Global Public Health: An International Journal for Research, Policy and Practice

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/rgph20

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Published online: 16 Aug 2006.

To cite this article: R. Rheingans , R. Dreibelbis & M.C. Freeman (2006) Beyond the Millennium Development Goals: Public health challenges in water and sanitation, Global Public Health: An International Journal for Research, Policy and Practice, 1:1, 31-48, DOI: 10.1080/17441690500443139

To link to this article: http://dx.doi.org/10.1080/17441690500443139

Global Public Health, February 2006; 1(1): 31–48

Routledge
Taylor & Francis Group

Beyond the Millennium Development Goals: Public health challenges in water and sanitation

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Abstract
Over 1 billion people lack access to improved water sources and 2.6 billion lack access to appropriate sanitation, greatly contributing to the global burden of disease. The international community has committed to reducing by half the proportion of the world's population lacking access to water and sanitation as a part of the Millennium Development Goals (MDGs). However, the disease burden due to poor access, is borne primarily by the poorest countries and the poorest people within them. Simply reducing the proportion of people without adequate access will not automatically result in proportional reductions in the related disease burden. The public health challenge inherent in meeting the MDG targets is ensuring that improvements result in access to water and sanitation for the critical at-risk populations. Innovative approaches are required to ensure the availability of low-cost, simple, and locally acceptable water and sanitation interventions and integrating these approaches into existing social institutions, such as schools, markets, and health facilities.

Keywords: *Water, sanitation, hygiene, equity, Millennium Development Goals*

Divine Providence has made those things neither scarce nor dear which are necessary for mankind, as are pearls, gold, silver, and the like, which are neither necessary for the body nor nature; but has diffused abundantly, throughout the world, those things, without which the life of mortals would be uncertain . . . Water is of infinite utility to us, not only as affording drink, but for a great number of purposes in life; and it is furnished to us gratuitously.

Vitruvius

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ISSN 1744-1692 print/ISSN 1744-1706 online
DOI: 10.1080/17441690500443139

Introduction

The Roman architect Vitruvius recognized the centrality of water to society and individuals as both an intimate need and threat. As the quote above suggests, he believed that an element this essential to life would be provided to meet our basic needs. Although three-quarters of the earth's surface is covered by water, Vitruvius' vision of a world where divine forces provide sufficient water for all seems illusory.

The challenge of providing safe water where it is needed most is also at the heart of a key global health challenge. In 2002, 1.1 billion people lacked access to improved water sources such as a protected well or piped water, and an additional 2.6 billion people, approximately 40% of the global population, lack adequate sanitation (UNICEF 2004). This lack of basic services, combined with inadequate hygiene, exposes people to bacteria, viruses, and parasites in water and faeces. The Millennium Development Goals (MDGs) seek to reduce by half the proportion of people who do not have access to improved water sources and adequate sanitation by the year 2015 (UN 2000) in order to contribute to the goal of reducing extreme poverty. However, providing basic water and sanitation services to a significant portion of those in need will not necessarily result in a commensurate fall in disease burden unless it reaches those at greatest risk of mortality. The challenge is to ensure that improving water and sanitation access will result in significant reductions in disease burden, and childhood mortality in particular.

Background

Health impacts of lack of access to water and sanitation

Inadequate water, sanitation, and hygiene are a major cause of diarrhoeal disease, causing 2.2 million deaths and 82 million Disability Adjusted Life Years (DALYs) per year (Pruss et al. 2002). The majority of this DALY burden is from diarrhoeal mortality in children under 5 years of age. Illness caused by helminthes (including ascariasis, trichuriasis, hookworm, schistosomiasis and trachoma) account for an additional 5.9 million DALYs and 26,000 deaths (Pruss et al. 2002). Combined, these water, sanitation, and hygiene related diseases account for 5.7% of the burden of disease globally, not including the effects of water-related vector borne diseases, such as malaria (Ijumba and Lindsay 2001) and lymphatic filariasis (Erlanger et al. 2005).

In addition to the burden caused by microbial pathogens, unsafe drinking water can result in exposure to chemical contaminants such as arsenic, lead, solvents, and other industrial pollutants. While microbial pathogens attract the majority of attention due to their global scale, chemical exposure can be a major problem locally and regionally, illustrated by the experience with arsenic exposure in Bangladesh (Smith et al. 2000).

What works?

Experiences in US and European cities in the past 150 years demonstrate that improvements in water, sanitation, and hygiene can greatly reduce diarrhoea and

overall childhood mortality. Cutler and Miller (2005) estimated that the impact of chlorination and filtration of urban water supplies in US cities during the late 1800s and early 1900s accounted for three quarters of the infant mortality reduction and two thirds of the under-five mortality reduction between 1900 and 1936. These improvements essentially eliminated typhoid from US cities (Cutler and Miller 2005). A similar analysis on the impact of improved water supply and sewage in Stockholm suggested that the impact of improvements on mortality reduction may depend on who receives improved services (Burstrom et al. 2005). Installation of household water connections lagged in households of lower socio-economic status. While diarrhoea mortality rates among children under 2 years of age began declining after 1878, the benefits fell primarily on better off households. The resulting gap in diarrhoeal mortality between the lowest and highest wealth quintiles doubled during the 1901–1908 period. Over the next 60 years as lower status households received water connections, mortality for the poorer group declined, resulting in a mortality difference less than what it was in 1878 (Burstrom et al. 2005). Between 1880 and 1925, Troesken (2002) compared improvements in water and reduction in infant mortality in Memphis and Savannah. He found that the two cities differed greatly in the extent to which water improvements reached black and white residents. In Memphis, city officials were committed to providing universal access and the mortality reduction was pronounced and disproportionately benefited black residents due to their higher baseline risks. In Savannah, access to piped water lagged in the black communities within the city, resulting in slower mortality reduction, particularly in the under-served communities (Troesken 2002).

These historical examples have important implications for current efforts to improve access and reduce the associated mortality. Firstly, improvements in access can reduce infant and child mortality if they reach the high-risk populations. Secondly, changes in household attitudes toward hygiene and sanitation that accompany these improvements are likely to contribute to the disease reduction. Lastly, these cities are strikingly different than the growing urban areas in low-income countries today. In 1900, the per capita Gross Domestic Product of the US and Sweden was US$2,561 and US$4,091, respectively, much higher than the countries of Africa and Asia that currently bear the majority of the burden of water borne disease (Maddison 2001). Also the past challenges faced by cities in the US and Europe are likely to be dwarfed by those of much larger cities in rapidly urbanizing areas today.

Studies in developing countries have also demonstrated the health benefits of water, sanitation, and hygiene improvements. A recent meta-analysis by Fewtrell and Colford (2004) revealed that water supply, water quality improvements, hygiene, and sanitation reduced diarrhoea incidence in children by 25–37%, and even stronger effects were seen when poor quality studies were excluded. Water quality improvements, especially those focusing on households, or point-of-use (POU) level treatment with chlorine, filters, solar disinfection, or other means, along with safe storage were effective in reducing diarrhoea incidence. Hygiene

interventions, especially those focused on hand-washing, were particularly effective in settings where water and sanitation improvements already existed. Interestingly, improvements in water supply (e.g. new wells, connections to piped water) were the least effective in reducing diarrhoea incidence (25% reduction) and showed the greatest variability depending on the quality of the new source (Fewtrell and Colford 2004). However, water supply improvements can also reduce collection time and increase water availability for other activities, such as agriculture.

Policy push to expand coverage

Access to water and sanitation for the poor has seen an increase in visibility over the last 25 years. The United Nations declared the 1980s to be the International Decade for Clean Drinking Water, with the optimistic goal of providing universal access to safe drinking water. While over 1 billion people gained access to improved water sources, and 770 million achieved improved sanitation during that decade, the number of people without access remained unchanged (Global Development Research Center 2005), the gains in coverage were not enough to keep pace with population growth, much less to achieve universal access. Additionally, the focus was on infrastructure improvement, and many of the projects fell into disrepair due to insufficient local financial and technical resources needed to sustain them. The development community came to realize that more time, greater sector investment, and a focus on holistic country and context specific approaches are essential to improve water and sanitation coverage.

In 2000, the MDGs were signed by 189 countries as a framework for the world to reduce poverty, reduce child mortality, improve access to education, and improve maternal health. In an effort to provide additional focus and momentum for the water sector, the UN declared 2005–2015 the International Decade for Action—Water for Life (UN 2005). Improved access to water and sanitation is a target of Goal 7, to ensure environmental sustainability. However, meeting this target is essential for other aspects of poverty reduction and health improvement MDGs, through increased productivity and income generation activities (Goal 1); improved access to education, especially for girls (Goal 2); decreased water collection times for women and greater gender equity (Goal 3); reduced childhood diarrhoeal disease morbidity and mortality (Goal 4); decreased prevalence of vector breeding areas, disease transmission, and injuries during water collection (Goals 5 and 6); and a promotion of participatory, community-focused approaches to development (Goal 8).

While improving water and sanitation coverage impacts many of the MDG targets, the established definitions of access reveal a focus on development rather than on public health. Access to water is defined as having regular access to 20 litres of water per person per day within 1 kilometre of the house from an improved source including piped water, protected wells, protected springs, or rainwater (UNICEF 2004). While 'improved' sources are considered safer than

unprotected surface water, they are not necessarily free of pathogens; the two most notable examples are urban piped water supplies that are inadequately chlorinated and rural water that is collected from a safe source but not safely stored (Conroy et al. 1999, WHO/UNICEF 2000). Similarly, the sanitation indicator focuses on access to improved services such as flush toilets, VIP latrines, and simple pit latrines. It does not directly consider whether sewage is treated or properly disposed. Since the MDG targets for water and sanitation are constructed from the development point-of-view, rather than from a public health point-of-view, primary emphasis has been given to improvements in coverage. Less attention has been given to ensuring that these improvements in water and sanitation access actually align with and contribute to the stated reductions in childhood mortality, poverty, and gender equality. While the MDG indicators provide important benchmarks for monitoring, they may not be sufficient to ensure that improvements in water and sanitation have an impact on health, poverty alleviation, and gender equality.

Achieving the MDGs within the realistic context of limited resources may not result in access for the poorest, most marginalized communities. However, it is these groups that are most at risk of death due to diarrhoeal disease.

The public health perspective on the MDG targets for water and sanitation

Disparities in access

Lack of access to water and sanitation is not random. Instead it follows predictable patterns generated by other socio-economic inequities. Access to water and sanitation differs substantially between high- and low- to middle-income countries, a result of disparities in fresh water resources, income, power, and institutional capacity between and within countries. Coverage is greater than 98% in high income countries for both water and sanitation; in low- and middle-income countries, only 79% of the population has water access and 49% has access to sanitation (UNICEF 2004). There are significant variations in water and sanitation access even within the low- and middle-income countries, with the majority of countries having the lowest coverage rates for improved water sources concentrated in Sub-Saharan Africa and the lowest coverage of improved sanitation concentrated in South and Southeast Asia (see Figure 1). Of the 1.1 billion people lacking access to an improved water source, 720 million (68%) are concentrated in just 10 countries and 2 billion of the 2.5 billion lacking access to sanitation (76.8%) are again found in just 10 countries (see Table I) (UNICEF 2004). Further complicating the situation, the majority of the countries where access to an improved water source is lowest are also the countries where water scarcity is projected to increase in the coming decades (International Water Management Institute 2000).

According to the Task Force on Water and Sanitation of the UN Millennium Project, 34 countries have made little to moderate progress in reaching the MDG

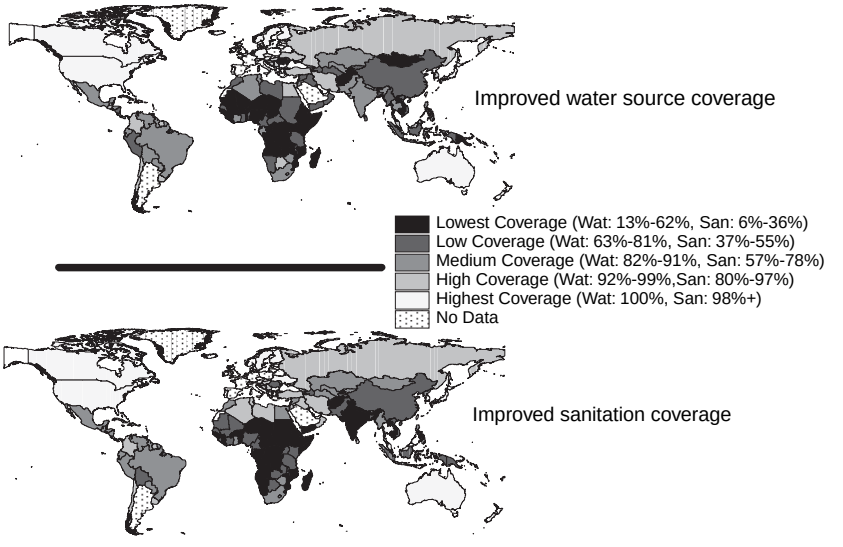

Figure 1. Quintile distribution of water and sanitation coverage (UNICEF 2004).

targets for water and sanitation access (see Table II). National-level estimates on the number of child deaths attributable to diarrhoea were calculated by dividing the total number of child deaths in 2002 (UNICEF 2004) by nation-specific estimates on the proportion of child deaths attributable to diarrhoea prepared by Parashar et al. (2003). The 34 countries in danger of not reaching either the water or sanitation MDG targets account for approximately 60% of the global population under 5 years old population (calculated from UN 2004), but over 67% of child diarrhoea mortality. Those nations identified as having both low

Table I. Countries with the largest populations lacking access to an improved water source and improved sanitation (UNICEF, 2004).

Water*		Sanitation**	
Country	Population lacking access to improved water source	Country	Population lacking access to improved sanitation
China	298 million	India	735 million
India	147 million	China	725 million
Ethiopia	54 million	Indonesia	104 million
Nigeria	48 million	Nigeria	75 million
Indonesia	48 million	Bangladesh	75 million
Bangladesh	36 million	Pakistan	69 million
Dem. Rep of Congo	28 million	Ethiopia	65 million
Vietnam	22 million	Vietnam	47 million
Afghanistan	20 million	Brazil	44 million
Brazil	19 million	Dem Rep. of Congo	36 million
Total	720 million	Total	1.98 billion
% of Total*	67.8%	% of Total**	76.8%

* Based on available data from 174 countries, total population lacking access: 1.06 billion.
** Based on available data from 165 countries, total population lacking access: 2.57 billion.

Table II. Countries with slow to moderate progress in achieving MDG targets in water and sanitation (adapted from UN Millennium Task Force 2005).

	Water supply		Sanitation	
	Low access, slow progress	Moderate access and progress	Low access, slow progress	Moderate access and progress
Countries	Ethiopia	CAR	Benin	Botswana
	Guinea	China	CAR	Brazil
	Haiti	Cote d'Ivoire	Dominican Republic	Burundi
	Libya	Malawi	Ethiopia	Cameroon
	Madagascar	Namibia	Guinea	Chad
	Mauritania	Niger	Haiti	China
	Oman	Nigeria	Madagascar	Cote d'Ivoire
	Papua New Guinea	Philippines	Mali	India
	Togo	South Africa	Niger	Indonesia
		Uganda	Sudan	Malawi
			Togo	Namibia
			Yemen	Nepal
				Pakistan
				Papua New Guinea
				South Africa
				Zimbabwe
% of world's population under 5 years old*	3.4%	23.8%	5.7%	48.4%
% of total child deaths attributable to diarrhoea**	7.2%	21.0%	12.2%	44.9%

* UN 2004.

** Parashar et al. 2003 UNICEF, 2005.

access and little progress in expanding either water or sanitation coverage account for over twice the proportion of child deaths attributable to diarrhoea than their proportion of the total population under the age of 5 years (see Table II).

Disparities in access also exist within individual, where coverage differs based on geography and household characteristics. In developing countries, urban households are 30% more likely to have improved water source and 135% more likely to have improved sanitation facilities, compared to rural households (UNICEF 2004). Potential explanations for this disparity include: differences in income, increased costs of providing services to lower density rural populations, greater demand for water and sanitation services in urban areas, and less political power or influence for rural communities.

This difference between urban and rural access, however, masks a more complicated dynamic. Globally, improved drinking water coverage in urban areas has remained 95% since 1990, while rural coverage increased from 63% to 72% between 1990 and 2002. During the same time period, however, the proportion of the world's population living in urban areas has increased from 43% to 48%. In absolute terms, compared to 1990, there are currently 40 million more urban residents lacking access to an improved water source and 80 million more lacking

access to improved sanitation. In contrast, the rural population lacking access declined by over 200 million for both water and sanitation. When urban and rural coverage levels for 1990 are applied to the 2002 urban-rural population distribution, less than 20% of the changes in urban water coverage (7.5 million people) can be attributed to a real expansion of services, with the remainder due to the larger proportion of the population residing in urban areas (calculated from UNICEF 2004).

Within urban and rural areas there are additional inequalities due to differences in income and wealth. Households in the lowest wealth quintile are 5.5 times more likely to lack improved water access and 3.3 times more likely to lack adequate sanitation, compared with households in the highest wealth quintile in the same country (based on Demographic and Health Surveys in 20 developing countries) (UNICEF 2004). In middle- and low-income countries, households earning less than US$1 per day are almost nine times as likely to lack improved water or sanitation, in comparison to those earning more than US$2 per day (Blakely et al. 2005).

These disparities may be further exacerbated when implementers seek to scale up programs or to ensure sustainability by requiring community 'buy-in'. Development agencies and other providers have increasingly required households to commit financial resources for infrastructure construction and household hook-up, in-kind labour or materials, and for communities to retain responsibility for oversight, operation, and maintenance of the systems. This has proven to be essential in order to ensure that services are adequately valued, maintenance is provided, over-use of scarce resources is avoided, and that limited external resources can be stretched as much as is practical. However, the combined pressures of scaling up and ensuring sustainability may also have an unexpected impact on equity. Fees can provide obstacles to communities and households, resulting in inequitable benefits. This has historically led to subsidized water tariffs that are unsustainable and limit incentives for providers to extend services to lower income areas (Olmstead 2003). Failure to charge adequate amounts can actually be a barrier to meeting the needs of the poorest urban residents, and the lack of sufficient population density discourages expansion into poor rural areas. As such, it is not surprising that often those people hardest to reach and with the fewest resources of their own are the least likely to benefit from market-based approaches.

Disparities in water and sanitation related disease burden are likely to be greater than those for access to services. Children in the poorest communities are more likely to have higher rates of undernutrition and lack access to health facilities and ORS treatment. As a result, mortality for diarrhoeal disease is likely to be concentrated in the poorest of the poor. If improvements in water and sanitation are to significantly reduce diarrhoeal disease burden, and subsequently child mortality, then these improvements must reach the populations that are at greatest risk.

Improving water quality

The MDGs call for improvements in access to improved water sources, while the larger issue of water quality remains unmentioned. Sources categorized as 'improved' are generally considered to be of better quality than untreated surface water, yet the actual safety of these improved sources is less understood. As previously noted, improvements in water quality show an equal (if not greater) reduction in diarrhoea incidence as improvements in water availability (Fewtrell and Colford 2004, Cutler and Miller 2005). The issue of water quality is particularly important in two key areas overlooked by the MDG targets: the risk of contamination during household storage and the frequent contamination of municipal water treatment systems.

Water use still requires regular collection, transportation, and storage for a significant portion of the world's population. This creates ample opportunity for unclean hands and objects to come into contact with water (Wright et al. 2004). In rural areas, distant water sources require transportation and storage, increasing the likelihood of contamination. In urban areas, households often respond to frequent service interruptions by storing water in unprotected containers, depleting residual chlorine levels and increasing the risk of contamination.

Often, chlorine treatment by the municipal system is depleted when it reaches the tap of users, and the frequent service interruptions can also create negative pressure, resulting in wastewater being drawn into the system. In a survey of municipal water providers, only 94.2% of African respondents and 92.1% of Asian respondents reported effective disinfection of the water supply (WHO/UNICEF 2000). Furthermore, 35.7% of water supply samples from African water supply systems, and 21.5% of Asian water supply samples, violated national microbial, chemical, or physical standards (WHO/UNICEF 2000). If the definition of coverage in urban areas was expanded to include those individuals with inadequate service, the proportion of urban residents lacking improved access could be as much as four times higher (UN-Habitat 2003). There has been little progress in expanding access to improved water supplies in urban areas, suggesting that the same drinking water sources are being used by an ever increasing number of individuals. Since the majority of the world's future population growth will be concentrated in urban areas, more and more municipal systems will be regularly compromised without significant investments in infrastructure improvements and expansions (UN 2003).

In the long-term, water quality must be addressed through infrastructure improvements in distribution systems, provision of household connections with reliable service, and development of new protected sources and adequate chlorination to ensure constant residual protection. In the short-term, various simple, low-cost, and locally acceptable strategies must be employed, including household water treatment, hygiene education and product campaigns, sanitation markets, community mobilization, and leveraging existing social and financial institutions.

Prospects: Can we reach the poorest of the poor?

A commitment to universal access to simple solutions

For improvements in water and sanitation to significantly reduce disease burden, improved services must reach those who are at greatest risk. Ensuring universal access to safe water and sanitation is central to achieving this goal. However, this long-term goal requires an enormous investment in infrastructure and services that exceeds current resource availability. In the interim, access to hygiene education, information about sanitation alternatives, and access to household water treatment would provide some protection and benefits to those individuals who would otherwise not benefit from our reaching the MDG targets.

For safe water provision, several simple and low-cost approaches are available, including POU water treatment technologies and safe storage. Three technologies, chlorination, coagulation with chlorination, and solar disinfection, have demonstrated significant reductions in diarrhoea prevalence in clinical field trials in various developing country settings (Conroy et al. 1999, Quick et al. 1999, 2002, Crump et al. 2005). Ceramic filters have been shown to be effective with appropriate maintenance (Clasen et al. 2004). Alone, the use of POU technologies does not constitute an improved water source, however, especially when used in concert with safe storage vessels, these technologies can greatly improve drinking water quality, prevent recontamination, and are much less expensive than large-scale infrastructure improvements (Hutton and Haller 2004). As a long-term solution, however, POU water treatment has the disadvantage of relying on the ability and willingness of individual households to adopt, properly use, and maintain the technologies, rather than ensuring water quality through its provision as a public good. Additionally, the processes of chlorination and solar disinfection are more difficult in places and times where source water is turbid.

The scale of the global sanitation crisis underscores the pressing need to identify sanitation interventions that can help reach the poorest of households. Simple and low-cost sanitation systems, such as VIP latrines, are effective in reducing the spread of faecal pathogens through the environment, but do not require the massive infrastructure investments of a sewerage or septic system. Communal latrine blocks, if properly maintained and managed, may be an effective sanitation intervention in densely populated peri-urban and urban areas where providing household connections to municipal sewerage systems is technically and financially impossible (UN Millennium Project 2005). Promoting sanitation, not as a health intervention but rather as an issue of privacy, convenience, and safety, has been shown to effectively increase the willingness to participate in sanitation improvements (Cairncross 2004).

Hygiene interventions, in particular hand-washing promotion, are an effective strategy for reducing faecal–oral transmission of pathogens and reducing diarrhoea incidence (Curtis and Cairncross 2003, Fewtrell and Colford 2004). Hygiene interventions are attractive due to their relatively low costs, but our

current understanding of the most effective hygiene promotion practices and their resultant impacts on health are limited.

It is important to note that improvements in water quality and sewerage in the US and Europe were preceded by changes in household awareness and attitudes towards basic hygiene (Troesken 2002), underscoring the need to address water, sanitation, and hygiene issues on both a community and a household level. While household-level software intervention requires a smaller capital investment (Varley et al. 1998), some hardware is needed to ensure its effectiveness (i.e. soap and sufficient water quantity for hand-washing, low-cost sanitation alternatives).

Integrating water, sanitation, and hygiene interventions into other social institutions

Ensuring access to a minimal package of water and sanitation services (i.e. point-of-use treatment options, hygiene promotion, sanitation alternative education) to the populations that need them the most is a feasible goal for the international community, but it requires alternative and innovative approaches to both technology and its delivery. One largely unexplored strategy for doing so is the use of existing social structures that currently reach large portions of the population, including schools, health care systems, and markets. Of course, this approach is not a panacea. These institutions may not be appropriate for providing hardware and infrastructure improvements; they do not necessarily reach those in greatest need and they may already be overextended. These approaches do not replace, but rather complement, ongoing efforts of the water and sanitation sector.

Healthcare system

The healthcare system provides a number of potential opportunities to reach two groups most in need of this minimum package of water, sanitation, and hygiene interventions: young children, who bear the brunt of the resultant health burden, and their mothers. Avenues for delivery within the healthcare system include: safe-motherhood programme, prevention of mother to child transmission (PMTCT) clinics, vaccination, nutrition programme, and diarrhoea treatment and control programme. A number of childhood health interventions reach a higher portion of children in developing countries compared to improved water and sanitation, including measles vaccination, vitamin A supplementation, and tetanus vaccinations (see Table III) (Jones et al. 2003). Recent experience in Western Kenya demonstrated that clinic-based promotion of hand-washing and household water treatment with chlorine was effective in generating changes in hand-washing practices in 45% of those exposed to the intervention, and in generating changes in water treatment behaviours in 65% (Parker 2005). The integration of water treatment and hand-washing promotion into HIV/AIDS patient care and outreach may also be an effective way to reach an additional population at high risk of diarrhoea mortality (Freeman 2005).

Table III. Coverage of various child survival interventions for countries accounting for 90% of worldwide child deaths in 2002 (adapted from Jones et al. 2003).

Preventive interventions	Estimated coverage (range)
Breastfeeding (6–11 months)	90% (42–100)
Measles vaccine	68% (39–99)
Vitamin A	55% (11–99)
Skilled birth attendant	54% (6–89)
Tetanus toxoid	49% (13–90)
Water, sanitation, hygiene	47% (8–98)
Exclusive breastfeeding (<6 months)	39% (1–84)
Treated bednets	2% (0–16)
Hib vaccine	1%
Net primary school attendance* (all developing countries)	80% (males) 77% (females)
Net primary school attendance* (least developed countries only)	57% (males) 52% (females)

* UNICEF, 2005.

While traditional child health interventions may reach a large portion of children in many countries, they do not always reach those in the greatest need (Victora et al. 2003). In a comparison of the relative access to immunizations and improved water source by socio-economic strata in rural Rajasthan, India, access to most vaccines was found to be high, but less equitable than access to an improved water source (Bonu et al. 2003). Efforts to promote water, sanitation, and hygiene in the context of other healthcare interventions will also have to confront the severe human resource constraints on healthcare workers in developing countries. Despite these challenges, the healthcare system does provide multiple opportunities for reinforcing water treatment and hygiene messages.

Schools

In most low- and middle-income countries, access to primary education, while not universal, is more widely available than access to improved water and sanitation (see Table III). Approximately half of the schools in low- and middle-income countries do not have safe water and appropriate sanitation facilities (UNICEF 2005). While school-aged children bear a small fraction of the global diarrhoea burden, they have the highest rates of infection from intestinal helminthes, which are associated with poor sanitation and hygiene practices (Pruss et al. 2002). Reducing these infections has been shown to result in nutritional gains and higher educational attainment (Simeon et al. 1995, Stoltzfus et al. 1997). In addition, the lack of gender-appropriate sanitation in schools is often cited as a cause of declining enrolment of girls, especially after puberty (UNICEF 2005). School-based interventions could include: hygiene education, hand-washing facilities, sanitation, water treatment and safe storage, and improved water supply.

In addition to the direct benefits for students, school-based interventions can potentially leverage change beyond the immediate school environment. While few long-term studies of health impacts are available, evaluations of existing school

projects suggest that behaviour and attitudinal changes in school result in changes in the home. The evaluation of a school hygiene and sanitation project in Bangladesh found an increase in the proportion of homes with latrines and the proportion of family members using latrines, as well as improved hand-washing behaviours among adult family members following the intervention (Snel 2004). School-based water supply improvements can also serve as a source of improved water for the surrounding community or as a distribution point (or vendor) of point-of-use water treatment supplies.

School-based interventions face several potential limitations that must be addressed before they can reach their full potential. Interventions must be sustainable. This can be challenging, not only in terms of financial sustainability, but also in terms of the human resource strains faced by many teachers in the developing world. The active involvement of educators, the ministry of education, and community members is essential for the development and long-term success of school-based programs (UNICEF 2005). If school-based interventions are to have a significant impact on the burden of water and sanitation related illness, schools must also serve as a catalyst for change at a household and community level. Operations research is needed to identify the best strategies for accomplishing this.

Markets

Markets provide another mechanism for using existing social institutions to assist in scaling up water and sanitation efforts. Traditional markets can be an efficient mechanism for increasing access to sanitation. Sanitation marts in South Asia provide customers in rural areas with access to a wide range of sanitation alternatives that differ in price and sophistication (Heierli et al. 2004). The success of these interventions requires attention to both demand and supply. On the demand side, customers must be interested in purchasing materials for constructing a latrine, whether to improve their health, quality of life, or social status (Cairncross 2004). On the supply side, local providers must be trained to produce appropriate materials and to offer a range of goods to meet the needs and resource availability of the community (Water and Sanitation Program 2000). The Global Public–Private Partnership for Handwashing is a leading example of utilizing the market for hand-washing and hygiene promotion, leveraging the experiences and participation of soap and hygiene-product manufacturers and developing outreach and promotion campaigns based on traditional advertising and marketing campaigns (Curtis 2002).

Over the last 5 years, numerous campaigns have distributed household water treatment supplies as market goods. Chlorine solution for water disinfection is available under a variety of brand names in countries in Latin America, Africa, and Asia. The approach, pioneered by the US Centers for Disease Control and Prevention (CDC), is promoted through social marketing by organizations such as Population Services International, by small micro-entrepreneurs, and commercial concerns. Proctor and Gamble also produces a water chlorination and

flocculation product, PuR™ that is sold through kiosks and other outlets in a number of countries. In some areas, improved storage vessels with narrow openings and taps are also produced and sold. Often, point-of-use treatment options and safe storage devices are sold alongside other health-related products, including bednets, fortified flour, and condoms (Thevos et al. 2003). In Kenya, women's groups purchase water treatment and other health products and sell them to community members as a form of income generation, extending the reach of commercial and social marketing efforts (Freeman 2005).

While markets may be ubiquitous, not all individuals have equal access. This is especially pronounced in rural areas where households have limited cash income. The question remains as to whether market-based water, sanitation, and hygiene interventions can ever reach the poorest of the poor. The marketing of other health promoting products, such as insecticide treated bednets and condoms, provides important lessons for utilizing market-based approaches. In their study of bednet sales in Nigeria, Onwujekwe et al. (2004) found that low-income households were less likely to purchase nets than higher income households. The results of their analysis suggest several reasons for these disparities. Households in the lowest wealth quintile may be less aware of the product (due to distance or lack of a radio), have only limited access to a place they are being sold, and may not have the income necessary for purchase. Evaluations of chlorine point-of-use treatment adoption in Western Kenya suggest that these same mechanisms may each produce a level of disparity in use (Abbott 2005, Freeman 2005). Future operations research can improve our understanding of those factors that contribute to the disparities associated with market-based interventions, as well as identify strategies for overcoming them.

In addition to these product markets, other market mechanisms may be important in expanding water and sanitation access. In rural towns, small cities, and large metropolitan areas, markets for piped water will be an important source of provision, if sustainable and equitable approaches are implemented. For example, in larger community systems, water tariff structures can be adjusted to ensure basic needs while discouraging overuse through block tariff pricing that subsidizes initial water allotments and raises rates as household consumption rises (Olmstead 2003).

Markets, schools, and health-care systems are but a few examples of the existing social and political institutions through which a basic package of water, sanitation, and hygiene interventions can be disseminated to the populations that need them the most. Other, largely unexplored, entry points include places of worship and grass roots community organizations. Each of these approaches will engage high-risk groups in a unique and specific manner, and the interventions most appropriate for dissemination will differ greatly. This underscores the need to continue operational research on identifying not only the most efficient ways of ensuring access to this basic minimum package but also which existing social institutions are most appropriate for delivering these services and under what conditions.

Measuring equity and impacts

A combination of research and evaluation information is essential to improve access, affordability, and sustainability of water and sanitation improvements for the poorest households. Systematic and standardized country-level monitoring data is needed to understand existing disparities and to measure progress to reduce it. The evaluation of progress in meeting the MDG for improving access should be complemented by explicit monitoring of whether those improvements are reaching the poorest of the poor.

The long-term political and financial commitment to universal access to safe water and sanitation would also be strengthened by careful measurement of the impact of interventions on health and development outcomes. This is an important way to ensure that services are equitable and contribute to reductions in the health burden. A recent WHO cost–benefit analysis has estimated that investments in water and sanitation would more than pay for themselves in terms of improved productivity and reduced healthcare costs (Hutton and Haller 2004). Further demonstrating this benefit empirically could be key in convincing national decision makers and international lenders to increase their commitment to ensuring access to improved and safe water and sanitation for all.

Conclusion

The MDGs provide an essential framework for the international community to approach the daunting task of eradicating extreme poverty. The water and sanitation targets of the MDGs are central to the promotion of sustainable development, but also a critical component in reducing childhood mortality and morbidity. For improvements in water and sanitation access to reach their full potential in disease reduction, there is a need to focus on them as a public health challenge as well as a development issue. When water and sanitation are viewed as a public health issue, attention must be given to the countries with the greatest needs and the highest-risk individuals within them. This requires an increased commitment to addressing disparities in access to ensure that interventions reach the populations that need them the most, as well as developing innovative approaches for reaching the poorest of the poor. Our current understanding of water coverage must expand beyond access to *improved* sources, and include access to *safe* drinking water sources. While we work towards the MDG targets for water and sanitation, we must also remember the hundreds of millions of individuals that will still lack access when the goals are met. There is a need to ensure the universal availability of simple and effective interventions, such as household water treatment, hygiene education, and basic sanitation. These interventions will be essential to achieving the potential health impact of the MDG water and sanitation targets, as well as provide some hope for those individuals who do not stand to benefit from this progress.

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