASH, which is responsible for 13% of all deaths in children under 5 years. This high disease burden could be largely prevented with existing interventions and prevention strategies, which are described in this report.

World Health Organization

ISBN 978-92-4-151689-1