Chapter 9

Water Supply, Sanitation, and Hygiene

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INTRODUCTION

Safe drinking water, sanitation, and hygiene (WASH) are fundamental to improving standards of living for people. The improved standards made possible by WASH include, among others, better physical health, protection of the environment, better educational outcomes, convenience time savings, assurance of lives lived with dignity, and equal treatment for both men and women. Poor and vulnerable populations have lower access to improved WASH services and have poorer associated behaviors. Improved WASH is therefore central to reducing poverty, promoting equality, and supporting socioeconomic development. Drinking water and sanitation were targets in the Millennium Development Goals (MDGs) for 2015; under the Sustainable Development Goals (SDGs) for the post-2015 period, Member States of the United Nations (UN) aspire to achieve universal access to WASH by 2030. The Human Right to Safe Drinking Water and Sanitation (HRTWS) was adopted in 2010 under a UN resolution calling for safe, affordable, acceptable, available, and accessible drinking water and sanitation services for all.[1]

The scope of WASH services included in this chapter is shown in table 9.1. The focus is on services at the household and institutional level and on services for personal rather than productive uses.

This chapter summarizes global evidence on current WASH coverage and effects of intervention options, and it recommends areas for research and policy. Evidence comes from published synthesized evidence, such as systematic reviews and meta-analyses, evidence papers, and literature reviews. When those sources were not available, evidence was compiled from the next best sources of published research, thus using accepted criteria of the hierarchy of evidence for studies on health effectiveness. Unpublished and grey literature was used where no peer-reviewed published evidence exists.

This chapter is structured as follows:

- Progress in improving drinking water, sanitation, and hygiene coverage
- Impacts of poor WASH, thereby summarizing the evidence on the continued decline in mortality from diarrheal disease and the emerging evidence on the long-term developmental and cognitive effects of inadequate WASH on children
- Effectiveness of interventions, thereby examining the health effects of specific WASH interventions, the approaches to service delivery, and the key role of broader institutional policy in accelerating and sustaining progress
- Intervention costs, efficiency, and sustainability, thereby assessing the socioeconomic returns of improved WASH and considering the requirements for populations to have continued access to WASH services
- Challenges, opportunities, and recommendations.

This chapter uses the World Health Organization (WHO) classification of superregions as follows: Africa, the Americas, South-East Asia, Europe, Eastern Mediterranean, and Western Pacific.

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Table 9.1 Scope of Water, Sanitation, and Hygiene Services Included in This Chapter

Service	Included	Excluded
Water supply	Water for drinking	Water for productive uses
	Other water uses in the home (cooking, hygiene, sanitation, cleaning, laundry)	
	Treatment, safe handling, and storage of water	
Sanitation	Toilets and onsite excreta management	Separate greywater management
	Management of septage (fecal sludge)	Industrial wastewater management
	Sewerage or combined sewer-drainage systems	Storm water drainage
		Solid waste management
Hygiene	Handwashing and other personal hygiene practices	Food hygiene
	Menstrual hygiene management	Environmental hygiene and cleanliness measures

STATUS OF DRINKING WATER, SANITATION, AND HYGIENE

Targets

The MDG targets called for halving the proportion of the population without sustainable access to safe drinking water and basic sanitation between 1990 and 2015. The targets were ambitious. In 1990, 76 percent of the global population used an improved drinking water source, and 54 percent had access to safe sanitation. The MDG's drinking water target was met in 2010; yet in 2015, the world remained 9 percentage points short of achieving the sanitation target. The SDGs for 2015–2030 have broadened from the MDG period to include (1) water-use efficiency across all sectors, sustainable withdrawals, and supply of freshwater to people suffering from water scarcity; (2) integrated water resource management, and (3) water-related ecosystems. The SDG also set ambitious WASH-related targets of universal access to safe water (target 6.1), adequate sanitation and hygiene, and the elimination of open defecation (target 6.2) as well as reduced untreated wastewater (target 6.3). In the overall aim of access for all, the SDG language and spirit emphasizes progressive reduction of inequalities and leaving no one behind, as well as providing inclusive, quality, and sustainable services—thereby ensuring access for women and for poor and vulnerable populations.

Definitions

To understand the status of drinking water, sanitation, and hygiene, one must make a distinction between different levels of service access and population practices. All populations meet water and sanitation needs in some way, but those ways are often not sufficient, reliable, safe, convenient, affordable, or dignified. To monitor the MDG water and sanitation target, the UN distinguished between improved and unimproved water and sanitation facilities at home. For the SDG targets, one indicator is proposed per target: (1) for target 6.1, the percentage of population using safely managed drinking water services and (2) for target 6.2, the percentage of population using safely managed sanitation services, including a handwashing facility with soap and water. Complementing these proposals is a broader set of indicators distinguishing basic and safely managed service levels (table 9.2) (WHO and UNICEF 2015a).

The indicators for global monitoring need to be kept simple for feasibility and cost. However, countries, organizations, and programs often monitor different aspects of service performance, such as quantity, quality, proximity, reliability, price, and affordability (Roaf, Khalfan, and Langford 2005). Some countries adopt more lenient definitions, and some adopt stricter definitions.

The definitions in existing monitoring systems have several limitations. Some limitations are partially addressed by the new indicators for higher-level services. The new indicators were informed by the five normative criteria, as stated in the HRTWS and shown in table 9.2: accessibility, acceptability, availability, affordability, and quality.[2]

- The Joint Monitoring Programme's (JMP) definition of improved facilities focuses on the technology type and is an imprecise proxy for the quality of services (Moriarty and others 2010; Onda, LoBuglio, and Bartram 2012; Potter and others 2010).

Table 9.2 Proposed Service Level Definitions for Monitoring SDG 6 WASH Targets

Service	Basic services	Safely managed services
Water	Percentage of population using an improved drinking water source with a total collection time of 30 minutes or less for a round trip, including queuing (termed "basic" water).[a]	Percentage of population using safely managed drinking water services. "Safely managed" refers to an improved[a] drinking water source that is located on premises, available when needed, and free from fecal (E. coli) and priority chemical (arsenic and flouride) contamination.
Sanitation and hygiene	Percentage of population not practicing open defecation. Percentage of population using an improved sanitation facility that is not shared with other households (basic sanitation).[b] Percentage of population with a handwashing facility with soap and water at home.	Percentage of population using safely managed sanitation services, including a handwashing facility with soap and water. "Safely managed" refers to an improved sanitation facility that is not shared with other households and where excreta are either safely disposed in situ or treated offsite.

Sources: Definitions of improved, WHO and UNICEF 2006; definitions of indicators, WHO and UNICEF 2015a.
Note: The higher service level indicators are proposed for SDG monitoring. SDG = Sustainable Development Goal; WASH = drinking water, sanitation, and hygiene; WatSan = water and sanitation.
a. Same as improved water monitored as part of the MDG target 7c: piped water into dwelling, plot, or yard; public tap and standpipe; tubewell and borehole; protected dug well; protected spring; rainwater collection.
b. Same as improved sanitation monitored as part of the MDG target 7c: flush or pour-flush to piped sewer system, septic tank, pit latrine or ventilated improved pit latrine; pit latrine with slab and composting toilet.

- Self-reported responses of access by household members may be biased (Stanton and Clemens 1987).
- Statistics on household access provide no indication of variations in access and practices among different household members. For example, even in communities with high coverage rates for sanitation, children still commonly defecate in the open.[3]
- Indicators do not adequately reflect accountability and sustainability, which are key elements that cut across all the service levels.

The existing approach to measuring access does not provide a good indication of sustainability. The surveys use representative sampling and do not follow individual households over time. Effective monitoring of higher service levels requires regulatory data, but coverage is poor in low- and middle-income countries (LMICs), especially in rural areas.

Coverage of Water Supply, Sanitation, and Hygiene

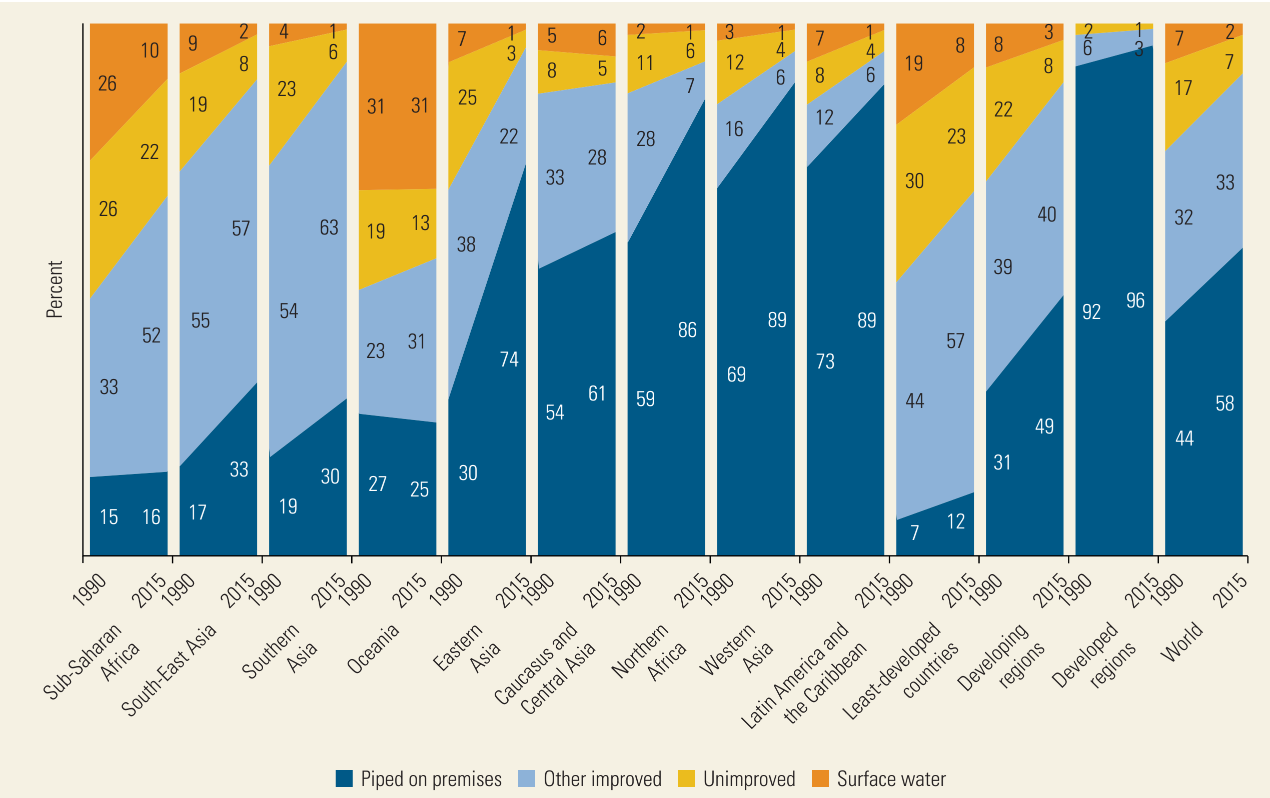
This section presents the coverage data at global and regional levels for drinking water and sanitation according to the JMP definitions used for monitoring MDG target 7c, thereby using the most recent update and MDG assessment report (WHO and UNICEF 2015b). Breakdowns are provided by rural and urban areas.[4]

Water Supply

Globally, the use of improved drinking water sources increased from 76 percent in 1990 to 91 percent in 2015 (WHO and UNICEF 2015b). Regional breakdowns for progress between 1990 and 2015 are shown in figure 9.1. In its 2012 report presenting 2010 estimates, the UN showed that its MDG target of halving the proportion of the population without access to safe drinking water had been met (WHO and UNICEF 2012b); however, such global estimates mask regional disparities and inequities in access between urban and rural populations. As of 2015, 663 million people still used unimproved water sources, compared to 1.3 billion in 1990; 2.6 billion people have gained access to improved water since 1990. Rural dwellers remain unserved compared with urban dwellers (16 percent and 4 percent, respectively). In Sub-Saharan Africa, 44 percent of rural dwellers continue to use an unimproved water supply. Water hauling costs Sub-Saharan Africans, especially women, billions of hours each year. In 2008, more than 25 percent of the population in several Sub-Saharan African countries spent more than 30 minutes to make one round trip to collect water; 72 percent of the burden for collecting water fell on women (64 percent) and girls (8 percent), compared with men (24 percent) and boys (4 percent) (WHO and UNICEF 2010).

Urban areas enjoy a higher level of water service, as indicated by the use of piped water supply; in 2015,

Figure 9.1 Drinking Water Coverage Trends, by Regions and World, Using the JMP Improved Water Definition, 1990–2015



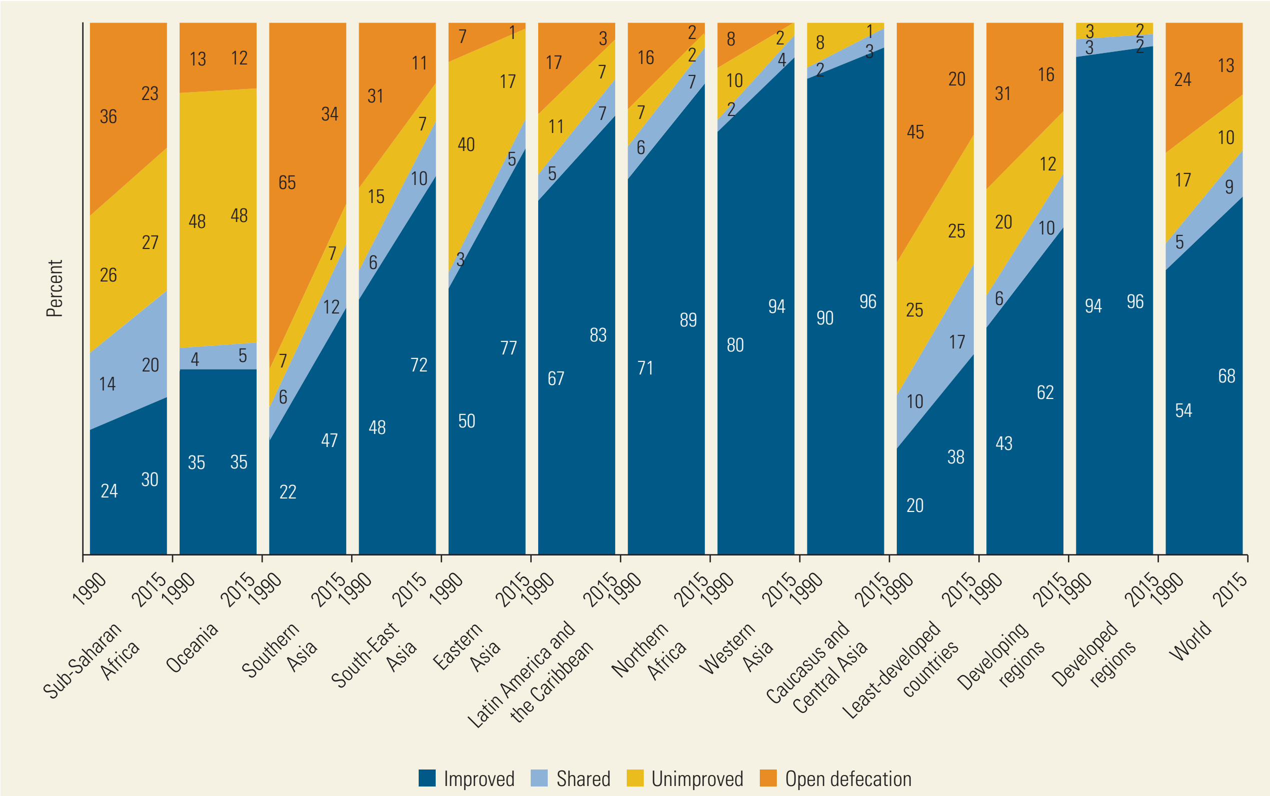
Source: WHO and UNICEF 2015b.
Note: JMP = Joint Monitoring Programme.

four of five people living in urban areas used piped water, compared to two of three in rural areas. Water sources classified as improved—even piped water—do not guarantee the safety or continuity of the water supply. Water quality surveys conducted in five countries showed that microbiological compliance with the WHO guidelines varied between water sources and countries (Onda, LoBuglio, and Bartram 2012). On average, compliance was close to 90 percent for piped water sources, and from 40 percent to 70 percent for other improved sources. Extrapolating to global estimates, the authors estimate that in 2010, 1.8 billion people (28 percent) used unsafe water, more than twice the population of 783 million (11 percent) that used an unimproved water supply.

Sanitation

The use of improved sanitation increased from 54 percent in 1990 to 68 percent in 2015, but those gains fell short of meeting the global MDG target (WHO and UNICEF 2015b). In 2015, 2.4 billion people still did not have access to their own improved sanitation facility, a fact that, due to population growth, reflects no change in the unserved population of 1990. However, these numbers mask the fact that since 1990, 2.1 billion people have gained access to improved sanitation. Regional breakdowns in progress between 1990 and 2015 are shown in figure 9.2. Globally, the proportion of population practicing open defecation declined from 24 percent in 1990 to 13 percent in 2015. In South Asia, 34 percent still defecate in the open, compared to 23 percent in Sub-Saharan Africa. Globally, 638 million people (9 percent) share their sanitation facility with another family or families. Comparing rural and urban areas, 51 percent of rural dwellers have access to improved sanitation, compared with 82 percent of urban dwellers. Rates of improved sanitation do not reflect the amount of fecal waste that is not isolated, transported, or treated safely; a study of 12 cities in LMICs found that whereas 98 percent of households used toilets, only 29 percent of fecal waste was safely managed (Blackett, Hawkins, and Heymans 2014).

Figure 9.2 Sanitation Coverage Trends, by Regions and World, Using the JMP Improved Sanitation Definition, 1990–2015



Source: WHO and UNICEF 2015b.
Note: JMP = Joint Monitoring Programme.

Hygiene

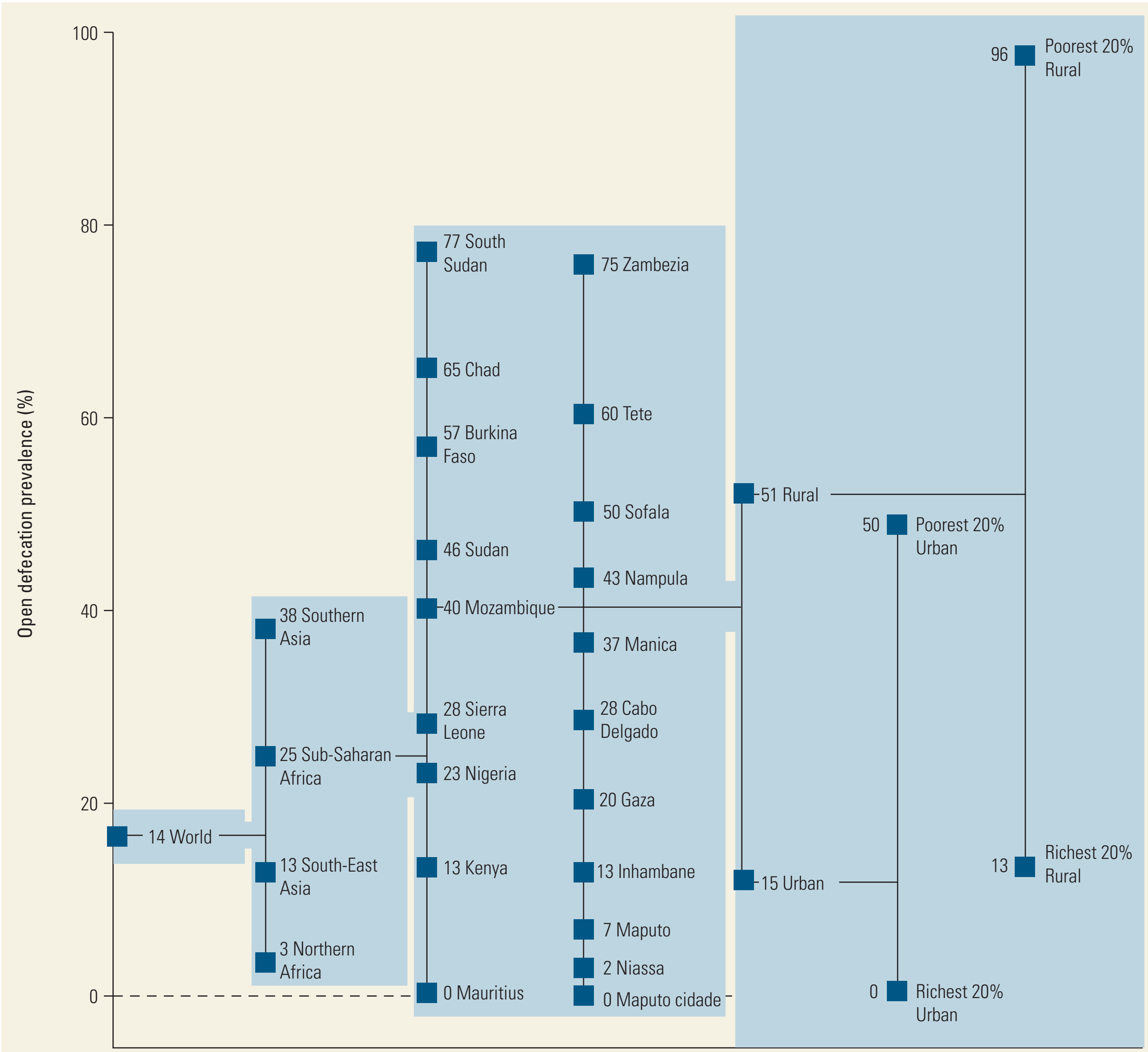
Although the MDG target 7c does not provide a global indicator for hygiene, the data on the presence of a handwashing facility with soap and water are increasingly collected as part of nationally representative surveys and will form the basis for efforts to monitor target 6.2 of the SDGs. Two main sources include nationally representative household surveys and a global review of published studies (Freeman and others 2014). Research studies suggest that the global prevalence of handwashing with soap after contact with excreta is 19 percent; rates are lower in Sub-Saharan Africa (14 percent) and South-East Asia (17 percent), where the most studies have been conducted (Freeman and others 2014). Proxy indicators for handwashing practice from nationally representative surveys are not reliable and tend to over report hygiene practices (Biran and others 2008).

Distribution of Services

The JMP has reported the distribution of water supply and sanitation services by wealth status, breaking the population into five equal wealth quintiles using an asset index. In 35 Sub-Saharan African countries, households in the poorest wealth quintile are 6 times less likely to have water access compared with the richest quintile; the difference for sanitation is at least 2.5 times less likely (WHO and UNICEF 2013). Figure 9.3 illustrates the levels of disparity—between regions, between countries in a region, and at the country level—in the differences between rural and urban areas and between wealth quintiles. Limited datasets are available on the disparities between population subgroups—for example, slum populations, ethnic groups, women, the elderly, and persons who have physical impairments—as the sample size and sampling methodology in nationally representative surveys generally do not enable sufficiently robust comparisons.

Global reporting of institutional WASH has not yet been standardized as it has for household-level WASH; efforts are under way to build a global reporting system of WASH in schools and health facilities for SDG monitoring. The Demographic and Health Survey (DHS) Service

Figure 9.3 Mozambique Example: How Average Values Mask Massive Disparities in Household Coverage



Source: WHO and UNICEF 2014.

Provision Assessment (SPA) monitors WASH in health facilities. WASH coverage in both primary schools and front-line health facilities is monitored and reported under the Service Delivery Indicators, currently for Sub-Saharan Africa. United Nations agencies collect data on WASH in schools (Education Management Information System operated by UNICEF), health facilities (Health Management Information System operated by the WHO), and refugee camps (UN High Commissioner for Refugees).

In addition to enhanced monitoring efforts by UN agencies, UN member countries need greater understanding of the challenges facing the world to meet the goal of universal access to institutional WASH within 15 years and to sustain that access beyond 2030. Unsustainable water extraction, along with competing demands, population growth and migration (including urbanization), and climate change and variability, puts significant pressure on water supply systems. In addition, new settlements require systematic, coordinated planning, and existing settlements require retrofitting to bring sustainable WASH services to citizens.

IMPACTS OF INADEQUATE WASH

Understanding the nature and extent of the demonstrated negative effects of inadequate WASH on individuals, the environment, and societies is important for those designing interventions and assessing benefits and efficiency. Many benefits of WASH interventions are nonhealth in nature; including only health effects in impact evaluations can severely underestimate the intervention benefits (Loevensohn and others 2015).

Health Consequences

Contaminated water and lack of sanitation lead to the transmission of pathogens through feces and, to a lesser extent, urine. The F-diagram explained here but not shown provides a basic understanding of these pathways by which pathogens from feces are ingested through transmission by fingers, flies, fluids, fields (soil), and food:

- Diseases transmitted by the fecal pathway include diarrheal disease, enteric infection, hepatitis A and E, poliomyelitis, helminths, trachoma, and adenoviruses (conjunctivitis) (Strickland 2000). Most of these diseases are transmitted through the fecal-oral pathway, but some are transmitted through the fecal-skin pathway (for example, schistosomiasis) and the fecal-eye pathway (for example, trachoma). These transmissions occur between humans, as well as between animals and humans.
- Pathogens carried through urine (for example, leptospirosis) mainly result from animal-to-human transmission.
- Poor personal hygiene causes fungal skin infections, such as ringworm (tinea) and scabies.
- Lack of handwashing is associated with respiratory infections (Rabie and Curtis 2006); inadequate hand hygiene during childbirth is linked to infection (Semmelweis 1983) and neonatal mortality (Blencowe and others 2011; Rhee and others 2008).

A systematic review and meta-analysis documented large and significant associations between poor water, sanitation, and maternal mortality (Benova, Cumming, and Campbell 2014). The precise mechanism has not been well established, but it is thought to be largely attributable to puerperal sepsis.

Children under age five years are especially vulnerable to infection. Regular exposure to environments with high fecal loads causes enteropathy[5]; compromises nutritional status; and leads to long-term consequences, such as stunting and retarded cognitive development (Humphrey 2009; Petri and others 2008).

The availability of water for drinking and household uses affects the quantity of water consumed and the time available to care for children in the household. Reducing the distance required to fetch water is associated with lower prevalence of diarrhea, improved nutrition, and lower mortality in children under age five years (Pickering and Davis 2012); these effects may be due to better hygiene practices (Curtis and Cairncross 2003; Esrey 1996; Esrey and others 1991), as well as to additional time available for child care or income-generating activities (Ilahi and Grimard 2000), thereby resulting in healthier children.

Inadequate quantities or consumption of water can also lead to dehydration, which has a number of adverse effects on physical and cognitive performance and bodily functions (Popkin, D'Anci, and Rosenberg 2010). Because there are no adequate biomarkers for measuring a population's hydration status, such an effect remains largely undocumented (Popkin, D'Anci, and Rosenberg 2010). Safe drinking water provides the basis for oral rehydration salts that save lives (Atia and Buchman 2009).

Exposure to harmful levels of arsenic in groundwater is estimated to affect 226 million people in more than 100 countries (Murcott 2012). Arsenic exposure causes skin lesions and long-term illnesses such as cancer, neurological disorders, cardiovascular diseases, diabetes, and cognitive deficits among children (Naujokas and others 2013).

Excess levels of water from heavy rainfall and inadequate drainage lead to flooding, thus causing injuries and death, as well as heightened risk of fecal-oral and skin diseases (Ahern and others 2005). Earthquakes, volcanic eruptions, tsunamis, and other natural disasters leave affected populations vulnerable to infection with waterborne diseases such as diarrhea, hepatitis A and E, and leptospirosis (Jafari and others 2011).

Diarrheal Disease

The most recent study estimated 842,000 global deaths from diarrheal disease for 2012 (Prüss-Ustün and others 2014); 43 percent of these were children under age five years. An estimated 502,000 deaths were caused by inadequate drinking water, 280,000 by inadequate sanitation, and 297,000 by inadequate hand hygiene (table 9.3). The regional breakdowns indicate that the major share of global burden is in South-East Asia and Sub-Saharan Africa. Precise estimates remain elusive because of poor quality data on the cause of death; insufficient data on hygiene practices; and poor quality evidence on the effectiveness of some water and sanitation interventions, especially onsite sanitation. This paucity of reliable data has led to conflicting estimates of the burden of disease. The Institute for Health Metrics and

Table 9.3 Diarrheal Disease Mortality Attributed to Poor Water Supply, Sanitation, and Hygiene in Low-and Middle-Income Countries, Regional and Risk Factor Breakdown

Region	Water supply	Sanitation	Hygiene	WASH
Africa	229,316	126,294	122,955	367,605
The Americas	6,441	2,370	5,026	11,519
Eastern Mediterranean	50,409	24,441	28,699	81,064
Europe	1,676	352	1,972	3,564
South-East Asia	207,773	123,279	131,519	363,904
Western Pacific	6,448	3,709	6,690	14,160
World	**502,061**	**280,443**	**296,860**	**841,818**

Source: Prüss-Ustün and others 2014.
Note: WASH = safe drinking water, sanitation, and hygiene. Totals may not be sum of rows because of rounding. Columns 2–4 do not sum to column 5 because of overlap in risk pathways.

Evaluation's Global Burden of Disease (GBD) study conducted a new meta-regression analysis of available experimental and quasi-experimental interventions. It found that poor water and sanitation account for 0.9 percent of global disability-adjusted life years (DALY) or 300,000 deaths per year (Lim and others 2012). The resulting difference between this study and the Prüss-Ustün and others (2014) study is 542,000 deaths, possibly because the studies included in the GBD study do not differentiate between different levels of quality of water supply and sanitation and between poor quality implementation and lack of effect.

Not all diarrheal diseases are caused by pathogens transmitted through inadequate WASH. Over time, different estimates have been made for the burden of diarrheal disease that can be attributed to fecal-oral transmission. Earlier estimates attribute 94 percent of diarrheal disease to poor WASH (Prüss-Ustün and Corvalan 2007); the more recent study attributes 58 percent (Prüss-Ustün and others 2014). This latter estimate is closely supported by a separate review of more than 200 studies that examined the causes of diarrhea in inpatients and found no pathogen present in 34 percent of cases (Lanata and others 2013). Importantly, deaths not easily preventable through WASH interventions (for example, rotavirus spread among young children and difficult to control) were excluded from the global burden of disease estimates for diarrheal disease shown in table 9.3. Thus, the data in table 9.3 provide a more realistic picture on how many deaths are considered preventable by WASH interventions.

Rising temperatures caused by climate change are expected to exacerbate the burden of diarrheal disease. The WHO estimates that an additional 48,000 deaths in children under age 15 years will be caused by climate change by 2030 and 33,000 deaths by 2050 (Hales and others 2014). These estimates may be conservative because they do not account for diarrheal deaths caused by other risk factors such as declining water availability and undernutrition.

Cholera is an endemic diarrheal disease, but it is strongly associated with natural disasters and civil conflict. An estimated 2.9 million cases of cholera cause 95,000 deaths each year in 69 endemic countries (Ali and others 2015). Cholera is transmitted through fecal contamination of water or food. Therefore, clean water and proper sanitation are critical to preventing its spread. However, good evidence is lacking as to which mix of interventions (including oral cholera vaccine, case management, and surveillance) is most cost-effective during outbreaks because few high-quality evaluation studies have been conducted (Taylor and others 2015).

Institutional settings—such as schools, health facilities, prisons, and other public settings such as refugee camps and public markets—can pose high risks if water and sanitation are not well managed. Studies have documented higher rates of diarrheal disease and gastrointestinal infection in schools that lack access to improved drinking water and sanitation facilities (Jasper, Le, and Bartram 2012). Improved hand hygiene is particularly important in institutional settings, given the ease with which infections spread in such environments.

Helminth Infections

Helminth infections are transmitted in water by fecal matter (schistosomiasis) and in soil by soil-transmitted helminths (STH). Although routine monitoring of infection rates is limited, the large number of prevalence surveys permits global estimates to be made.

One study of helminth prevalence data for 6,091 locations in 118 countries estimated that in 2010, 438.9 million people were infected with hookworm

(*Ancylostoma duodenale*), 819.0 million with roundworm (*A. lumbricoides*), and 464.6 million with whipworm (*T. trichiura*) (Pullan and others 2014). Of the 4.98 million years lived with disability (YLDs) attributable to STH, 65 percent of those were attributable to hookworm, 22 percent to *A. lumbricoides,* and 13 percent to *T. trichiura*. Most STH infections (67 percent) and YLDs (68 percent) occurred in Asia (Central, East, South, and South-East). A separate study estimated 89.9 million STH infections in school-age children in Sub-Saharan Africa (Brooker, Clements, and Bundy 2006). Annual global deaths are estimated at 2,700 for *A. lumbricoides* and 11,700 for schistosomiasis (Lozano and others 2010).

Helminth infections cause several adverse health outcomes, including anemia, malnutrition, growth stunting, and impaired physical and cognitive development; those outcomes result in low school attendance and educational deficits, thus leading to loss of future economic productivity (Victora and others 2008). The risk of STH infection is greatest for those in specific occupations and circumstances, such as people who work in agriculture, who live in slums, who are poor, who have poor sanitation, and who lack clean water (Hotez and others 2006).

Undernutrition and Environmental Enteric Dysfunction

Undernutrition causes an estimated 45 percent of all child deaths (Black and others 2013) and is responsible for 11 percent of global disease burden (Black and others 2008). Inadequate dietary intake and disease are directly responsible for undernutrition; however, multiple indirect determinants exacerbate these direct causes, including food insecurity, inadequate child care practices, low maternal education, poor access to health services, lack of access to clean water and sanitation, and poor hygiene practices (UNICEF 1990). Political, cultural, social, and economic factors play a role as well. Stunting (height-for-age below minus two standard deviations from median height-for-age of reference population) and underweight (weight-for-age below minus two standard deviations from median weight-for-age of reference population) are forms of undernutrition associated with weakened immune systems and severe long-term consequences that include poor cognitive development, a lower rate of school attendance, a lower level of job attainment, and a potentially higher risk of chronic disease in adulthood (Victora and others 2008).

The links between diarrhea and child undernutrition (Fishman and others 2004; Prüss-Ustün and Corvalan 2006) and other enteric infections (Brown, Cairncross, and Ensink 2013; Checkley and others 2008; Guerrant and others 2008; Lin and others 2013) are well documented. An emerging body of evidence suggests that a subclinical condition of the small intestine caused by chronic ingestion of pathogenic microorganisms results in nutrient malabsorption. This subclinical condition may be the primary causal pathway between poor WASH and child growth (Humphrey 2009).

The evidence on the etiology of diarrheal disease finds an association between levels of intestinal inflammation detected through fecal samples and subsequent growth deficits in infants. This evidence lends support to the environmental enteropathy hypothesis that stunting may be an outcome of frequent enteric infection and intestinal inflammation (Kotloff and others 2013). Because of the asymptomatic nature of environmental enteropathy, the extent and seriousness of the condition is not known; however, it appears to be nearly universal among those living in impoverished conditions (Salazar-Lindo and others 2004) and may be the cause of up to 43 percent of stunting (Guerrant and others 2013).

The risks of low birth weight and stunting are heightened in undernourished mothers (Özaltin, Hill, and Subramanian 2010), resulting in intergenerational consequences of undernutrition and related conditions.

Social Welfare Consequences

Improved water supply and sanitation provide individuals with increased comfort, safety, dignity, status, and convenience, and also have broader effects on the living environment (Hutton and others 2014). The social welfare effects are difficult to quantify, given their subjective nature. Nevertheless, those benefits are consistently cited as among the most important for beneficiaries of water supply and sanitation (Cairncross 2004; Jenkins and Curtis 2005) and may be particularly relevant for women (Fisher 2006).

In or Near Homes

Water supply in or adjacent to homes provides greater comfort to household members, notably women and girls tasked with fetching water; water sources closer to home, especially piped water, are associated with increased use (Howard and Bartram 2003; Olajuyigbe 2010).

Data from 18 countries indicate that women are five times more likely than men to have the responsibility for collecting household water (WHO and UNICEF 2012b). As the distance to the water source increases, the time that women could spend on income-generating activities, household chores, and child care decreases (Ilahi and Grimard 2000). A regular piped water supply can introduce the possibility of purchasing time- and labor-saving devices, such as washing machines and dishwashers. Although access to water infrastructure does not always translate into wage employment for women (Lokshin and Yemtsov 2005), one study finds that it can provide time savings in water collection, thus improving gender equality (Koolwal and Van de Walle 2013).

Individuals with access to on-plot sanitation benefit from greater privacy, comfort, and convenience. Accompanying a child to the toilet is more convenient if it is nearby and safe, and mothers can comfortably step away from household duties to practice hygiene. In Ghana, more than 50 percent of households considering adopting a toilet included convenience in their top three reasons for investing in sanitation (Jenkins and Scott 2007). In six countries of South-East Asia, the rural households that owned their own latrine saved from 4 to 20 minutes of travel time per trip (Hutton and others 2014). Privacy, comfort, and convenience benefits are magnified for vulnerable groups, such as the elderly or persons living with disabilities or debilitating chronic illness.

On-plot sanitation reduces the risk of theft or assault (including rape and sexual harassment), especially at night or in isolated locations. Improved pit latrines are safer, less likely to collapse, and easier for small children to use. On-plot water supply and sanitation help to avoid conflicts with neighbors, landowners, or others over the use of shared water resources and sanitation facilities and the use of fields or rivers for open defecation.

Schools and Workplaces

Access to improved WASH services in schools and workplaces contributes to school attendance, school performance, and choice of where to work, especially for girls and women. Recent evidence from India shows that a national government program to build toilets in schools led to an 8 percent increase in enrollment among pubescent-age boys and girls and a 12 percent increase among younger children of both genders (Adukia 2014). The comparably large effect of school sanitation on primary school children and the robust effects for boys and girls at all ages suggest that at least some of the effect of school sanitation is related to health (Jasper, Le, and Bartram 2012). Research has seldom analyzed academic performance as an outcome; however, given the role that improved water and sanitation have on child health and school attendance rates, the current evidence lacks research into their role in academic performance.

Menstrual Hygiene

Menstrual hygiene management (MHM) is a poorly understood and underresearched area of WASH services. This neglect has left women in many LMICs without access to appropriate products, facilities, and services (Sebastian, Hoffmann, and Adelman 2013). Lack of adequate MHM is frequently described as a hindrance to girls' education, but high-quality evidence is lacking (Sumpter and Torondel 2013). A randomized controlled trial in Nepal suggests that menses, and poor menstrual hygiene technology in particular, has no effect on absenteeism of girls; girls miss less than one school day a year on average because of menstruation (Oster and Thornton 2011). However, girls may avoid going to school while they are menstruating, not because they lack management methods but because they lack proper facilities for managing menses (Jasper, Le, and Bartram 2012).

Environmental Consequences

Two major environmental consequences of poor WASH practices are (1) the excessive extraction of water to meet population needs and (2) the pollution caused by poorly managed human excreta.

The water supply for domestic use represents a small proportion of overall extraction, but the concept of virtual water trade[6] has led to a greater understanding of the implications of population consumption patterns for water use. Globally, the combined effects of socioeconomic growth and climate change indicate that, by 2050, the population at risk of exposure to at least a moderate level of water stress could reach 5 billion people (Schlosser and others 2014). A population of up to an estimated 3 billion in 2050 is nearly double the current estimate of 1.7 billion people who live in areas with a high degree of water stress. The projections are made on the basis of a risk metric of frequency of water shortage in reservoirs (Sadoff and others 2015). This metric combines hydrological variability and water usage trends, which may be mitigated by storage infrastructure. This class of water insecurity is most severe in South Asia and Northern China, although the risk of water shortage exists on all continents.

Overextraction of groundwater and pollution of local surface water bodies have led many large urban population centers to source municipal water supplies from reservoirs or rivers that are tens or hundreds of kilometers from the site of treatment or consumption. Such schemes cost tens of millions of dollars each in reservoir construction, pipeline, and pumping costs. Groundwater resources are under increasing stress from unsustainable agricultural practices resulting from crop choice and energy subsidies to enable farmers to pump groundwater. In India and Mexico, for example, subsidized electricity and kerosene for farmers have led to serious groundwater overdraft (Scott and Shah 2004).

Poorly managed human excreta have major environmental consequences; excreta pollute human settlements, groundwater, and surface water such as lakes, rivers, and oceans. The degree of pollution depends on wastewater, sludge, and sewage management practices; climatic factors; and the population size and density in relation to the volume of water. In highly populated river basins, municipal sewage and wastewater contribute a high proportion to overall biological oxygen demand (Corcoran and others 2011; Rabalais and Turner 2013).

Heavily polluted surface water has serious effects on ecosystems, food webs, and biodiversity (Turner and Rabalais 1991). Coastal areas that are near the discharge of large, polluted rivers have reported compromised fish catch, such as in Argentina (Dutto and others 2012). In the coastal areas of the Philippines, water pollution was estimated to cost US$26 million per year in lost fish catch and degraded coral reefs (World Bank 2009). Water pollution of recreational areas affects the tourism industry, thus lowering visit rates or causing gastrointestinal illness or both.

Financial and Economic Consequences

Financial and economic studies convert the health, social, and environmental effects of poor WASH to a common money metric, thereby enabling aggregation as well as comparison across locations and over time. However, these estimates are often incomplete, using crude estimates of economic value or relying on the imprecise physical effects underlying the economic values.

Damage cost studies account for the broader welfare and productivity consequences of poor WASH beyond the health effects. A review of economic impacts of poor water and sanitation found estimates from more than 30 countries (see annex 9A), as well as global studies. Studies with economic impacts expressed as a percentage of gross domestic product (GDP) are shown in figure 9.4, disaggregated between health and nonhealth damages.

Although all the studies presented in figure 9.4 present effects in monetary units, the results are not directly comparable. They have different base years and different effects included; some include only sanitation, and others include water and sanitation. In East Asian and Pacific and Sub-Saharan African economies, the cost of poor sanitation exceeded 2 percent of total GDP; in South Asia, it exceeded 4 percent of GDP. A global study, including the health and time losses, valued the costs in LMICs at 1.5 percent of global domestic product (Hutton 2012). These significant economic effects raise awareness of the extent of the problem, but they do not indicate how to address the problem in a cost-effective manner.

INTERVENTION OPTIONS AND EFFECTIVENESS

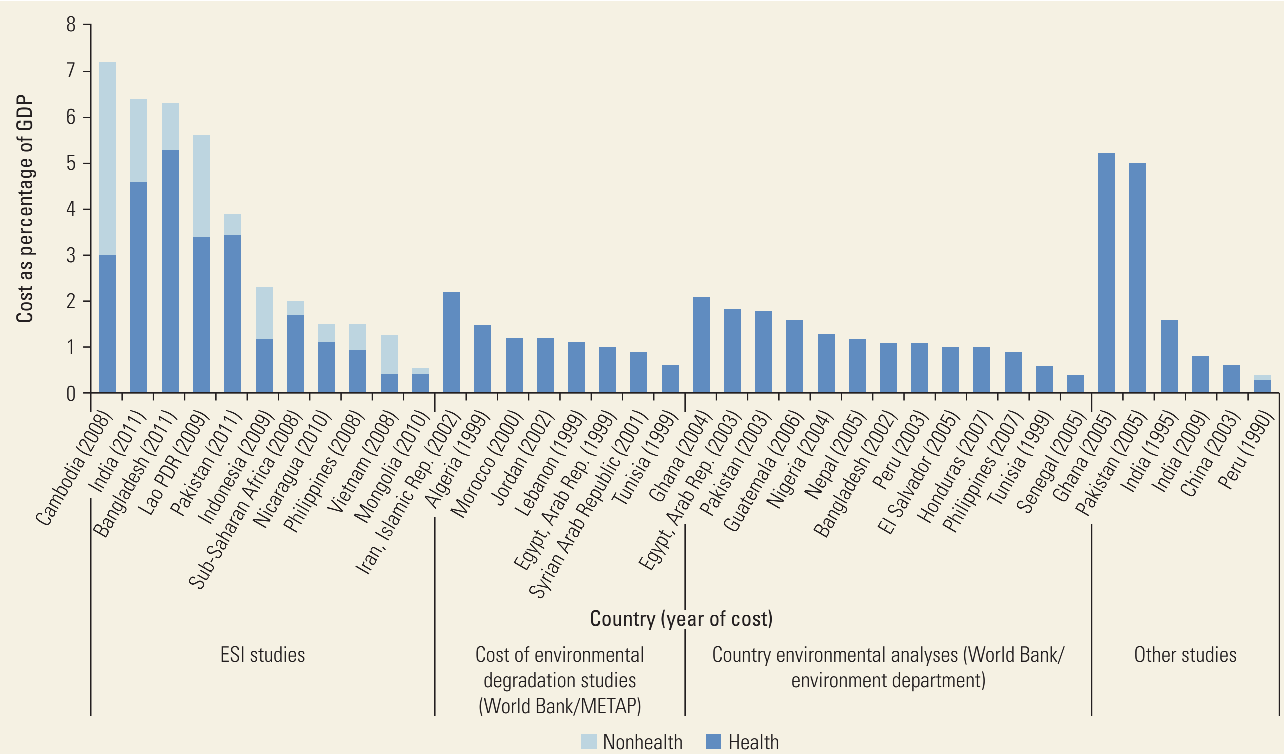
Three main categories of interventions to improve WASH are as follows:

- Technology options and WASH practices cover the type of hardware, equipment, and associated behaviors of WASH services. Not all water or sanitation technologies perform the same function, so they can be classified by the service level they provide.
- Service delivery models cover the components of WASH service implementation. Those components include (1) approaches to demand generation and WASH behavior change, (2) approaches to strengthen supply of water and sanitation goods and services, and (3) approaches to improve the effectiveness of WASH service delivery.
- Strengthening the enabling environment for WASH service delivery includes (1) measures to strengthen capacity, (2) legal framework, (3) policy and planning, (4) resource allocation, (5) monitoring and evaluation, and (6) other interventions to provide a stronger foundation for implementing the technology and service delivery models. The evidence is provided in annex 9B.

Effectiveness of Technologies and Practices

Water technologies are designed to source, treat, distribute, and monitor the supply of water. Epidemiological studies evaluate the effectiveness of water interventions in terms of the quantity and (microbial) quality of water supplied (Waddington and others 2009). Increasing evidence enables the comparison of the incremental health benefits of different water interventions, such as improved community source, piped water, higher-quality piped water, and point-of-use treatment (chlorine, solar, and filter). Utility regulators, as well as regional and global initiatives, monitor water quality according to service standards, such as continuity, consumption, and number of complaints (IBNET 2014). In 2010, The International Benchmarking Network for Water and Sanitation Utilities (IBNET) of the World Bank reported that only 16 percent of utilities in low-income countries supply water continuously 24 hours per day, compared to 86 percent of utilities in middle-income countries (Van den Berg and Danilenko 2010). Even a few days of interrupted water supply can result in significant adverse health consequences if beneficiaries revert to using unimproved sources of water (Hunter, Zmirou-Navier, and Hartemann 2009).

Figure 9.4 Economic Costs of Poor Water and Sanitation in Selected Countries, as a Percentage of GDP



Source: See annex 9A for fuller datasets and references.

Note: GDP = gross domestic product. Economics of Sanitation Initiative (ESI) studies have been implemented by the World Bank's Water and Sanitation Program in 34 countries of Latin America and the Caribbean, East Asia and Pacific, South Asia, and Sub-Saharan Africa. These studies estimated the costs of poor sanitation, including health and nonhealth impacts (access time, costs of accessing safe water, tourism). The Mediterranean Environmental Technical Assistance Program (METAP) of the World Bank conducted studies on the costs of environmental degradation in eight Mediterranean countries from 1999 to 2002. Country environmental analyses conducted by the World Bank in more than 20 countries since 2003 have estimated the health costs of poor water and sanitation.

To increase safety, drinking water can be treated either at the source or at the point of use through a process of filtration or disinfection or both. The greatest health effects for improved water treatment technologies concern the piped water supply, with greater health benefits associated with higher-quality piped water (water that is safe and continuously available) (Wolf and others 2014). Among household-level studies, filter interventions that also provided safe storage (for example, ceramic filters) were associated with a large reduction in diarrheal disease (Wolf and others 2014). Neither chlorine treatment nor solar disinfection shows significant impact on diarrhea after meta-analysis adjusted for non-blinding of the intervention (Wolf and others 2014), although an earlier systematic review and meta-analysis of water quality interventions found household-level treatment to be more effective than source treatment (Clasen and others 2005). Blinding participants to the intervention and longer follow-up periods are recommended to better understand the impact of point-of-use water treatment interventions on diarrhea (Clasen and others 2005).

To reduce the transmission of pathogens, sanitation technologies isolate, transport, and treat fecal waste, and they also provide users with a dignified and comfortable experience when going to the toilet. Different rungs on the "sanitation ladder" confer different health impacts and user experiences; hence, utilization of different kinds of sanitation services or facilities can vary. For example, communal facilities may be poorly maintained, in which case they are less likely to be used by women, children, and individuals who are disabled or infirm. Distance also decreases usage of communal toilets (Biran and others 2011).

Hygiene technologies enable users to perform basic personal hygiene functions. Epidemiological studies have typically used the presence of a place for handwashing with soap and water as a proxy for handwashing practice; however, this has been shown to be only loosely correlated with observed handwashing behavior (Ram 2013).

One synthetic review and meta-analysis of health impact assessments of water and sanitation interventions includes 61 individual studies for water, 12 observations comparing unimproved and improved sanitation conditions, and only 2 observations comparing unimproved sanitation and sewer connections (Wolf and others 2014).

Table 9.4 shows relative risk reductions for different movements up the water supply and sanitation ladders. The summary risk ratio for all observations on diarrhea morbidity is 0.66 (95% confidence interval [CI]: 0.60–0.71) for water interventions and 0.72 (95% CI: 0.59–0.88) for sanitation interventions (Wolf and others 2014). An earlier review of 25 studies investigating the association between sewerage and diarrhea or other related outcomes estimated an average risk ratio of 0.70 (95% CI: 0.61−0.79), which increased to as much as 0.40 when starting sanitation conditions were very poor (Norman, Pedley, and Takkouche 2010).

A meta-analysis of hygiene interventions found an average risk ratio for diarrhea of 0.60 for promotion of handwashing with soap (95% CI: 0.53–0.68) and 0.76 for general hygiene education alone (95% CI: 0.67–0.86) (Freeman and others 2014). These results are summarized in table 9.4. An earlier systematic review found a relative risk compared to no handwashing of 0.84 (95% CI: 0.79–0.89) for respiratory infection (Rabie and Curtis 2006).

A meta-analysis that combined sanitation availability and use examined the impact of improved sanitation on soil-transmitted helminths. The meta-analysis reported the following overall odds ratios:[7] 0.51 (95% CI: 0.44–0.61) for the three soil-transmitted helminths combined, 0.54 (95% CI: 0.43–0.69) for *A. lumbricoides*, 0.58 (95% CI: 0.45–0.75) for *T. trichiura*, and 0.60 (95% CI: 0.48–0.75) for hookworm (Ziegelbauer and others 2012).

Access to sanitation has been associated with lower trachoma, as measured by the presence of trachomatous inflammation–follicular or trachomatous inflammation–intense with odds ratio 0.85 (95% CI: 0.75–0.95) and *C. trachomatis* infection with odds ratio 0.67 (95% CI: 0.55–0.78) (Stocks and others 2014).

A systematic review examined the impact of improved WASH on child nutritional status. Specifically, a meta-analysis of five randomized controlled trials found a mean difference of 0.08 in height-for-age z-scores of children under age five years (95% CI: 0.00–0.16) for solar disinfection of water, provision of soap, and improvements in water quality (Dangour and others 2013). However, the authors raised concerns about the low methodological quality of the included studies and the short follow-up periods; there was insufficient experimental evidence on water supply improvement and sanitation to include in the meta-analysis. Since publication of the Dangour and others (2013) review, several additional randomized controlled trials of household sanitation interventions have been completed (Briceno, Coville, and Martinez 2014; Cameron, Shah, and Olivia 2013; Clasen and others 2014; Hammer and Spears 2013; Patil and others 2014),

Table 9.4 Meta-Regression Results for Water and Sanitation Interventions: Relative Risks Compared with No Improved Water, Sanitation, or Hygiene Practice

Baseline	Outcome[a]			
Baseline water	*Outcome water*			
	Improved community source	*Piped water, noncontinuous*	*Piped water, high quality*	*Filter and safe storage in the household*
Unimproved source	0.89 [0.78, 1.01]	0.77 [0.64, 0.92]	0.21 [0.08, 0.55]	0.55 [0.38, 0.81]
Improved community source		0.86 [0.72, 1.03]	0.23 [0.09, 0.62]	0.62 [0.42, 0.93]
Basic piped water			0.27 [0.10, 0.71]	0.72 [0.47, 1.11]
Baseline sanitation	*Outcome sanitation*			
	Improved sanitation, no sewer		*Sewer connection*	
Unimproved sanitation	0.84 [0.77, 0.91]		0.31 [0.27, 0.36]	
Improved sanitation, no sewer			0.37 [0.31, 0.44]	
Baseline hygiene	*Outcome hygiene*			
	General hygiene education		*Handwashing with soap*	
No hygiene education or handwashing	0.76 [0.67, 0.86]		0.60 [0.53, 0.68]	

Sources: Water and sanitation: Wolf and others 2014; hygiene: Freeman and others 2014.
a. Brackets represent 95 percent confidence intervals.

most of them failing to find a significant relationship between the interventions and child health or growth outcomes. One exception is a study in rural Mali of Community-Led Total Sanitation (CLTS), which led to taller children on average (+0.18 height-for-age z-score, CI on z-score: 0.03–0.32). These children were 6 percentage points less likely to be stunted after the intervention (Pickering and others 2015). Econometric studies drawing on time series data establish links between open defecation and stunting (Spears 2013), between open defecation and childhood diarrhea in India (Andres and others 2014), and between open defecation and cognitive development in India (Spears and Lamba 2013). A source of regularly updated evidence reviews on WASH interventions with strict inclusion criteria is the Cochrane Library.[8]

Effectiveness of Service Delivery Models

Effectiveness of service delivery models is measured by intervention uptake, change in risky behaviors, sustainability, and, to a lesser extent, health outcomes. Large-scale approaches that include demand raising and behavior change are needed to achieve universal access, but experience has shown these approaches result in lower average effectiveness.

Approaches to Demand Generation and WASH Behavior Change

Demand-based approaches start from the premise that lasting change is brought about when individual and community behaviors are affected. CLTS and its school-based counterpart, School-Led Total Sanitation (SLTS), promote broader changes in sanitation and hygiene behaviors at the community level. Since its founding in 1999, the CLTS approach has rapidly expanded to more than 50 developing countries, where many thousand successful applications of the approach have been made; at least 16 national governments have adopted CLTS as national policy.[9] Rigorous evaluation of the CLTS approach has been limited, and the reliance on the emergence of natural leaders presents difficulties in testing the effectiveness of CLTS using conventional experimental methods. One exception comes from a recent example in rural Mali, in which CLTS was well implemented in a random set of villages and shown to almost double coverage of a private latrine (Pickering and others 2015).

Specific behaviors, such as household water treatment and storage (HWTS) and handwashing with soap, have been the subject of behavior change campaigns. HWTS combines marketing of low-cost water treatment (for example, boiling, filtration, disinfection using chemicals, solar and ultraviolet lamps, and flocculation) and safe storage technologies with communication- and behavior-change techniques (Peal, Evans, and van der Voorden 2010). Despite substantial evidence pointing to health benefits of HWTS, skepticism remains that the results may largely be the result of bias; concerns remain about the extent of uptake, use, and scalability of commercially marketed HWTS, particularly among poor populations most at risk of diarrheal disease (Schmidt and Cairncross 2009).

Handwashing promotion has been tested in formative research and has applied social cognitive models to determine what motivates and changes behavior. The promotion has used a variety of communication channels—such as television, radio, theater groups, community meetings, and face-to-face visits—to reach target groups who typically are mothers of young children or school-age children. A pre- and post-evaluation of the approach in Burkina Faso, which targeted the behavior of safe disposal of child feces and handwashing after contact, documented increases in handwashing (Curtis and others 2001). A similar approach to improve handwashing behavior was piloted on a large scale under the Water and Sanitation Program's Global Scaling Up Handwashing Projects in Peru, Senegal,[10] Tanzania, and Vietnam. Experimental evidence from Peru (Galiani and others 2015), Tanzania (Briceno, Coville, and Martinez 2014), and Vietnam (Chase and Do 2012) suggests the campaigns were only marginally successful. The Peru study did find large changes in behavior in a subset of communities with children who participated in a school-based handwashing promotion intervention. Effects on health were not observed in any of the countries, and the sustainability of handwashing was not measured. A key obstacle identified in both Tanzania and Vietnam was the difficult trade-off between scale and intensity of activities.

The Global Public-Private Partnership for Handwashing (PPPHW) combines the marketing expertise of the soap industry with government support and the enabling environment to trigger behavior change and reduce diarrhea. Whereas the PPPHW has expanded globally, the coalition has not yet been subject to rigorous effectiveness trials (Peal, Evans, and van der Voorden 2010). Evaluations of PPPHWs have been commissioned by private soap companies and involved providing free soap to households (Nicholson and others 2013), thus limiting their external validity.

Approaches to Strengthening Supply of Water and Sanitation Goods and Services

Supply-side approaches to water and sanitation service delivery cover the full value chain from production and assembly of inputs, importation, sales, distribution, installation, and maintenance of water infrastructure and latrines. Services range from micro and small-scale independent water resellers; network operators; well and pit diggers; operators offering masonry, pit, and septic tank emptying; and public toilet operators to medium-scale sanitation markets—or sanimarts—offering a full range of sanitation goods and services. Small-scale operators can effectively serve rural markets, where the majority of people without access to piped water and sanitation live. However, the existing literature highlights several obstacles to growth and the ability of such providers to effectively serve these rural populations.

Rural operators often face higher per capita costs because they lack economies of scale enjoyed by larger utilities and therefore have lower revenue potential (Baker 2009). Investment financing needed for growth can be difficult to secure, and the lack of formalization in the sector can result in insecure operating environments (Sy, Warner, and Jamieson 2014). The availability of alternative sources of free or low-cost water makes rural areas less attractive to independent operators. Low or uneven demand has limited growth opportunities for small-scale onsite sanitation service providers. Despite these obstacles, small-scale service providers are increasingly recognized as a central part of the solution to close the gap in water and sanitation access, particularly among the poor.

Supply-side strengthening is predominant in the Community Approach to Total Sanitation (CATS) promoted by the United Nations Children's Fund and the Total Sanitation and Sanitation Marketing (TSSM) approach of the World Bank Water and Sanitation Program. Recent randomized control trial impact evaluations of TSSM in Madhya Pradesh, India (which included a hardware subsidy to households below the poverty line); East Java, Indonesia; and 10 rural districts of Tanzania found the approach varied widely in its effectiveness across the countries, with no increase in improved sanitation in Indonesia (Cameron, Shah, and Olivia 2013) and increases of 19 and 15.7 percent in Madhya Pradesh (Patil and others 2014) and Tanzania (Briceno, Coville, and Martinez 2014), respectively. Despite better sanitation coverage in Madhya Pradesh, large numbers of adults continued to practice open defecation.

Approaches to Improve the Effectiveness of WASH Service Delivery

Addressing the supply- and demand-side constraints of WASH service delivery has led to large increases in access. But the persistence of regional and socioeconomic disparities in access suggests that current delivery models could be improved to enhance the quality of services as well as increase take-up of services, especially among the poorest populations.

Results-based approaches[11] to development that offer financial or nonmonetary rewards upon demonstration of measurable outputs or outcomes are used increasingly for achieving desirable outcomes. The specific details differ, but such approaches share a common aim of shifting the overall incentive structure from financing infrastructure to delivering services. Until recently, the experience using results-based approaches in water and sanitation was limited. A review by the World Bank in 2010 indicated that less than 5 percent of its output-based aid (OBA) portfolio was in water and sanitation (Mumssen, Johannes, and Kumar 2010). The use of OBA has increased under the Global Partnership on Output-Based Aid (GPOBA), which lists 22 projects in water supply and sanitation whose outputs include water, sewerage, or sanitation connections.[12] Multilateral and bilateral agencies such as the World Bank, Inter-American Development Bank, and Department for International Development (DfID) have shifted funding toward results-based approaches in water and sanitation. As of early 2016, the World Bank's Program-for-Results Financing (PforR) has six active operations in water supply, sanitation, and hygiene.

Microfinance or microcredit can help poor households facing liquidity constraints to invest in water supply and sanitation by (1) smoothing consumption over time, (2) encouraging households to be more willing to adopt improved services, and (3) giving those households an opportunity to purchase more durable, higher levels of service. Consumer credit has been applied successfully to increase the installation and use of household piped water connections (Devoto and others 2011), but experimental evidence of consumer lending for sanitation remains limited. However, emerging interest in the potential of microfinance for household sanitation and the results of small-scale pilots are promising. A randomized study in Cambodia found a fourfold increase in uptake when households were offered a 12-month low-interest loan to purchase a latrine (Shah 2013).

Finally, interest is emerging for using large-scale delivery platforms for social services and poverty reduction. These platforms can help improve the targeting of WASH services and will make use of the tools and mechanisms those programs have for improving livelihoods and outcomes for the poor. Examples include the following:

- Sanitation subsidies and financing can be targeted to conditional-cash transfer (CCT) participants, many of whom lack adequate sanitation. A more ambitious

approach could make receipt of cash transfers conditional on a household's use of improved sanitation. These programs also provide outreach and counseling to reach target households with sanitation promotion messages that build awareness and help change behavior.
- Community-driven development (CDD) programs can be used as a platform to deliver CLTS and to follow up with participatory planning and budgeting to ensure that communities become free of open defecation.
- Safety-net programs that build skills and strengthen sources of livelihood can include sanitation businesses and services such as masonry, plumbing, and electrical skills among the list of profitable investments for beneficiaries.
- Many nutrition interventions already promote handwashing with soap, safe water, and sanitation. Handwashing demonstrations are often included in promotions for breastfeeding and interventions for feeding infants and young children, which also stress the use of safe water in food preparation.

More innovative integration approaches may use those same channels to discuss with the community sanitation product options and services that are available. Evidence is needed on the effectiveness and the cost of integrated approaches. Such information may highlight the need for more operational research and impact evaluations to inform policy and program design.

INTERVENTION COSTS, EFFICIENCY, AND SUSTAINABILITY

Any intervention in the WASH sector requires an economic rationale, thus satisfying conditions of efficiency, affordability, and relevance. *Cost-benefit analysis* compares the intervention costs with the benefits, expressed in monetary units. *Cost-effectiveness analysis* compares the intervention costs with the benefits, expressed in some other common unit, such as lives gained or pollution load to the environment averted.

Costs

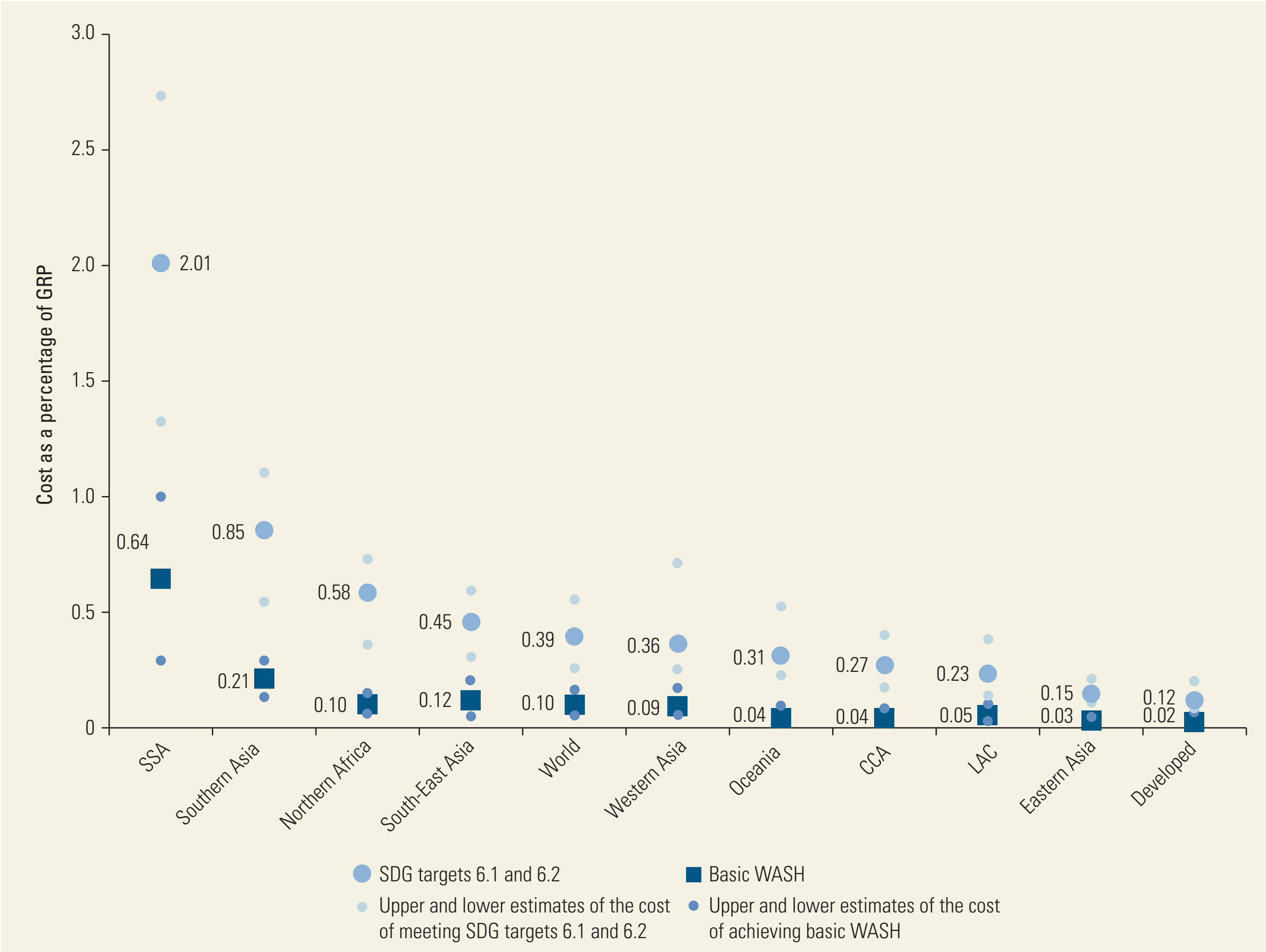
The cost of interventions is one key piece of evidence for decision making, because it is relatively easy to obtain and is often cited as a constraint for an investment decision, whether by governments, private sectors, households, or individuals. Costs can be measured for the WASH technology (the hardware), the service delivery approach (the "software" or program management), and the enabling environment.

Despite its importance, cost information is not commonly tabulated in an appropriate format to support decision making. At the policy level, budgets and resource allocations are fragmented among subsectors, levels of government, and sector partners or financiers. Considerable differences exist between budget allocations and disbursements. WASH-BAT (bottleneck analysis tool), developed by UNICEF, helps consolidate the budgetary needs so that sector bottlenecks can be removed (see annex 9B) (UNICEF 2014). At the program or service delivery levels, implementers do not easily share information on their costs, and budgets may not be structured for simple breakdowns between software and hardware costs. Cost studies for WASH technologies are more abundant, and at the local level, the market or subsidized price is available. However, the price is rarely the same as the cost. The price commonly contains either a profit or a subsidy; because both are transfer payments, they should be excluded from economic analysis. However, to ease the research burden, it is common practice in economic analysis to use prices as a proxy for cost, adjusting for any known subsidy or profit.

Published cost evidence is available in aggregated and unit forms. Aggregated cost includes the expenditure required to meet specified targets. The World Bank estimates that the global capital costs of achieving universal access to WASH services by 2030 are US$28.4 billion per year confidence interval [CI]: US$13.8 billion to US$46.7 billion) from 2015 to 2030 for basic WASH and $114 billion per year (CI: US$74 billion to US$166 billion) for safely managed WASH (Hutton and Varughese 2016).[13] Those costs are equivalent to 0.10 percent of global product for basic WASH and 0.39 percent of global product for safely managed WASH, including 140 LMICs. Those needs compare with 0.12 percent of its gross product spent on meeting the MDG water target and making progress toward the sanitation target. Universal basic access by 2030 is feasible at current spending but requires reallocations to sanitation, to rural areas, and to off-track regions. However, substantial further spending is needed to meet the higher standard of safely managed services. The costs as a proportion of gross regional product are shown by MDG region in figure 9.5. Regions most challenged to reach universal access are South Asia and Sub-Saharan Africa.

Many countries also produce investment plans for meeting national targets, thereby focusing on the financing the government will provide. The Organisation for Economic Co-Operation and Development (OECD) has created FEASIBLE, a tool for developing national financing strategies by comparing the costs of meeting national

Figure 9.5 Costs of Basic and Safely Managed Services as a Percentage of GRP, by Region, with Uncertainty Range



Source: Hutton and Varughese 2016.
Note: CCA = Caucasus and Central Asia; GRP = gross regional product; LAC = Latin America and the Caribbean; SDG = Sustainable Development Goal; SSA = Sub-Saharan Africa; WASH = water, sanitation, and hygiene. See table 9.2 for details on upper and lower values on variables varied in sensitivity analysis. GRP is based on the aggregated gross domestic product of countries in each region. An economic growth rate of 5 percent is assumed across all regions.

targets with the projected financing available.[14] FEASIBLE has been applied in at least 12 countries (OECD 2011).

A key input to these aggregated studies is the unit costs of WASH provision at the household or community level. Because of climatic, topographical, and socioeconomic differences, the costs of providing service vary highly between studies, contexts, and levels of service. The costs per cubic meter of water and of wastewater services, as well as average monthly household bills, are available for utility services through national regulators, regional associations, and global initiatives (IBNET 2014). Studies commonly compare the cost of different sources of water supply, and they find piped water to be significantly cheaper per unit compared with vendor-supplied water. However, those studies find monthly expenditure is more similar between the two sources because of higher consumption of piped water than of other water sources (Whittington and others 2009). The IRC WASHCost project calculated benchmark capital and recurrent costs for basic levels of water service in Andhra Pradesh, India; Burkina Faso; Ghana; and Mozambique (Burr and Fonseca 2013). Benchmark capital costs ranged from US$20 per person for boreholes and hand pumps to US$152 for larger water schemes. Benchmark recurrent costs ranged from US$3 to US$15 per person per year, but actual expenditures were substantially lower. Construction cost for equivalent latrines varies widely between settings (Hutton and others 2014). Comparison of alternative sanitation transportation and treatment technologies also provides important policy direction; in general, fecal sludge management is considerably cheaper than sewerage, as in Dakar, Senegal, where it was found to be five times cheaper (Dodane and others 2012). Extrapolating available data from one context to another carries risks. Therefore, simple costing tools and investment in evidence gathering are required so that cost estimates of specific locations can be made.[15]

Ideally, those who determine the costs of water supply and sanitation services would consider the externalities and the long-run cost of supply. One study provides an illustrative example of the full costs of water supply and sanitation (including opportunity costs and environmental costs) with the low costs, varying from a high of US$2.00 per cubic meter to a low of US$0.80 per cubic meter (table 9.5) (Whittington and others 2009).

From a policy perspective, the affordability and willingness to pay for those costs is a critical issue. A global review found that water supply costs as a proportion of household income are significantly higher for poorer populations (Smets 2014) and well above the benchmark of between 3 percent and 5 percent used by some governments and international organizations.

Benefits

WASH services have a large array of welfare and development benefits. Table 9.6 classifies those benefits under health, convenience, social, educational, reuse, water access, and other.

Those benefits have been evaluated extensively, but few studies evaluate the benefits comprehensively. The most robust scientific studies, such as randomized or matched prospective cohort studies, have been conducted on health effects. But only few of those studies exist, and economic variables are rarely captured. The majority of economic studies build models filled with data from a mixture of sources. Global studies assessing the economic benefits of improved water supply and sanitation include health economic benefits and convenience time savings (Hutton 2013; Whittington and others 2009). Country studies have also evaluated the value of health and time savings (Pattanayak and others 2010). Regional studies from Southeast Asia assess the water access, reuse, and tourism benefits of improved sanitation as a proportion of avoided damage costs (Hutton and others 2008, 2014).

Willingness-to-pay (WTP) studies have estimated the economic value of water quality improvements, but only very few studies use experimental methods (Null and others 2012). Other studies have assessed WTP to avoid health impacts (Guh and others 2008; Orgill and others 2013) and to receive piped water (Whittington and others 2002). A systematic review of those studies has shown that the economic value derived from the WTP for improved water quality is less than the cost of producing and distributing it (Null and others 2012). Social benefits have been assessed, but few have been expressed in money values except WTP studies, which tend to capture all benefits and make differentiating social from other benefits difficult.

Economic value is associated with river cleanup that includes improved management of municipal wastewater, as well as improved management of industrial discharge, agricultural runoff, and solid waste. The financial viability of WASH services has been expressed in terms of financial returns. The most comprehensive source of data is from projects of multilateral development banks that routinely conduct a financial assessment of WASH services before project approval and that, in some cases, report on the completion of project implementation.

Table 9.5 Cost Estimates of Improved Water and Sanitation Services

US$ per cubic meter

Cost component	Full cost	Minimal cost
Opportunity cost of raw water supply	0.05	0.00 ("steal it")
Storage and transmission to treatment plant	0.10	0.07 (minimum storage)
Treatment to drinking water standards	0.10	0.04 (simple chlorination)
Distribution of water to households	0.60	0.24 (PVC pipe)
Collection of wastewater from home and conveyance to treatment plant	0.80	0.30 (condominial sewers)
Wastewater treatment	0.30	0.15 (simple lagoon)
Damages associated with discharge of treated wastewater	0.05	0.00 ("someone else's problem")
Total	**2.00**	**0.80**

Source: Whittington and others 2009.

Note: PVC = polyvinyl chloride. Discount rate used is 6 percent. Using a 3 percent discount rate, the total cost is US$1.80 per cubic meter at full cost and US$0.70 per cubic meter at minimal cost.

Table 9.6 Benefits of Improved Drinking Water Supply and Sanitation

Benefit	Water	Sanitation
Health, burden of disease	• Averted cases of diarrheal disease • Reduced malnutrition, enteropathy, and malnutrition-related conditions (stunting) • Less dehydration from lack of access to water • Less disaster-related health impacts	• Averted cases of diarrheal disease • Averted cases of helminths, polio, and eye diseases • Reduced malnutrition, enteropathy, and malnutrition-related conditions (stunting) • Less dehydration from insufficient water intake because of poor latrine access • Less disaster-related health impacts
Health, economic savings	• Costs related to diseases, such as health care, productivity losses, and premature mortality	• Costs related to diseases, such as health care, productivity losses, and premature mortality
Convenience time savings	• Saved travel and waiting time for water collection	• Saved travel and waiting time from having nearby private toilet
Educational benefits	• Improved educational levels because of higher school enrollment and attendance rates from school water • Higher attendance and educational attainment because of improved health	• Improved educational levels because of higher school enrollment and attendance rates from school sanitation • Higher attendance and educational attainment because of improved health
Social benefits	• Leisure and nonuse values of water resources and reduced effort of averted water hauling and gender impacts	• Safety, privacy, dignity, comfort, status, prestige, aesthetics, and gender effects
Water access benefits	• Pretreated water at lower costs for averted treatment costs for households	• Less pollution of water supply and hence reduced water treatment costs
Reuse		• Soil conditioner and fertilizer • Energy production • Safe use of wastewater
Economic effects	• Incomes from more tourism and business investment • Employment opportunity in water provision • Rise in value of property	• Incomes from more tourism and business investment • Employment opportunity in sanitation supply chain • Rise in value of property

Sources: Adapted from Hutton 2012; Hutton and others 2014.

Intervention Efficiency: Cost-Benefit Analysis

The discussion of efficiency should distinguish between cost-benefit analysis, which uses a common money metric for all costs and benefits, and cost-effectiveness analysis, which compares interventions for one type of outcome. Reviewed cost-benefit studies are provided in annex 9C.

Efficiency studies can be conducted in two ways (Whittington and others 2009):

- By generating estimates of cost and benefit in specific sites or field studies for the purposes of either evaluating intervention performance or selecting a site for a future project (Kremer and others 2011)
- By using model costs and benefits for specific sites or larger jurisdictions, such as country or global level, and best-available evidence from multiple sources (Hutton 2013; Whittington and others 2009)

Given the high costs and challenges associated with collecting all the cost and benefit data required for the first approach, it is common practice to combine site-specific values with data extrapolated from other sources (Hutton and others 2014). Table 9.7 shows the most recently available global studies that have modeled selected water supply and sanitation interventions. One important finding from these studies is that lower technology interventions have higher returns than more expensive networked options.

Global studies indicate the projected overall costs and benefits from intervention alternatives, but they are not particularly useful in guiding decisions on

Table 9.7 Benefit-Cost Ratios from Global Studies

Study and intervention	Benefit-cost ratio
Whittington and others (2009): modeled approach[a]	
Networked water and sewerage services	0.65
Deep borehole with public hand pump	4.64
Total sanitation campaign (South Asia)	3.00
Household water treatment (biosand filters)	2.48
Hutton (2013): modeled approach[b]	
Improved water supply (JMP definition)	2.00
Improved sanitation (JMP definition)	5.50

Sources: Hutton 2013; Whittington and others 2009.
Note: All studies include the value associated with health and convenience time savings.
a. Ranges on each parameter value are then used to conduct Monte Carlo simulation that enables exploration of intervention performance in a range of different settings. Hence, even interventions with a benefit-cost ratio of 2.0 or more are expected to have a benefit-cost ratio of less than 1.0 under some runs of the model.
b. Estimates indicate global averages, and regional averages are available in the paper. A separate working paper provides results for each country (Hutton 2012).

which technology and service level to choose in specific settings. One randomized implementation study in India finds similar health costs between study arms. However, it finds statistically significant savings in time in the intervention group of US$7 per household (US$5 for water and US$2 for sanitation) during the dry season, or roughly 5 percent of monthly cash expenditures (Pattanayak and others 2010). A study from South Africa estimates a benefit-cost ratio of 3.1 for small-scale water schemes (Cameron and others 2011). A study from Indonesia compared three wastewater treatment interventions and finds limited economic rationale for the interventions (Prihandrijanti, Malisie, and Otterpohl 2008). However, a broader cost-benefit study at the river basin level estimated the benefits of cleaning up the Upper Citarum river in Indonesia exceeded costs by 2.3 times (Hutton and others 2013).

Targeting the poor could be justified; children from poorer households are at increased health risk because they live in communities with lower access to improved water and sanitation facilities. A study in Bangladesh, India, and Pakistan estimating the cost per episode for income quintiles shows that costs of an illness represent a higher proportion of income for lower quintiles (Rheingans and others 2012).

The cost efficiency of technologies depends on the local geological setting, population density, and number of households to be served. Large water distribution and sewerage systems may only be cost efficient if they serve large, dense populations. Providing water service on a smaller scale through either communal or in-compound wells or boreholes and onsite household sanitation may be a more appropriate and cost-efficient service level for sparsely populated areas (Ferro, Lentini, and Mercadier 2011).

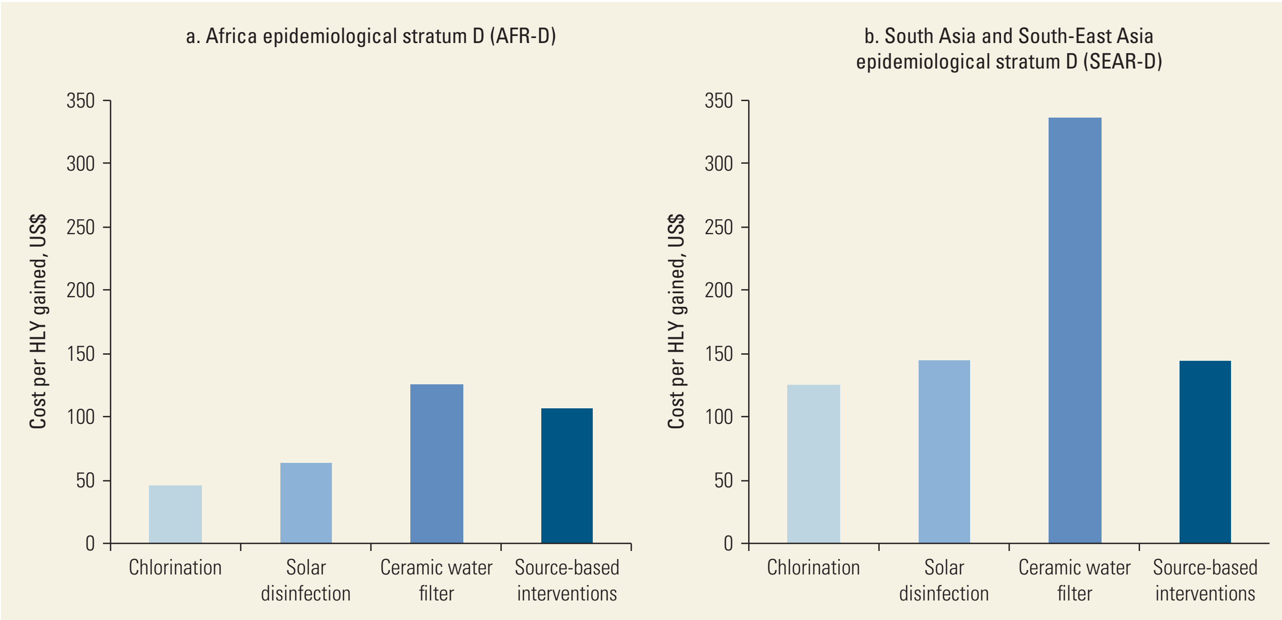
Intervention Efficiency: Cost-Effectiveness Analysis

The main outcomes used in cost-effectiveness studies are health and environmental outcomes. When used to compare programs in a sector, cost-effectiveness can be measured by program outcomes, such as the number of latrines constructed, the number of water connections installed, or the percentage of beneficiaries changing behavior. For water supply interventions, health cost-effectiveness studies have been conducted (see annex 9C). Studies focus on improved water supply according to the JMP definition and point-of-use treatment by households or schools. A global study compares water supply interventions at the regional level (Clasen and others 2007).

Figure 9.6 shows the cost per healthy life-year (HLY) gained for four interventions in two regions. It shows that the selected interventions vary by a factor of approximately 2.5 between the most cost-effective (chlorination) and the least cost-effective (ceramic filter). However, all interventions have a cost per HLY that is below the GDP of countries in these regions, thereby indicating a cost-effective use of health resources. Another global study found the incremental costs averted of adding point-of-use water disinfection on top of improved water supply costs resulted in a cost per DALY averted of less than US$25 in Sub-Saharan Africa, of US$63 in India and Bangladesh, and of less than US$210 in South-East Asia and the Western Pacific (Haller, Hutton, and Bartram 2007).

Fewer studies have conducted health cost-effectiveness analyses of sanitation and hygiene interventions. Two global studies by the WHO and World Bank examine the cost-effectiveness of water supply and sanitation combined (Günther and Fink 2011; Haller, Hutton, and Bartram 2007). Using regions defined by epidemiological strata, WHO estimates that the cost in countries with high child and high adult mortality is less than US$530 per DALY averted in the Eastern Mediterranean and Middle East, US$650 in Sub-Saharan Africa, US$1,400 in South and South-East Asia, and US$2,800 in Latin America and the Caribbean. A World Bank study on child mortality reduction estimates the average cost per life year saved in Sub-Saharan African countries is US$1,104 for basic improved water and sanitation

Figure 9.6 Cost Per HLY Gained from Four Water Supply and Water Quality Interventions in Two World Subregions, US$, 2005



Source: Clasen and others 2007.
Note: AFR-D = African Region–high child, high adult mortality countries; HLY = healthy life-year; SEAR-D = South-East Asian Region–high child, high adult mortality countries. AFR-D and SEAR-D are part of the World Health Organization's epidemiological subregions.

and is US$995 for privately piped water and flush toilets (Günther and Fink 2011).

In country studies in South-East Asia, the cost per DALY averted of basic sanitation is less than US$1,100 in selected rural areas of Cambodia, China, Indonesia, the Lao People's Democratic Republic, and Vietnam; the exception is in the Philippines, where it is US$2,500 (Hutton and others 2014). Few recent country-specific studies are available on hygiene interventions; one study from Burkina Faso estimates a cost of US$51 per death averted for health education to mothers (Borghi and others 2002).

Sustainability of water supply, sanitation, and hygiene is covered in annex 9D; financing is covered in annex 9E.

CONCLUSIONS

Although global deaths from diarrhea have declined significantly over the past 20 years, poor water supply, sanitation, and hygiene are still responsible for a significant disease burden. An estimated 842,000 global deaths in 2012 were due to diarrhea caused by poor WASH. Other less well-quantified but important long-term health consequences of poor WASH, such as helminths and enteric dysfunction, remain. Those diseases affect children's nutritional status, thereby inhibiting growth and mental development. Overall, the health impacts of poor WASH lead to economic consequences of several percent of GDP and continue to significantly affect quality of life and the environment. Furthermore, water stress is a growing phenomenon that will affect at least 2.8 billion people in 48 countries by 2025. Climatic factors are harder to control, but water scarcity can be mitigated by changing water use patterns and reducing pollution of surface waters.

Important progress has been made in achieving the MDG global water and sanitation targets. In September 2015, new global targets for universal access to safe WASH were adopted. At the current rates of progress and using current indicators, achieving those targets will take at least 20 years for water supply and 60 years for sanitation (WHO and UNICEF 2014). Covering the poor and marginalized populations will continue to be a challenge; the remaining unserved populations are likely to be harder to reach as universal access is approached. The service level benchmark of targeting safely managed services will require better policy and regulatory frameworks and more resources. Indeed, as environmental consequences intensify and populations demand a higher quality of service, a higher target for service level will be increasingly required. This demand will raise questions about priorities; countries will face a trade-off between (1) dedicating policy space and spending public subsidies to move populations that are already served higher up the water and sanitation ladder and (2) reaching populations that are not served with basic WASH services. Each country will have its unique set of challenges. The human right to drinking water and sanitation can serve as a reminder that priority should be given to ensuring at least a minimum level of affordable WASH service for all citizens.

Populations are growing and moving, economies are developing and becoming richer, and the climate is changing. Each one has its challenges and opportunities. Population migration to greenfield sites offers a chance of implementing new and appropriate technologies, and selection of cost-effective and affordable technologies in urban planning is essential. Economic growth leads to greater tax revenues for local governments and increased ability to upgrade infrastructure and expand urban renewal. Climate change challenges the delivery of WASH services by affecting rainfall patterns, freshwater availability, and frequency of heat events, and it exacerbates health risks. However, this new threat, when taken seriously, can be an opportunity to overhaul outdated policies and technologies. Furthermore, as nutrient sources for chemical fertilizer become scarcer, price increases will force suppliers to seek alternatives; the price of composted sludge is expected to increase, thereby attracting investments. New research, data, and technologies are increasingly available to present new possibilities for addressing entrenched problems in the WASH sector.

The following research priorities are recommended for immediate attention:

- To adequately address equity considerations in the SDG era, there is a need to understand where poor people live and what their levels of access are. Disaggregated data on the underserved—including slum populations, ethnic groups, women, elderly, and persons with disabilities—can support prioritization. Greater focus is needed on how to increase access in the lagging regions of South Asia and Africa, where a large proportion of the unserved live. At the country level, policy and financial incentives need to be aligned and the economic arguments made for allocating resources to WASH services.
- More evidence is needed to support the emerging understanding of the wider health effects of water, sanitation, and hygiene. Multisectoral approaches will become more important as the complementarities among WASH, health, and nutrition are better understood. Further, rigorously designed and controlled studies are needed to quantify these benefits, including the measurement of cost-effectiveness to guide policy and program design.
- The social welfare consequences of poor WASH are not well documented but are potentially very large. In particular, a greater understanding is needed of the gender effects of inadequate WASH and of how improved WASH services contribute to gender equality.
- A large part of the remaining challenge of improving access to sanitation and hygiene is behavioral rather than technical. However, little evidence exists on the effectiveness of behavior change using conventional methods at scale or on the transferability of behavior change interventions that are successful in a particular context. A better understanding of habit formation and what leads to sustainable behavior change is needed.
- Innovative delivery platforms that leverage national poverty reduction programs, such as CCT and CDD programs, have the potential to achieve wide coverage at little marginal cost. Such approaches can also provide the methodology and data sources to support targeting areas of poverty in WASH services.
- A better understanding is needed on which WASH interventions work in slum areas and low-income neighborhoods and under what conditions the interventions work.
- A greater understanding is needed of how output-based incentives can be used to improve WASH service delivery and to lead to greater sustainability of services.
- Innovations in subsidies and microfinance are needed to ensure that the poor gain access to improved sanitation. Despite greater availability and lower cost of sanitation goods and services, some people remain too poor to afford adequate water supply and sanitation. Such populations should be identified to receive hardware and financial subsidies.

ANNEXES

The annexes to this chapter are as follows. They are available at http://www.dcp-3.org/environment.

- Annex 9A. Overview of Studies Presenting Damage Costs of Poor Water, Sanitation, and Hygiene at the National Level
- Annex 9B. Effectiveness of Enabling Environments
- Annex 9C. Cost-Effectiveness and Cost-Benefit Studies on Water, Sanitation, and Hygiene
- Annex 9D. Intervention Sustainability
- Annex 9E. Intervention Financing

NOTES

World Bank Income Classifications as of July 2014 are as follows, based on estimates of gross national income (GNI) per capita for 2013:

- Low-income countries (LICs) = US$1,045 or less
- Middle-income countries (MICs) are subdivided:
  a) lower-middle-income = US$1,046 to US$4,125
  b) upper-middle-income (UMICs) = US$4,126 to US$12,745
- High-income countries (HICs) = US$12,746 or more.

1. United Nations Human Rights Council, Resolution 18/1, "The Human Right to Safe Drinking Water and Sanitation," adopted September 28, 2011, http://www.worldwatercouncil.org/fileadmin/wwc/Right_to_Water/Human_Rights_Council_Resolution_cotobre_2011.pdf.
2. United Nations Human Rights Council, Resolution 18/1.
3. Whereas no academic literature is available with such examples, national surveys (such as the Demographic and Health Survey or the Multiple Indicator Cluster Survey) show that a higher proportion of households practice unsafe management of children's feces as compared with overall household unimproved sanitation practices.
4. JMP reports for country data and additional breakdowns are available at http://www.wssinfo.org.
5. Characterized by villous atrophy, crypt hyperplasia, increased permeability, inflammatory cell infiltrate, and modest malabsorption.
6. The hidden flow of water if food or other commodities that require water to be produced are traded from one place to another.
7. An odds ratio (OR) is a measure of association between an exposure and an outcome. The OR represents the odds that an outcome will occur given a particular exposure, compared with the odds of the outcome occurring in the absence of that exposure.
8. For more on the Cochrane Library, see http://www.thecochranelibrary.com.
9. For more information on CLTS, see http://www.communityledtotalsanitation.org/page/clts-approach and http://cltsfoundation.org/clts-map.html.
10. The impact evaluation in Senegal was compromised because of contamination of the treatment group with the handwashing with soap intervention group.
11. Examples of results-based approaches include the following: output-based aid (OBA), results-based financing (RBF), pay-for-performance (P4P), program for results (PforR), and conditional-cash transfer (CCT).
12. Accessed March 31, 2014, through the OBA website, https://www.gpoba.org.
13. *Basic water:* percentage of population using a protected community source or piped water with a total collection time of 30 minutes or less for a round-trip, including queuing (same as JMP improved definition except time criteria has been introduced). *Basic sanitation:* percentage of population using a basic private sanitation facility (same as JMP improved definition). *Basic hygiene:* percentage of population with handwashing facilities with soap and water at home. *Safely managed water:* percentage of population using safely managed drinking water services. Corresponds to population using an improved drinking water source located on the premises, available when needed, and free of fecal and priority chemical contamination. *Safely managed sanitation:* percentage of population using safely managed sanitation services. Includes safe onsite isolation, extraction, conveyance, treatment and disposal, or reuse.
14. For information about the OECD's methodology and FEASIBLE computer model, see http://www.oecd.org/env/outreach/methodologyandfeasiblecomputermodel.htm (accessed November 11, 2015).
15. For example, the IRC International Water and Sanitation Center has developed the WASHCost Calculator (www.ircwash.org/washcost), whereas the World Bank's Economics of Sanitation Initiative has developed an economic assessment toolkit under the Economics of Sanitation Initiative (http://www.wsp.org/esi).

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