

# Water, Well-Being, and the Prosperity of Future Generations

Claire Chase and Richard Damania

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# Water, Well-Being, and the Prosperity of Future Generations

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# Abstract

Water-related diseases are a major health burden for populations, especially the poor. Meeting global aspirations for poverty reduction will require addressing the global water and sanitation challenge. This discussion paper provides an overview of the poverty-related impacts of inadequate water supply and sanitation services, and highlights the new policy challenges that have emerged in a more populated, polluted, and urbanized world with finite water resources. New approaches that assure sustained changes in individual behavior, more equitable access to services, and incentives for improved water resource stewardship are needed.

## Main Messages

Poverty and poor health are close companions, with links that run in both directions. The poor remain more vulnerable to a range of preventable diseases and health disorders, while poor health, in turn, limits employment opportunities and labor productivity, thereby accentuating poverty. Waterborne diseases are heavily implicated in this vicious cycle of poverty and ill-health. By some estimates, every minute a child dies of a water-related disease (IMF 2015). Meeting global development aspirations and the World Bank's "twin goals" of poverty reduction and shared prosperity will require addressing the global water and sanitation challenge as a priority.

This document provides a brief overview of the poverty-related impacts of inadequate water supply and sanitation services. It highlights the new policy challenges that have emerged in a more populated, polluted, and urbanized world with expanding water deficits. It briefly identifies the policy needs and priorities that must be addressed to meet

the challenges of the new Sustainable Development Goals (SDGs).

Hundreds of millions of the poor in less developed countries live without safe drinking water and sanitation. Services typically fail to reach these populations. Those that do are seldom affordable or of adequate quality. These conditions create an environment where water-related diseases thrive, requiring greater spending on health care, limiting productivity, and sending the poor deeper into poverty.

Young children bear the brunt of this disease burden, the effects of which may become more apparent only over a lifetime, with reduced school attendance, impaired academic performance, reductions in earning potential, and higher susceptibility to chronic disease—a side effect of early childhood disease and undernutrition. The economic costs of poor water and sanitation are significant and estimated at \$260 billion a year, or about 1.5 percent of the GDP of developing countries (Hutton 2013).

New evidence suggests that these effects may in fact be an underestimate. In the past the effects of poor water and sanitation were thought to occur

**Water-related diseases disproportionately affect the poor and create a vicious spiral of poverty that often persist across generations.**

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primarily through diarrhea and other infectious diseases. More recent research indicates that a substantial portion of the burden of undernutrition, and stunting in particular, may be due to poor gut conditions caused by poor water and sanitation environment that do not produce symptoms such as diarrhea (Humphrey 2009).

There is mounting evidence of other adverse impacts of poor water and sanitation, such as higher rates of infection during birth due to poor hygiene practices. Lack of running water and improper containment and disposal of human waste greatly hindered response efforts in some clinics during the 2014 outbreak of Ebola in West Africa. Industrializing countries now confront a dual disease burden: the pollutants generated by rapid industrializa-

tion have introduced new disease risks, even before countries have dealt with existing diseases of underdevelopment such as diarrhea and undernutrition.

Over the past several decades, the global community has invested billions of dollars to improve water and sanitation infrastructure. These investments helped to achieve the Millennium Development Goal (MDG) target for safe drinking water five years ahead of schedule. But similar levels of investment did not occur for sanitation; as a result, this target was missed for 700 million people.

Even reaching these access targets would not signal “mission accomplished.” Drinking water supplied from a source that meets the MDG target of an “improved source of water” does not guarantee that the water is safe to consume, is nearby, or is available when needed. By the same token, sanitation solutions that do not provide an option for transporting, treating, and disposing of waste risk introducing harmful pathogens back into the environment.

There are other issues that have less to do with engineering and more to do with human behavior. Household behaviors—safe storage of drinking water, use of latrines, handwashing—largely mediate the effects of water and sanitation infrastructure, especially where infrastructure is of lower quality.

The solutions to this multifaceted problem are not straightforward. The Sustainable Development Goals (SDGs) aim to ensure availability and sustainable management of water and sanitation for all, including ending open defecation. Spending on infrastructure alone—which is still far from adequate in many parts of the world—will not be enough, while conventional methods for changing people’s behavior, such as Community Led Total Sanitation and large-scale handwashing campaigns, have demonstrated limited success.

To change the behavior of millions and achieve the ambitious targets of the SDGs, innovation is needed. New ways of marketing better behavior and influencing social norms are needed. Some initiatives appear to be promising. The use of unconventional media and communication techniques, subliminal nudges, and other devices that cater to behavioral biases have been shown to work and should be scaled up. Innovation will also need to come in the form of new financial products and services that enable the poor to invest in water and sanitation, or better targeting of subsidies to those who are most in need.

Water insecurity—loosely defined as water stress or scarcity—will compound the problems the poor face in accessing water and sanitation. Water constraints in developing countries are set to worsen with population growth, urbanization, and climate change. Somewhat paradoxically, many of the most water stressed countries in the world (in the Middle East and North Africa and Central Asia) are also the least efficient users of water. As the

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**To change the behavior of millions and achieve the ambitious targets of the SDGs, innovation is needed.**



SDGs move the goalpost to universal coverage of a higher standard, more water will be demanded and regional shortages of water will become even more severe.

Most often, water stresses are heightened by water management policies and subsidies that promote and condone overuse, wastage, and inefficiency. In urban areas, subsidized or free piped water is typically provided to the middle and upper classes, while the unserved poor, particularly in urban slums, are compelled to pay a much higher price for water of uncertain quality from vendors. “Free” water is therefore especially costly for the poor—in terms of both the higher price they pay per drop of water as well as the health effects of contaminated water.

Water stresses are further compounded by declining water quality in all developing countries, often to the point of irreversible damage. The pollution plumes of cities and intensive agriculture are growing larger with expanding economies and rapid industrialization. The health effects of chemicals and metals such as arsenic, mercury, and pesticides are often less immediate but more damaging than the effects of biological pathogens. Chemical pollutants are much harder and more expensive to treat than sewage. As a result, it is often cheaper to control and mitigate these pollutants at source rather than seek end-of-pipe solutions. This is especially challenging in developing countries, where the required policies, institutional capacities, and compliance regimes need to be developed.

Going forward, it is clear that a higher level of investment in the hardware of water and sanitation infrastructure is necessary but will not be sufficient. Investments will need to be accompanied by an equivalent investment in the policy “software.” This will call for greater innovation and investment in the 3-I’s that will be

pivotal to success—Individuals, Institutions, and Integrated water resource management:

1. Invest in *Individuals* to promote and sustain behavior change using new communication tools, “nudges,” and subsidies where needed.
2. Strengthen emphasis on *Institutional* capacity to assure sustainable access of good quality and affordable services through equitable cost-recovery mechanisms and greater accountability to the consumer.
3. Promote *Integrated water resource management* through incentives that address issues of water quality, as well as the integrity of watersheds and the wider resource base.

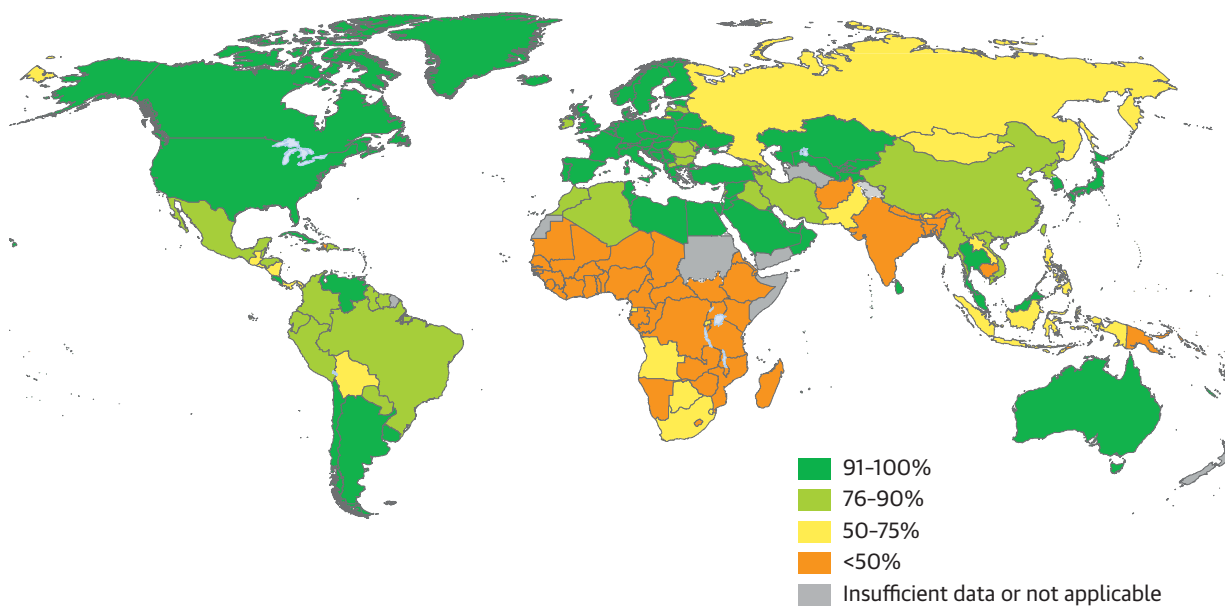
## Progress on the MDGs—and the SDGs Going Forward

Hundreds of millions of the poor in less developed countries lack access to safe drinking water and sanitation. About 30 percent of humanity—an estimated 2.4 billion people—lack access to sanitation facilities that meet adequate standards of hygiene (map 1).<sup>1</sup> About 600 million people rely on what development agencies call unimproved drinking water sources, susceptible to high levels of contamination (map 2) (WHO and UNICEF 2015). Many more use sources that are classified as improved, but the water is still unsafe for consumption. Recent estimates suggest that 1.8 billion people (28 percent of the global population) use unsafe water, and one in eight people defecate in the open (WHO and UNICEF 2015). The consequences: every minute a child dies of a water-related disease (IMF 2015).

• **Beyond investments in infrastructure, greater innovation and investment in the 3-I’s—Individuals, Institutions, and Integrated water resource management—will be pivotal to success.**

• **2.4 billion people lack improved sanitation, 600 million lack access to an improved water source, and another 1.2 billion drink unsafe water from an “improved” source.**

**MAP 1. Proportion of Population with Improved Sanitation**



Source: WHO and UNICEF 2015.

One of the four targets of Millennium Development Goal 7 (MDG-7) was to halve the proportion of the population that lacked access to safe drinking water and basic sanitation. Achieving it would likely have brought about greater development returns than any other single intervention. This is because water-related health shocks have direct impacts on incomes, assets, and earning capacities—often lingering across generations. Although the target for safe drinking water was achieved five years ahead of the 2015 target date, the world fell behind on sanitation, missing that target by 700 million people.<sup>2</sup>

And having met the MDGs of an improved water source is no guarantee that the water provided is either accessible or supplied continuously, that it meets the desired health standards, or that the sanitary latrines built are used or sustainable. There already are signs of regression on all these fronts.

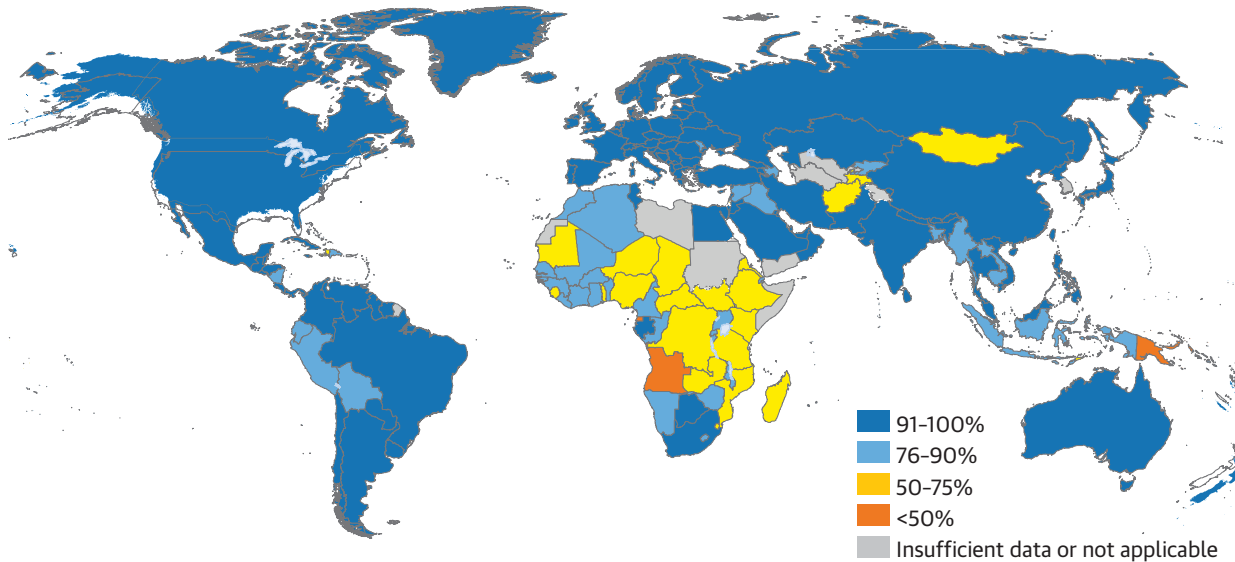
These and other challenges on equity, affordability, and quality have motivated the post-2015 Sustainable Development Goals (SDGs). These goals are even more ambitious than the MDGs, with six targets aimed at assuring safe and sustainable availability of water supply and sanitation for all. As development continues at breakneck speed in most developing countries and regions, the world is faced with an ever more challenging problem where an emerging burden of disease caused by industrialization coexists with diseases of underdevelopment like diarrhea and undernutrition. These emerging problems have received somewhat less attention in the SDGs.

**An emerging burden of disease caused by industrialization coexists with diseases of underdevelopment. These emerging problems have received somewhat less attention in the SDGs.**

**Despite Progress, Many Challenges Remain**

Millions of poor households were left behind. In India for example, nearly 80 percent of the poor defecate in the open, compared with just 8 percent of the wealthiest.

**MAP 2. Proportion of the Population with an Improved Water Source**



Source: WHO and UNICEF 2015.

### Poverty Is Intertwined with Unsafe Water and Sanitation

Poverty is closely intertwined with access to adequate water and sanitation. Poverty makes water and sanitation services less affordable and accessible, while inadequate water and sanitation services provoke conditions for waterborne diseases to thrive, inducing more poverty. The economic burden is significant through the effects on health and productivity. Safety and dignity are also concerns, especially for girls and women. New evidence suggests that the severity and extent of the effects of poor water and sanitation on health and development have been underestimated.

### Myriad Effects of Unclean Water, Bad Sanitation, and Poor Hygiene on Health and Development

The developed world takes clean water for granted, but for hundreds of millions of the poor in less developed countries, the difference between safe and

unsafe drinking water and sanitation is often a matter of life and death.

Inadequate sanitation, poor hygiene, and the lack of access to enough clean water are linked to diarrheal diseases, enteric infections, helminthes, and parasitic infections. These diseases originate from human and animal feces that contaminate the open environment.

It is well known that some of the largest declines in child deaths in the United States and Great Britain came from investments in clean water and sanitation infrastructure (UNDP 2006). Indeed, child mortality increased in Great Britain for most of the second half of the nineteenth century, despite a doubling of average income. It was not until major sanitation reforms in the late 1800s that life expectancy and child survival improved significantly (Cutler and Miller 2005). More recently, the substantial health improvements observed on Native American reservations in the United States have been attributed to piped water and sanitation (Watson 2006).

The tremendous global health burden of diarrheal disease falls disproportionately on young children. The World Health Organization (WHO) estimates that 58 percent of diarrheal deaths are caused by poor water, sanitation, and hygiene, killing 1,000 children each day (Prüss-Ustün et al. 2014). Poor water and sanitation cause just under 1 percent of all Disability Adjusted Life Years (DALYs) globally (Lim et al. 2012). Vaccines can help protect against some of the most deadly forms of viral diarrhea, such as rotavirus and cholera (box 1). But diarrhea remains one of the top three killers of infants and young children worldwide. Not all cases can be effectively treated, suggesting that prevention remains a top priority (Liu et al. 2012).

Feces, and the pathogens they carry, can enter a person's body through contaminated water, through flies that rest on food, or through dirty shoes or soles of the feet that come into contact with contaminated soil, bringing harmful pathogens into the home.

Latrines that safely contain feces are a primary barrier, blocking them from entering the environment, where they are transmitted by fingers, flies, fluids, fields, and food. Handwashing with soap, especially after defecation, is another primary barrier. Treating water that has become contaminated can eliminate these pathogens.

### More than 1.7 Billion People Have Worms

Poor water and sanitation have other health consequences. Children, especially those of school age, and adults living in poor sanitary conditions, risk infection by parasitic worms that live and breed in water and feces. More than 1.7 billion people are infected with hookworm, roundworm, and whipworm, with those in Asia at highest risk (Pullan et al. 2014). The infections are associated with anemia, listlessness, and stunted growth— symptoms that keep children out of school or impair their academic performance and reduce their earning potential (Miguel and Kremer 2004).

#### BOX 1. Cholera Afflicts 2.9 Million People a Year

Cholera causes severe diarrhea and kills about 95,000 people a year, most of them children. An estimated 2.9 million cases of cholera occur each year in over one-third of countries worldwide where the disease is endemic (Ali et al. 2015).

The fecal contamination of water or food transmits cholera. Clean water and sanitation are critical to preventing it from spreading. A promising oral cholera vaccine has enormous potential to protect those at risk, but this does not diminish the central importance of clean water, sanitation, and hygiene as long-term weapons in the fight against cholera.

A coordinated approach is being taken, for instance, in the World Bank's \$50 million investment targeting cholera hotspots in Haiti. The project will provide 300,000 people with improved water sources and sanitation facilities. It will also strengthen the national cholera control program through support to epidemiological surveillance; joint training for water, sanitation, and health actors; and improve coordination with the Ministry of Health and Population (MSPP). These investments recognize that cholera control requires the effective integration of health and water and sanitation interventions, as well as an integrated approach to treatment at the health facility-level, provision of water treatment products, and community-level education and prevention campaigns.

### **Fecal Pathogens Assault the Gut**

Perhaps more critical to children's well-being and life-time potential are the invisible infections that children harbor in areas with poor water and sanitation. Pathogens in the environment, especially fecal pathogens, constantly assault the gut. The infections damage the gut lining and deprive it of its ability to absorb nutrients, leading to malnutrition. The small intestine becomes more porous, and disease-causing pathogens enter the bloodstream more easily, activating an immune response and diverting energy from human growth. Up to 43 percent of stunting may be due to these silent infections (Guerrant et al. 2013).

### **Food May Do Little to Nourish**

Malnutrition is a multifaceted problem that involves more than availability and affordability of food. Infectious diseases such as diarrhea impede the absorption of nutrients from food and determine nutritional status. An abundance of food may do little to nourish communities in contact with fecal germs, waterborne infections, and poor health and care practices. Malnutrition can be widespread even in regions with plentiful supplies of affordable food and low-cost calories. Even near-universal coverage of the most effective nutrition interventions in high-burden countries would make only a dent in resolving the stunting problem (Bhutta et al. 2013).

### **Stunting Kills 1 Million Children Each Year**

Stunting is a particularly harmful symptom of malnutrition because it is associated with irreversible effects on the body and brain. One-quarter of children under five are stunted. The conditions of stunting interact with infectious disease to cause 1 million deaths each year (Black et al. 2013). Children who suffer from repeated bouts of diarrhea caused by poor water and sanitation have trouble absorbing nutrients, which can in turn cause stunting. With its focus on diarrhea, previous research has underestimated the health impacts of inadequate water and sanitation.

The cumulative evidence from a variety of sources suggests links between height and exposure to pathogens caused by poor water (Fink, Gunther, and Hill 2011). The problem is especially prevalent in India where children born in Indian districts with high levels of open defecation are shorter than their counterparts born elsewhere in the country (Spears, Ghosh, and Cumming 2013). Children in India are considerably shorter than children in Africa, despite India's higher GDP, and also shorter than in Bangladesh, whose population is genetically similar and also poorer than India (box 2). A higher incidence of and exposure to open defecation in India and its higher population density may partially explain the apparent South Asian Enigma of malnutrition—an unresolved paradox whereby despite higher GDP, South Asians fare worse on nutritional outcomes than many countries in Africa with lower GDP (Ramalingaswami et al. 1997). The average Indian child is exposed to more than 200 open defecators in the immediate neighborhood of a square kilometer, while a counterpart in Chad is exposed to only seven (Coffey 2013).

### **The Sanitation of Communities, Not Just Households, Needs to Be Improved**

The majority of the benefit of improved sanitation comes from a community's access to sanitation, not just a household's (Gunther and Fink 2010, Andres et al. 2014). As population density and the number of people defecating in the open in a given area increase, so do the negative health impacts, suggesting that risks vary spatially.

Stunting would not matter much if the consequences were restricted to stature. But it is also associated with severe and permanent cognitive deficits, impaired vaccine responses, obesity, chronic disease, and the inter-generational transmission of poverty (Guerrant et al. 2013). The association between an individual's height and earnings is robust, largely explained by cognitive function. Healthier babies are better able to develop their cognitive potential and accumulate more human capital, which translates into higher earnings. Even in

## BOX 2. Two Bengals—One Taller, One Shorter

Children in West Bengal, India and in Bangladesh likely share the same genetic height potential, on average. Per capita incomes are higher in West Bengal than in Bangladesh, but Bangladesh has lower infant mortality, reflecting successful social investments. In West Bengal, higher wealth is reflected in a child population that is taller, on average. However, at each level of income or wealth, an average child in Bangladesh is taller than a counterpart in West Bengal.

Why might this be so?

Statistical evidence suggests that the differences in open defecation, controlling for wealth, can account for the differences in height. In Bangladesh, more than 80 percent of the population use latrines, while in West Bengal, the share is only about 50 percent. The height gap at any given level of wealth can be statistically “explained” by the open defecation gap (Ghosh et al. 2015).

the United Kingdom, an extra inch of height is associated with a 1-2 percent increase in earnings, reflecting the effects of early childhood nutrition on future human capital (Case and Paxson 2008).

### Stunted Mothers Have Stunted Children

Perhaps more concerning is that stunting and the poverty induced by open defecation persist across generations. Stunted mothers are more likely to give birth to stunted children (Spears 2012) because poor maternal nutrition and exposure to infectious disease have impacts even before a child is born—setting out a trajectory of shorter growth over the lifetime (Victora et al. 2010) and conditioning a child for worse health outcomes later in life (Barker 1990).

### Poor Water, Sanitation, and Hygiene Cost \$260 Billion a Year

The economic costs of poor water supply, sanitation, and hygiene are estimated at \$260 billion a year, or about 1.5 percent of the GDP of developing countries (Hutton 2013). The bulk comes from the *time lost* fetching water, and to a lesser extent the time spent walking to sites for open defecation. Death and disease caused by poor water and sanitation account for most of the rest—costs incurred by the health sector, by

individuals inflicted with illness, and by communities that must cope with elevated health risks.

### There Are Many More Consequences

The lack of clean water and sanitation facilities has other less well documented consequences. Poor hygiene practices of birth attendants can cause infection, sepsis, and infant and maternal mortality (Benova, Cumming, and Campbell 2014). Yet four of 10 health care facilities in Sub-Saharan Africa have no source of clean water on the premises and soap for handwashing is missing in one-third of them. Clean water and soap are also critical for preventing and controlling the spread of infection, particularly outbreaks such as Ebola and cholera (WHO and UNICEF 2015). Indeed, countries affected by the 2014 outbreak of Ebola in West Africa have some of the worst coverage of water, sanitation, and hygiene in the world, impeding effective responses to epidemics. Many clinics that routinely operated without running water were forced to close to avoid becoming hotbeds for the spread of disease.

Access to water and sanitation has been found to contribute to a reduction in a wide range of seemingly unrelated diseases and to reduce the overall

background burden of disease. This is known as the Mills-Reincke phenomenon (Segwick and Macnutt 1908). It may have its biological basis in the altered immune response and gut function caused by exposure to fecal pathogens.

## Remedies—Changing People’s Habits and Price Incentives

Why, despite decades of investment, do poor water, sanitation, and hygiene prevail? Perhaps because water, sanitation, and hygiene influences health, welfare, and development outcomes through complex and multiple channels. Consider handwashing. It is one of the most effective interventions for reducing diarrhea and child deaths, but it depends on an array of preconditions. The household must have continuous access to a convenient supply of clean water; this is harder to achieve when water is scarce. And handwashing must take place frequently, and at certain junctures for it to work.

Investments in infrastructure alone—which are still far from adequate in many parts of the world—will not be enough to deliver the desired development outcomes. Behavioral change, at the level of individuals and communities, is pivotal to realizing health outcomes of water and sanitation investments and is necessary to reap the rewards of these investments. These behaviors are particularly relevant for non-piped, mostly rural, systems where it is difficult and costly to control contamination.

Despite evidence that shows that sanitation and handwashing are of primary importance to maintain a clean environment, access to sanitation lags far behind that of water. Rates of handwashing are dismally low, even in high-income countries. A likely reason is that both these require fundamental changes to human behavior, and changing behavior is not easy. How to do so effectively and efficiently remains a challenge and continues to occupy the minds of policy makers.

## Total Sanitation, Led By Communities?

One way to change sanitary practices, which has spread rapidly in the developing world, is community-led total sanitation (CLTS). This radical approach uses shock and shame to change social norms and behaviors and nudge entire communities to stop defecating in the open. Eschewing subsidies, it encourages households to build basic latrines using locally available materials. This approach is credited with moving most of Bangladesh from widespread open defecation to household latrines. Bangladesh now outpaces many other emerging economies in ending open defecation.

But CLTS has not enjoyed unequivocal success. There is limited understanding of why CLTS works better in some countries and circumstances than in others. In Indonesia and Tanzania, which also supported local masons and retailers to ensure that toilets were affordable, only small numbers of households actually improved their sanitation because of the intervention (Cameron, Shah, and Olivia 2013; Briceño, Coville, and Martinez 2015). In India, people continued to defecate in the open despite having a toilet in their home (Clasen 2014; Patil 2014). Also in some parts of India, child height increased substantially, despite only modest improvements in village sanitation, suggesting health effects may be largely driven by changes in open defecation, as opposed to infrastructure improvement (Hammer and Spears 2013).

## Simply Knowing about Good Hygiene Is Not Enough

Most people already know that washing their hands or using a toilet for defecation is a necessary part of good hygiene and health (Curtis, Danquah, and Aunger 2009), so they respond more strongly to

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**Behavioral change, at the level of individuals and communities, is pivotal to realizing health outcomes of water and sanitation investments and is necessary to reap the rewards of these investments.**

emotional appeals such as a desire to be clean and modern, or a desire to nurture their children. Market researchers first try to find out what motivates people to wash their hands or buy a toilet and then appeal to these desires using print and media advertising in an effort to “sell” better behaviors. Some go a step further to get an audience’s attention, creating cartoon superheroes, staging live plays, and running soap operas on national radio. These efforts uniquely blend education and entertainment in edutainment, which can be powerful in influencing social norms. In Brazil, soap operas are credited with reducing the country’s fertility rate (Ferrera, Chong, and Duryea 2012). The children’s show Sesame Street has even broached the topic of water and sanitation (box 3).

Considerable effort goes into identifying features of sanitation products that are important to local consumers at affordable prices to improve take up of sanitation interventions. What is considered a clean toilet in rural Ethiopia may not pass the test in rural Vietnam. Indeed, it may come as a surprise to many that much of the world has a preference for squatting rather than sitting. These factors are remarkably important when designing sanitation interventions.

### Subliminal Nudges Can Change Behavior

Behavioral economics offers promising remedies through subliminal nudges and other devices, but has yet to be fully exploited to improve water, sanitation, and hygiene (Coville and Orozco 2014). Minor tweaks can sometimes be highly cost-effective. For example, loss-aversion is one technique that can be used to motivate change. People dislike losses more than they like gains, so messages that highlight the costs and losses of not washing hands are likely to be more effective (Kahneman and Tversky 1979). This is counter to the predominant messaging in the sector, which emphasizes the health and other positive benefits of improved water and sanitation. Savings accounts that require people to precommit to saving a certain amount or saving for a particular goal could be used to save for latrines, helping poor people resist the many temptations to spend their scarce funds.

Simple reminders can reinforce hygienic behaviors. People may have trouble remembering to treat their drinking water. And treating water can add to an already heavy financial burden facing poor rural households. In rural Kenya, free chlorine dispensers at community water collection points address some of the behavioral biases and financial constraints that inhibit households

#### **BOX 3. Sesame Street—Showing Children How to Wash Can Shift Mindsets, Behaviors, and Social Norms**

Sesame Street’s first Global Health Ambassador, Raya, was created to show kids, families, and communities about proper water, sanitation, and hygiene (WASH) routines like handwashing with soap and wearing footwear in the latrine. Sesame Street has learned that when children have the tools and information, they go from being just passive recipients of health information to active participants in their own health and well-being. Now, through the help of Raya, messages about the importance of WASH reach the most vulnerable kids in Bangladesh, India, and Nigeria.

Identifying champions for children like Sesame Street’s popular characters, the Muppets, can thus be pivotal role. Complementing it with child-facing education through mass media and multiplatform community approaches creates unparalleled opportunities to shift mindsets, behaviors, and social norms.



from treating their water. The chlorine dispensers were a *reminder* and made water treatment more *convenient*. Making water treatment public, the dispensers added an element of *social pressure* (Kremer et al. 2009).

### Sometimes, a Nudge Isn't Enough

Sometimes, information and behavioral nudges are not enough to trigger behavioral change, especially when it requires costly durable goods, as for sanitation. The poor find it difficult to purchase goods requiring large lump sums of cash and consistently cite the high cost of sanitation as the main barrier to installing improved toilets (Banerjee and He 2003). In such cases, price incentives may be needed.

### Smoothing Consumption Can Help

Stabilizing income and spreading payments over time can encourage the poor to adopt beneficial durable goods such as household latrines (Dupas 2011). Consumer credit has increased the take-up of piped water connections (Devoto et al. 2011), clean cookstoves (Levine et al. 2012), and insecticide-treated bednets (Tarozzi et al. 2014). Experimental evidence of consumer lending for sanitation is limited, particularly among poorer households. In Cambodia, households were randomly offered financing to purchase a latrine at the market price of \$50, dramatically increasing uptake (Shah et al. 2013). In Vietnam, the Vietnam Bank for Social Policy financed septic tanks and sewerage connections for low-income households. In India and Tanzania, microfinance institutions provided direct microloans for toilets (Trémolet, Kolsky, and Perez 2010). Socially oriented microfinance institutions can increase access for the poor to sanitation by offering small loan sizes and making application processes more flexible (Trémolet, Mansour, and Muruka 2015).

### So Can Targeted Subsidies

Some households will never have enough cash to afford a toilet. Subsidies may be their only means of acquiring adequate sanitation. Subsidies lower the cost for households to practice healthy behaviors,

making it more convenient and thus making behavior change more likely (Gertler et al. 2015). Reducing open defecation in a community also generates positive health spillovers, justifying the subsidies.

Ensuring that these subsidies are well targeted is key. In many developing countries, a large proportion of the poor, particularly in urban slums, source water from informal vendors. They are compelled to pay a higher price—often 10 times more than the higher-income populations that are serviced by the municipality at prices below service costs (Petrie 1989). It is tempting to justify subsidies on the grounds that water is a necessity and human right. But the poor seldom get this benefit, paying on average a greater proportion of their disposable income for such services, compared to their wealthier counterparts (Zetland and Gasson 2012; Komives et al. 2005).

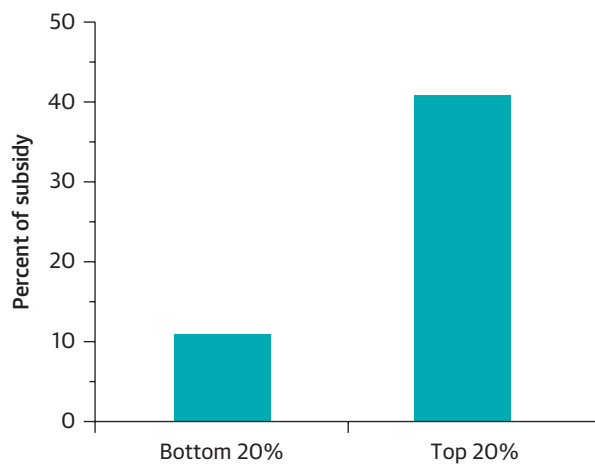
Even when the poor are connected, subsidies for water tend to be highly regressive, typically favoring the better-off with subsidies related to the volume of water consumed (figure 1). Free water paradoxically ends up costing the poor more of their resources and their health.

### Solutions, Information, and Resources Are Lacking

Inequalities in access also relate to gender and geography, often stemming from a lack of technical solutions, a lack of information, or a lack of resources. It is surprising that information on who the poor are, where they live and their level of access is not consistently generated or used at the country level to inform service delivery. Simple visual tools can be used to map levels of access with other population characteristics such as poverty levels or prevalence of undernutrition. These can be extremely effective in dialogue with client countries, but are not yet widely available.

The fundamental technology of the toilet and waste management has been around for decades. But the technology has limitations, especially when

**FIGURE 1. Share of Subsidy Captured by the Poorest 20% and Richest 20% of the Population**



Source: Komives et al. 2005.

Note: Countries in the sample are Cabo Verde, Nepal, and Nicaragua.

considering the decline in water resources, and the immense unmet need for sanitation in rural areas. Innovators have recently begun to develop new ways to deal with human waste that operate without water, pipes or electricity and produce valuable resources such as clean water, electricity and fertilizer. Equally important, these new technologies are aiming for low-cost production that is affordable to poor households.

## A New Generation of Challenges

### In 10 Years, 2.8 Billion People Will Face Water Stress or Even Scarcity

Water constraints in developing countries are set to worsen with population growth, urbanization, and rising living standards. Twenty developing countries have renewable water resources of less than 1,000

cubic meters per capita—defined as water scarcity—and another 18 have less than 2,000—defined as water stress. A decade from now, an estimated 2.8 billion people in 48 countries will face water stress

**The world is faced with a problem compounded by looming water shortages and declining water quality before the poor have even been fully covered.**

or water scarcity (UNEP 2008). For many countries—especially in Africa, the Middle East, and South Asia—climate change is likely to compound this baseline scarcity.

At the same time, water quality is low and getting worse. It is uniformly declining in all developing countries—in some cases to the point of irreversible damage. Water resources are further degraded by the “pollution plume” of cities, industry, and intensive agriculture—contamination that includes both chemical pollutants (fluoride, iron, nitrate, arsenic, and the like) and microbial (feces) pollutants. Even developed countries manage to treat only a fraction of their sewage.

Water constraints in the form of quantity and quality foreshadow a new burden the poor will be faced with in the future, with consequences for health, livelihoods, and economic development.

### Water Efficiency Is Low and Declining

Too many of the most water-stressed countries (in Central Asia, the Middle East, and North Africa) are the least efficient users of water; efficiency is even declining in some cases. Policies that promote and condone overuse and waste make such natural scarcity worse. For example, water is provided to large-scale industrial and agricultural users at no cost or highly subsidized rates, so there is little incentive to economize on its use. In highly water-stressed regions, baseline growth projections will not be achievable without significant changes in the way water is managed. But because water scarcity emerges gradually, with often invisible (for now) consequences, responses can be put off.

So the world is faced with a problem compounded by looming water shortages, and declining water quality before the poor have even been fully covered. As the SDGs move the goalpost to universal coverage, global shortages will become even more likely as more and more people gain access. Much of the burden will fall on the poor, who end up having to pay for the profligacy of others.

## Chemical and Microbial Contaminants Need to Be Contained

Most ground and surface water in densely populated developing countries is contaminated with a combination of microbial pathogens and chemicals contaminants from human waste, agriculture, mining, and industry.

Many of the world's poor urban residents rely on non-piped systems for sanitation. Rarely treated, the fecal sludge is left to accumulate or is discharged directly into drains or open water bodies. Solid waste is disposed of in unhygienic ways, dumped into the sea, rivers, wasteland, and landfills. Chemical and microbial pollutants from poorly maintained pit latrines can also seep into groundwater. In urban settings where even just a handful of households defecate in the open, most waste is disposed of in unsafe manner (see figure 2).

A sanitation value chain—that hygienically captures, stores, transports, treats, and disposes of waste and that connects with markets for reuse—redefines access to sanitation as access that goes beyond simply providing a toilet. Each stage of the value chain is a service that helps ensure access to safe and reliable sanitation.

Few studies record the health consequences of chemical pollution, which are associated with long-term exposure to pollutants, and may include gastrointestinal illness; reproductive problems; toxic effects on the nervous, digestive, and immune systems; and on lungs, kidneys, skin, and eyes, as well as neurological disorders.

Fluoride and arsenic are the most commonly measured chemical contaminants, likely affecting millions of people. High levels of naturally occurring arsenic contaminates large areas of groundwater, especially in East and South Asia, leading to changes in the skin's pigment and structure as well as various forms of cancer. An estimated 226 million people in more than 100 countries are exposed to harmful levels of arsenic in groundwater—the “largest mass poisoning of a population in history” (WHO 2000). Private wells can make

the problem worse by drawing arsenic-contaminated water into previously uncontaminated aquifers, with potentially disastrous consequences for future generations (Van Geen et al. 2013).

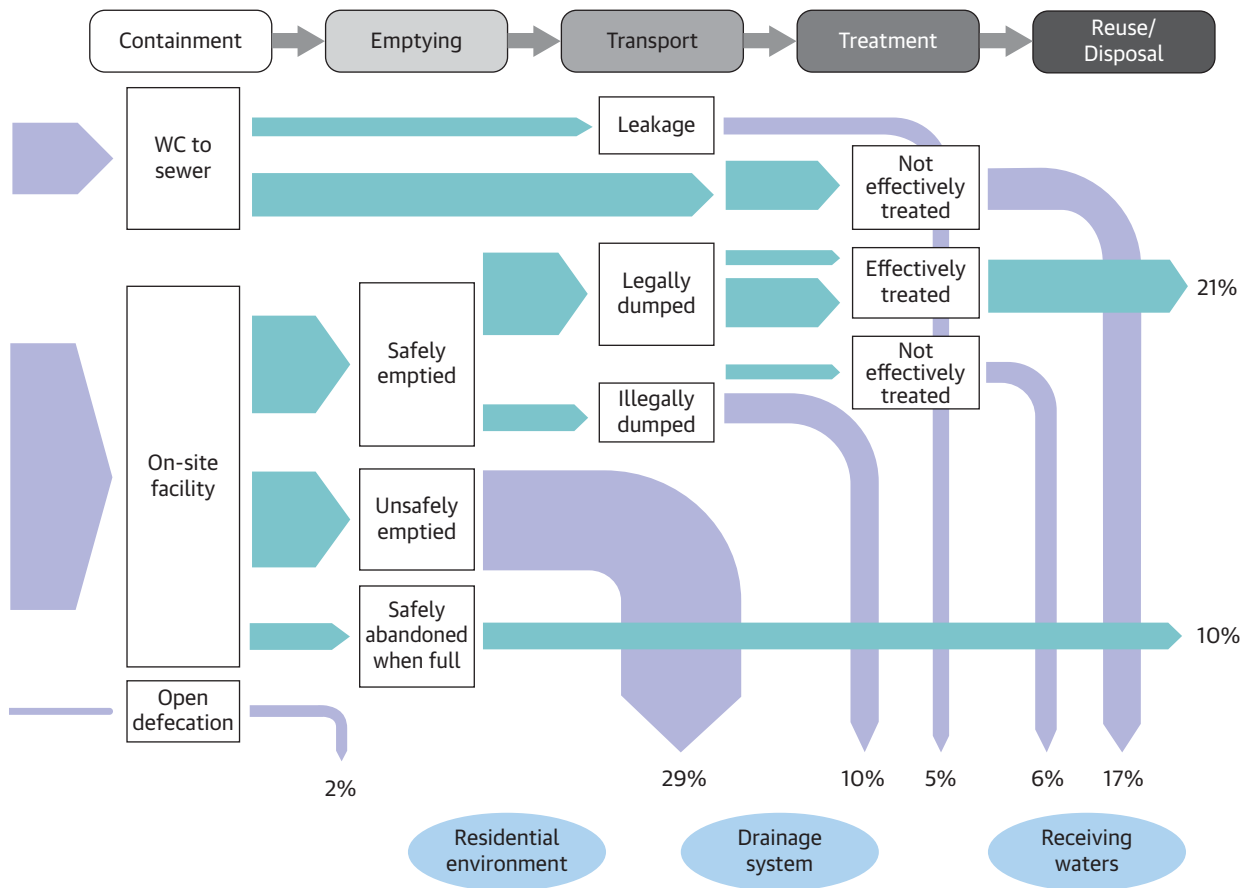
## Water Treatment Needs to Become a Priority

Governments at all levels rarely consider water treatment a priority, partly because the benefits are largely invisible to beneficiaries, while the investments are capital intensive and operating and maintenance costs are high. Treating contaminated water is one solution, but is of limited value where cost-effective (or any) treatments are not available. It is often more cost effective to give polluters incentives to mitigate emissions at the source. This entails sophisticated policies such as the pollution permits issued by the U.S. Environmental Protection Agency that place the onus of mitigation on the polluter. Trials for such policies have not been conducted in developing countries, but given the size of the problem, interest is growing.

Surprisingly few data are systematically collected on water quality trends, nor is there an accepted measure to compare how countries perform on water quality. Poor data coverage and quality are largely to blame, but there are also problems with measurement, standards, and definitions that undermine global indexing efforts. Even the United Nations Global Environmental Monitoring Systems (UN GEMS)—the only global database of national water quality parameters—relies on self-reported data and lacks spatial representativeness and comparability over time and space.

So there is no consistent way of tracking and measuring a growing problem. The Joint Monitoring Program (JMP) run by the World Health Organization (WHO) and United Nations Children's Fund (UNICEF)<sup>3</sup> is developing rapid, reliable, and cost-effective tests that can be administered alongside household surveys to monitor water quality, but these are still in a pilot phase and cover only a subset of indicators that relate to biological pollutants.

**FIGURE 2. Flow of Fecal Sludge in Dakar, Senegal**



Source: World Bank/WSP 2014.  
 Note: WC = water closet.

Without adequate information, benchmarking is difficult, limiting evidence-based policy because of lack of comparable data.

### Sustaining Gains

Water and sanitation management has traditionally been approached as an engineering problem. It must now be viewed through a lens of financial, environmental, and behavioral sustainability.

### Financial Sustainability—Decide Who Gets Water and What They Pay

Recognizing the role of water as a valuable economic input can ensure more equitable access and more sustainable supplies. Delivering good quality services requires service providers to be accountable and responsive to community needs. But they must at the minimum be allowed to recover operation and maintenance costs and make a predetermined profit—or they will have no funds to make capital investments.

*Pricing.* Pricing can convey information about scarcity and abundance. In the European Union, water consumption declined by about 30 percent when users were charged higher service fees to cover running costs. Given the “human right” view of access to water, pricing can be a very sensitive issue. But such a right does not mean that governments or other players need to provide services to those who can afford them at no charge. Service providers must be properly compensated, for quantity and quality.

Mechanisms have been piloted to reconcile equity and financial sustainability. Block tariffs—which increase the cost increases along with the volume used—are one way of ensuring a fair baseline access. Another is targeting cash subsidies or free water to those below a certain income threshold.

Where utilities are heavily subsidized, decisions on who gets served and on quality becomes politicized, nearly always to the detriment of the poor—who end up paying more. Full cost recovery for water utilities can thus ensure more equitable access to water.

*Recovering costs.* Recovering costs is also essential for operating and maintaining expensive water supply and sanitation investments. Short-term savings are a false economy and can shorten asset life. This is particularly devastating in the area of water supply and sanitation, in which the assets are expensive, capital intensive, and long lived (pipes can last for more than 100 years). Investment costs are therefore recovered over decades, and sometimes over generations, so the private sector has virtually no natural incentive to invest in such risky endeavors. The uncertain (and politically determined) flow of future revenue is the only attraction—and a limited one.

*Allocating to the highest value.* Viewing water as an economically valuable resource also implies that it should be allocated to uses that generate the highest value. With growing pressures on water resources, this means that eventually agriculture, which typically consumes

70–80 percent of water, especially in more arid areas, will need to concede water to other economic sectors.

Countries thus need to decouple water from their growth aspirations and development goals. Surprisingly, the more arid countries tend to be the more inefficient and intensive users of water, with a disproportionate reliance on the more water-dependent sectors of the economy—agriculture, textiles, and mining. To decouple growth from water, these economies will need mechanisms that allocate water to more productive uses. Australia, an exemplar, has pioneered penalizing wastage and overuse of water, while encouraging a shift to higher value added uses. Chile has a similar approach, with successful results (World Bank 2016).

### **Environmental Sustainability—Consider Chemical Contaminants and Microbial Pathogens**

Many developing countries now face a dual burden from waterborne diseases: diseases of underdevelopment like diarrhea and diseases of development from industrial pollutants. The new hazards typically take the form of chemical pollutants that are much harder and more expensive to treat than sewage. And they require different processes, akin to technically complex desalination techniques. It is often cheaper to mitigate the pollution at the source, rather than seeking “end-of-pipe” solutions.

The health effects of persistent organic pollutants (POPs) are especially worrying. They do not decay, and they accumulate and transfer from one species to the next through the food chain. Because they can be transported through water, most POPs generated in one country can affect people and wildlife far from where they are released. That is one reason why the Stockholm Convention on POPs seeks to discourage their use. But where toxins carry only local footprints, there are no global agreements. Addressing these local issues has proven difficult because it calls for investments in monitoring, mitigation, and new infrastructure (to contain and clean pollutants when mitigation is infeasible).

## Behavioral Sustainability—Shift from Daily Practices to Enduring Habits

The behaviors that underlie hygiene are practiced multiple times a day, and every day over a lifetime. So it is especially important for these behavioral practices to become entrenched to avoid reverting to former ways, as in times of crisis or extreme hardship.

Changing behavior is a process, not a single event. It requires reaching minds at an early age, so that behaviors become practices, which later become habits that endure into adulthood. It may also require societal shifts in what is considered acceptable and normal behavior—where the behavioral drivers that dictate water, sanitation, and hygiene practices are deeply embedded in the social fabric.

## Conclusion

This document has provided a brief overview of the health-related impacts of inadequate water supply and sanitation services. It has emphasized the new policy challenges that have emerged in a more populated, polluted, and urbanized world with finite water resources. The challenges are significant. A substantial shift in policies and investments is needed to meet the global goals of poverty reduction and access to water supply and sanitation envisaged in the new Sustainable Development Goals (SDGs).

The evidence is overwhelming that water-related diseases disproportionately affect the poor and create a vicious spiral of poverty that often persists across generations. The most widely documented impacts are through familiar waterborne diseases such as diarrhea, which some estimates suggest impose costs of about 1.5 percent of the GDP of developing countries.

But there are more subtle and insidious impacts of likely even greater magnitude. Recent research indicates that a substantial portion of the burden of undernutrition and stunting may be due to poor gut conditions caused by a poor water and sanitation environment. There is mounting evidence for other

adverse impacts of poor water and sanitation, such as higher rates of infection during birth due to poor hygiene practices.

Addressing the water and sanitation challenge will be pivotal to achieving poverty reduction goals in many developing countries. Meeting the new ambitious water and sanitation targets of the SDGs will require adopting an integrated perspective to water resources. It must address both the expanding water deficits as well as the degradation of water resources through pollutants and destruction of watersheds, especially in countries where water scarcity and stress is growing.

The solution to these multifaceted problems is not straightforward. Human behavior—safe storage of drinking water, use of latrines, handwashing—largely mediates the effects of water and sanitation infrastructure, especially where infrastructure is of lower quality. Behavior change has become a vital ingredient in the elusive search for solutions. Spending on infrastructure alone—which is still far from adequate in many parts of the world—will not be enough. New approaches are required that assure sustained changes in individual behavior, more equitable access to services, and incentives for improved water resource stewardship, especially where water scarcity is growing.

## Notes

1. These are sanitation facilities that hygienically separate human feces from the environment.
2. Globally, improvements in sanitation have increased only to 68 percent, 9 percentage points below the MDG target.
3. <http://www.wssinfo.org/>.

## References

- Ali, M., A. Nelson, A. Lopez, D. Sack. 2015. “Updated Global Burden of Cholera in Endemic Countries.” *PLoS Negl Trop Dis* 9(6). doi:10.1371/journal.pntd.0003832.
- Andres, Luis A., Bertha Briceño, Claire Chase, and Juan A. Echenique. 2014. “Sanitation and Externalities: Evidence from Early Childhood Health in Rural India.” Policy Research Paper 6737, World Bank, Washington, DC.

- Banerjee, Abhijit V., and Ruimin He. 2003. "The World Bank of the Future." *American Economic Review* 93 (2): 39-44.
- Barker, D. J. 1990. "The Fetal and Infant Origins of Adult Disease." *BMJ* 301 (6761): 1111.
- Bhutta, Zulfiqar A., J. K. Das, A. Rizvi, M. F. Gaffey, N. Walker, S. Horton, P. Webb, A. Lartey, and R. E. Black. 2013. "Evidence-based Interventions for Improvement of Maternal and Child Nutrition: What Can Be Done and At What Cost?" *The Lancet* 382 (9890): 452-77.
- Benova, L., O. Cumming, and O. M. Campbell. 2014. "Systematic Review and Meta-analysis: Association between Water and Sanitation Environment and Maternal Mortality." *Tropical Medicine & International Health* 19: 368-87.
- Black, R. E., S. P. Walker, Z. A. Bhutta, P. Christian, M. de Onis, M. Ezzati, S. Grantham-McGregor, J. Katz, R. Martorell, and R. Uauy. 2013. "Maternal and Child Undernutrition and Overweight in Low-income and Middle-income Countries." *The Lancet* 382 (9890): 427-51.
- Bleakley, H. 2007 "Disease and Development: Evidence from Hookworm Eradication in the American South." *The Quarterly Journal of Economics* 122 (1): 73-117.
- Briceño, Bertha, Aidan Coville, and Sebastian Martinez. 2015. "Promoting Handwashing and Sanitation: Evidence from a Large-Scale Randomized Trial in Rural Tanzania." Policy Research Working Paper 7164, World Bank, Washington, DC.
- Cameron, Lisa, Manisha Shah, and Susan Olivia. 2013. "Impact Evaluation of a Large-Scale Rural Sanitation Project in Indonesia." Policy Research Working Paper 6360, World Bank, Washington, DC.
- Case, Anne, and Christina Paxson. 2008. "Height, Health, and Cognitive Function at Older Ages." *American Economic Review* 98 (2): 463-67.
- Clasen, Thomas. 2014. "Effectiveness of a Rural Sanitation Programme on Diarrhoea, Soil-transmitted Helminth Infection, and Child Malnutrition in Odisha, India: A Cluster-Randomised Trial." *The Lancet Global Health* 2 (11): e645-e653.
- Coffey, D. 2013. "Sanitation, the Disease Environment, and Anaemia among Young Children." Rice Institute, India. [http://riceinstitute.org/wordpress/wp-content/uploads/downloads/2013/09/Coffey\\_2013.pdf](http://riceinstitute.org/wordpress/wp-content/uploads/downloads/2013/09/Coffey_2013.pdf).
- Coville, Aidan, and Victor Orozco. 2014. "Moving from Efficacy to Effectiveness: Using Behavioural Economics to Improve the Impact of WASH Interventions." *Waterlines* 33 (1): 26-34.
- Curtis, V. A., L. O. Danquah, and R. V. Aunger. 2009. "Planned, Motivated and Habitual Hygiene Behaviour: An Eleven-Country Review." *Health Education Research* 24 (4): 655-73.
- Cutler, David M., and Grant Miller. 2005. "The Role of Public Health Improvements in Health Advances: The Twentieth-Century United States." *Demography* 42 (1): 1-22.
- Devoto, Florencia, Esther Duflo, Pascaline Dupas, William Parienti, and Vincent Pons. 2011. "Happiness on Tap: Piped Water Adoption in Urban Morocco." NBER Working Paper 16933, National Bureau of Economic Research, Cambridge, MA.
- Dupas, Pascaline. 2011. "Health Behavior in Developing Countries." *Annual Review of Economics* 3 (1): 425-49.
- Ferrara, Eliana La, Alberto Chong, and Suzanne Duryea. 2012. "Soap Operas and Fertility: Evidence from Brazil." *American Economic Journal: Applied Economics* 4 (4): 1-31.
- Fink, G., I. Gunther, and K. Hill. 2011. "The Effect of Water and Sanitation on Child Health: Evidence from the Demographic and Health Surveys 1986-2007." *International Journal of Epidemiology* 40 (5): 1196-204.
- Gertler, Paul, Manisha Shah, Maria Laura Alzua, Lisa Cameron, Sebastian Martinez, and Sumeet Patil. 2015. "How Does Health Promotion Work? Evidence from the Dirty Business of Eliminating Open Defecation." NBER Working Paper 20997, National Bureau of Economic Research, Cambridge, MA.
- Ghosh Aarabinda, Ashish Gupta and Daniel Spears. 2015. "Are children in West Bengal shorter than children in Bangladesh?." *Economic & Political Weekly* 48: 21-24.
- Guerrant, R. L., M. D. DeBoer, S. R. Moore, R. J. Scharf, and A. A. M. Lima. 2013. "The Impoverished Gut—A Triple Burden of Diarrhoea, Stunting and Chronic Disease." *Nature Reviews Gastroenterology & Hepatology* 10 (4): 220-29.
- Gunther, Isabel, and Gunther Fink. 2010. "Water, Sanitation, and Children's Health: Evidence from 172 DHS Surveys." Policy Research Working Paper 5275, World Bank, Washington, DC.
- Hammer, Jeffrey, and Dean Spears. 2013. "Village Sanitation and Children's Human Capital: Evidence from a Randomized Experiment by the Maharashtra Government." Policy Research Working Paper 6580, World Bank, Washington, DC.
- Hutton, Guy. 2013. "Global Costs and Benefits of Reaching Universal Coverage of Sanitation and Drinking-water Supply." *Journal of Water and Health* 11 (1): 1-12.
- IMF. 2015. "Is the Glass Half Empty or Half Full?" International Monetary Fund, Washington DC.
- Kahneman, Daniel, and Amos Tversky. 1979. "Prospect Theory: An Analysis of Decision under Risk." *Econometrica* 47 (2): 263-92.
- Komives, K., V. Foster, J. Halpern, and Q. Wodon. 2005. "Water, Electricity, and the Poor. Who Benefits from Utility Subsidies?" World Bank, Washington, DC.
- Kremer, M., A. Ahuja, A. Peterson-Zwane. 2010. "Providing Safe Water: Evidence from Randomized Evaluations." Discussion Paper 2010-23, Cambridge, Mass.: Harvard Environmental Economics Program.
- Levine, David I., Theresa Beltramo, Garrick Blalock, and Carolyn Cotterman. 2012. "What Impedes Efficient Adoption of Products? Evidence from Randomized Variation in Sales Offers for Improved Cookstoves in Uganda." University of California-Berkeley. <http://faculty.haas.berkeley.edu/levine/papers/2013-April%2012%20What%20Impedes%20Efficient%20Product%20Adoption.pdf>.
- Lim, Stephen S., et al. 2012. "A Comparative Risk Assessment of Burden of Disease and Injury Attributable to 67 Risk Factors and Risk Factor Clusters in 21 Regions, 1990-2010: A Systematic Analysis for the Global Burden of Disease Study 2010." *Lancet* 380 (9859): 2224-60.

- Liu, L., H. L. Johnson, S. Cousens, J. Perin, S. Scott, J. E. Lawn, I. Rudan, H. Campbell, R. Cibulskis, C. Mathers, and R. E. Black. 2012. "Global, Regional, and National Causes of Child Mortality: An Updated Systematic Analysis for 2010 with Time Trends since 2000." *Lancet* 379 (9832): 2151-61.
- Miguel, Edward, and Michael Kremer. 2004. "Worms: Identifying Impacts on Education and Health in the Presence of Treatment Externalities." *Econometrica* 72 (1): 159-217.
- Patil, Sumeet R. 2014. "The Effect of India's Total Sanitation Campaign on Defecation Behaviors and Child Health in Rural Madhya Pradesh: A Cluster Randomized Controlled Trial." *PLoS Medicine* 11 (8). <http://dx.doi.org/10.1371/journal.pmed.1001709>.
- Petrie, A. H. 1989. *El Gasto Publico Social y Sus Efectos Distributivos*. Santiago: ECIEL.
- Prüss-Ustün, Annette, Jamie Bartram, et al. 2014. "Burden of Disease from Inadequate Water, Sanitation and Hygiene in Low- and Middle-income Settings: A Retrospective Analysis of Data from 145 Countries." *Tropical Medicine & International Health* 19 (8): 894-905.
- Pullan, Rachel L., Jennifer L. Smith, Rashmi Jasrasaria, and Simon J. Brooker. 2014. "Global Numbers of Infection and Disease Burden of Soil Transmitted Helminth Infections in 2010." *Parasites & Vectors* 7 (37). doi:10.1186/1756-3305-7-37.
- Ramalingaswami, V., U. Jonson, J. Rohde. 1997. "The Asian Enigma." *The Progress of Nations*, UNICEF, New York.
- Sedgwick, W. T., and S. Macnutt. 1908. "An Examination of the Theorem of Allen Hazen that for Every Death from Typhoid Fever Avoided by the Purification of Public Water Supplies, Two or Three Deaths are Avoided from Other Causes." *Science* 28: 215-16.
- Shah, N. B., S. Shirrell, A. Fraker, P. Wang, and E. Wang. 2013. "Understanding Willingness to Pay for Sanitary Latrines in Rural Cambodia: Findings from Four Field Experiments of iDE Cambodia's Sanitation Marketing Program." *idInsight*, Patna, India.
- Spears, Dean. 2012. "Height and Cognitive Achievement among Indian Children." *Economics & Human Biology* 10 (2): 210-19.
- Spears, Dean, Arabinda Ghosh, and Oliver Cumming. 2013. "Open Defecation and Childhood Stunting in India: An Ecological Analysis of New Data from 112 Districts." *PLoS ONE* (September 16). <http://dx.doi.org/10.1371/journal.pone.0073784>.
- Tarozzi, Alessandro, Aprajit Mahajan, Brian Blackburn, Dan Kopf, Lakshmi Krishnan, and Joanne Yoong. 2014. "Micro-loans, Bednets and Malaria: Evidence from a Randomized Controlled Trial in Orissa (India)." *American Economic Review* 104 (7): 1909-41.
- Trémolet, S., P. Kolsky, and E. Perez. 2010. "Financing On-site Sanitation for the Poor." Technical Paper, Water and Sanitation Program, World Bank, Washington, DC.
- Trémolet, Sophie, Goufrane Mansour, and George Muruka. 2015. "Microfinance for Sanitation: What Is Needed to Move to Scale?" *Waterlines* 34 (3): 227-40.
- UNDP (United Nations Development Programme). 2006. *Beyond Scarcity: Power, Poverty and the Global Water Crisis*. Human Development Report. New York: United Nations Development Programme.
- UNEP (United Nations Environment Programme). 2008. "An Overview of the State of the World's Fresh and Marine Waters." In *Vital Water Graphics*, 2nd edition. United Nations Environment Programme and UNEP/GRID-Arendal, Norway.
- Van Geen, Alexander, et al. 2013. "Retardation of Arsenic Transport through a Pleistocene Aquifer." *Nature* 501 (7466): 204-07.
- Victoria, C. G., M. de Onis, P. C. Hallal, M. Blössner, and R. Shrimpton. 2010. "Worldwide Timing of Growth Faltering: Revisiting Implications for Interventions using the World Health Organization Growth Standards." *Pediatrics* (February). <http://pediatrics.aappublications.org/content/early/2010/02/15/peds.2009-1519>.
- Watson, Tara. 2006. "Public Health Investments and the Infant Mortality Gap: Evidence from Federal Sanitation Interventions on U.S. Indian Reservations." *Journal of Public Economics* 90 (8-9): 1537-60.
- WHO (World Health Organization). 2000. "Contamination of Drinking-Water by Arsenic in Bangladesh: A Public Health Emergency." *Bulletin of the World Health Organization* 78: 1093-1103.
- WHO and UNICEF (World Health Organization and United Nations Children's Fund). 2015. "Progress on Sanitation and Drinking Water: 2015 Update and MDG Assessment." World Health Organization, Geneva.
- World Bank. 2016. "High and Dry: Climate Change, Water, and the Economy." World Bank, Washington, DC.
- World Bank/WSP. 2014. "The Missing Link in Sanitation Service Delivery: A Review of Fecal Sludge Management in 12 Cities." World Bank, Washington, DC.
- Zetland, D., and C. Gasson. 2012. "A Global Survey of Urban Water Tariffs: Are They Sustainable, Efficient and Fair?" *International Journal of Water Resources Development* 29 (3): 327-42.



