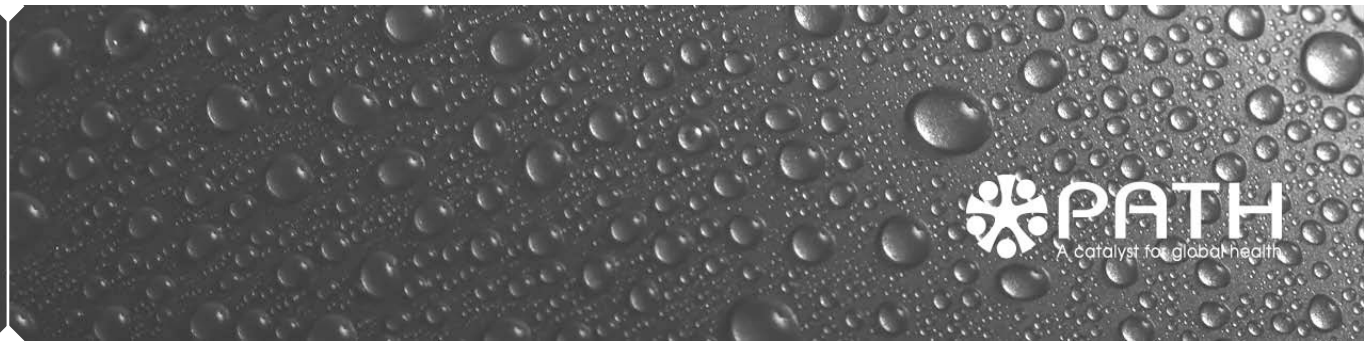
>>WORKING DRAFT



This is one in a series of working draft documents that discuss key questions and preliminary findings of PATH's Safe Water Project. The purpose of these documents is to foster dialogue and the exchange of ideas among partners in the household water treatment and storage arena and to capture early Safe Water Project thinking that will evolve based on new findings and feedback.

Safe Water Situation in Four Countries: 2007 Findings in Brief

I. Introduction

In 2006 PATH launched the Safe Water Project to examine how commercial market forces can help reduce the incidence of waterborne disease.[1] The project seeks to facilitate the growth of local household water treatment and storage (HWTS) industries that can provide practical and affordable HWTS products to poor families on a sustainable basis.

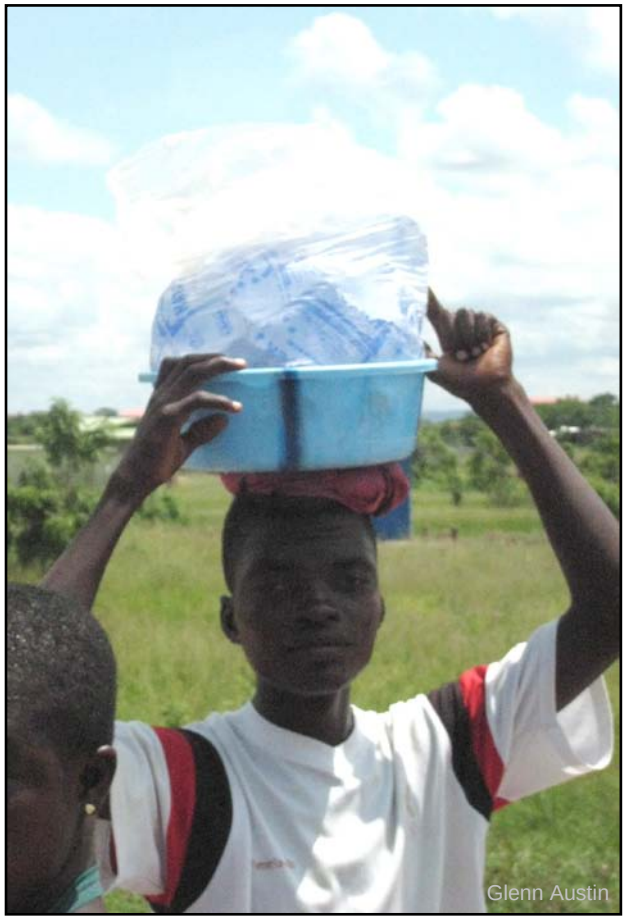
While the project is focusing initially on India, the lessons learned there will be applied and tested in other countries. Therefore, in 2007 PATH commissioned snapshot reports on the safe water situation in four countries of interest: Ghana, Tanzania, Cambodia, and Vietnam. These reports will be used to inform follow-on research, identify potential partners, and contribute to the development of pilot activities. The content and focus of the reports varies, and each draws on a somewhat different mix of sources, including literature and policy reviews, discussions with key stakeholders, a review of private- and public-sector water activities, and rapid assessments of consumers. All four reports are summarized here. These findings are a preliminary effort to understand the situation in each country; richer data will follow, and Safe Water Project thinking will undoubtedly evolve.

II. Northern Ghana

Nearly two-thirds (64%) of Ghana's 21 million people live in rural areas. Poverty is decreasing, but remains widespread. Waterborne disease poses a significant problem. The overall burden of disease can be assessed using the disability-adjusted life year (DALY), which measures years of life lost to premature mortality and poor health. A DALY can be thought of as one year of healthy life lost. In Ghana, diarrheal diseases (including cholera, typhoid, and dysentery), which are often transmitted by contaminated water, accounted for 286,600 DALYs lost in 2002; this was 4% of the country's total DALYs lost. About one in 12 deaths (8.6%) in 2002 could be attributed to these diseases.[2] Parasitic worms spread by water, including guinea worms and schistosomes, also cause much death and disease in Ghana. Ghana ranks second in the world for guinea worm infection, after Sudan.[2] In 2002 schistosomiasis accounted for 1.3% of all deaths in Ghana and 56,800 DALYs lost, or 0.8% of the total DALYs lost.[2]

The northern sector is the poorest area of Ghana. It faces unique water challenges:

- It is a semi-arid savannah with a nine-month dry season, so water is often scarce.
- Rising population density, overgrazing, and deforestation are contributing to increased flooding.
- The surface water is extremely turbid, so removing particles is an important first step in any water treatment process.
- Guinea worm remains endemic in the north.



Bagged or sachet water is popular in Ghana. Some are factory-produced, some are packed by hand.

Sources of drinking water. Only 11% of rural households in Ghana have access to piped water, compared with almost three-quarters of urban households.[3] The major sources of drinking water for rural households are various kinds o f wells (57%) and surface sources (31%). There are large regional disparities. Access to improved water sources (including boreholes, household connection, public standpipe, rainwater harvesting, and protected springs and dug wells) ranges from a low of 45% in the Northern Region to 85% in Greater Accra.[3,4]

Ghana has a thriving sachet, or bagged, water industry. Many people buy sachet water from vendors when they are away from home, but some rely on sachet water as their sole source of drinking water because of its convenience and the scarcity of water supplies.[5] Factory-produced sachet water is treated by point-of-entry systems imported from China. There is also a cottage industry for sachet water in which plastic bags are filled directly from the municipal supply and tied shut by hand. Factory-produced 500-ml sachets of treated water sell to consumers for US$0.054. Hand-tied 700-ml sachets of water cost US$0.022.[*]

Household water treatment. A market study in Accra found that urban residents may treat their water with alum[†] or boil it, but there are no other water treatment methods in common use. In contrast, households in rural northern Ghana recognize the danger of guinea worm and routinely pass their water through a special cloth filter. In addition to the cloth filter, some households also treat their drinking water with alum in the dry season, when it is especially dirty, or with Aquatabs.

According to a consumer preference survey in northern Ghana, purchasing decisions for HWTS products are driven largely by their potential health impact. The look and taste of treated water, treatment time, and price are lesser concerns. Consumers showed a strong preference for a traditional durable product, such as a ceramic or plastic filter, compared with other HWTS products.[6] However, there may also be a role for chemical disinfectants: two small studies found that many consumers reacted positively to a chlorine taste, perhaps because they associate it with municipally treated or bottled water.[6,7]

In a 2003 survey, almost 90% of households nationwide listed drinking water as one of their biggest problems.[7] However, it is not clear how much people are willing to pay for treated water. A market study conducted in Accra found that 94% of respondents were interested in treating their water with Aquatabs, and most were willing to pay at least 5 pesewas (about US$0.03) a tablet. Similarly, respondents interviewed in rural northern Ghana said they would be willing to pay a moderate amount to treat their water, either with a disinfectant or a ceramic filter. Yet earlier studies in Ghana found that only 40–60% of households were willing to pay for guinea worm cloth filters.[8] Household income and expectations about HWTS pricing may influence willingness to pay, as shown by a study of 57 households using ceramic filters who were asked to add Aquatabs to their treatment regimen. After trying Aquatabs, almost all of the lower-middle class households, who had bought their ceramic filters on credit, were willing to pay full price for Aquatabs. In contrast, only one-fourth of lower-class families, who had received the ceramic filters for free, were willing to pay for Aquatabs.[7]

[*] The original Ghana snapshot report gave many costs only in US$. Those figures remain unchanged here. When costs are given in Ghanaian New Cedis (GHS), however, the amount in US$ has been recalculated using the current exchange rate of US$1 = GHS1.45. The rate used in the snapshot report was US$1 = GHS0.95.

[†] Alum is a chemical coagulent that binds suspended particles into larger clumps that settle to the bottom where they can be easily removed.

Recontamination of water during transportation and storage poses a substantial problem in both urban and rural communities. Possible solutions include adapting locally available buckets and jerry cans with a spigot, narrow mouth, and fitted lid; marketing taps for existing containers; and promoting the use of chlorine disinfectants to provide residual protection after water is treated with alum or filtered.[9]

Stakeholders

Government policy and programs. The Ministry of Works and Housing formulates and coordinates policy for the water and sanitation sector, while the Water Resources Commission is responsible for managing the utilization of water resources. The Ghana Environmental Protection Agency regulates and enforces environmental quality laws, including those related to water pollution. It is unclear what agency is responsible for monitoring the quality of drinking water; the Ghana Standards Board, the Environmental Protection Agency, and the Food and Drugs Board have all played a role.[10]

The Community Water and Sanitation Agency facilitates the development of water and sanitation services in rural areas and towns. Local District Assemblies are responsible for providing water and sanitation services.[10] However, the political and economic priorities of the District Assemblies suggest that safe water for children and families is a low government priority.

NGO and donor involvement. Nongovernmental organizations (NGOs) active in the water and sanitation sector in Ghana include World Vision International, Water Aid, ProNet, the Carter Center, and several church-funded organizations. Principal donors include the World Bank, Danida, Canadian International Development Agency, the Government of the Netherlands, and the European Union. Most donors are focused on water supplies in rural areas and small towns.[10]

HWTS and Other Water Treatment Products on the Market

Alum. Alum is well known and fairly readily available in village markets and urban centers. Women in Northern Ghana treat drinking water with alum in the dry season, when surface sources dry out and turbidity increases. The sale of alum balls is a "bottom of the pyramid"[‡] private-sector business. Certain vendors in the central marketplace serve as core distributors to stallholders and street vendors who sell single balls of alum to consumers. Alum is imported from outside the country, so the supply can be unpredictable. Because of alum's low cost and broad acceptability, it could be combined with other treatments, such as chlorine disinfection, to create an affordable and effective solution for turbid water found in rural areas.[9]

[‡] "The bottom of the pyramid" refers to the 4 billion people living on less than US$2 per day, as defined in 1998 by Professors C.K. Prahalad and Stuart L. Hart. It was subsequently expanded upon by both Prahalad in 2004 in *The Fortune at the Bottom of the Pyramid* and by Hart in 2005 in *Capitalism at the Crossroads*.

Chemical disinfectants. Precision, a commercial business based in Accra, is building a commercial distribution network for Aquatabs, which are manufactured by Medentech. One or two tablets can treat 20 liters of water. Retailers will charge an estimated 3 pesewas (US$0.02) per tablet. This is less than the price consumers in Accra say they are willing to pay, but may be more than households in the Northern Region can afford. Precision is actively marketing Aquatabs on radio and plans to expand its advertising to billboards, television, brochures, bumper stickers, and t-shirts. It also plans to launch a safe water education campaign in the Central Region with volunteer promoters.

Cloth filters. The NGO Guinea Worm Eradication Program (GWEP) distributes cloth filters for free in Ghana. It takes less than one minute to filter enough water to fill a standard 44-liter metal bucket, but the cloth filters have a tendency to tear and need frequent replacement. GWEP buys the filters from Vestergaard Frandsen S.A., which manufactures them in factories in India. Shipments totaled some 300,000 filters in 2007, 500,000 filters in 2006, and 600,000 filters in 2005. Including transport costs, each filter costs more than US$1.00.

Bio-sand filters. International Aid, a Christian aid group based in the United States, is introducing an injection-molded plastic version of the bio-sand filter to Ghana. They have branded this product, which is imported from the United States, the HydrAid filter. The filter initially did not function well with the highly turbid water common in Ghana, so International Aid has added another layer of fine sand to the existing layers of gravel and sand. International Aid is distributing the initial shipment of 2,000 filter containers free to NGOs, including the United Nations Children's Fund (UNICEF), Water Aid, and WASNET. The plastic container costs US$35. With sand and gravel transported from Tema, the full price of the entire system is US$65. There is also a local plastic design that is half the price of the HydrAid filter container and comparable in efficacy.

Ceramic filters. Water Health Care Ltd, a Ghanaian business with retail outlets in Accra, Kumasi, and Tamale, sells three brands of commercial ceramic candle filters. Two are designed for household use: the British Berkefeld filter and OK Candle Filters. The former is manufactured in the United Kingdom, contains two filter elements, and costs US$42 for the base unit and US$32 for each candle. The latter is imported from India, contains a single candle, has a slower flow rate, and costs US$19 for the base unit and less than US$2 for each candle.

Pure Home Water (PHW), a nonprofit organization assisted at start-up by Massachusetts Institute of Technology (MIT), sells ceramic clay pot filters to low-income households in northern Ghana under the brand name Kosim. The filter elements, plastic storage receptacles, and lids are made in Ghana, while the spigots are imported. Customers are highly satisfied with the Kosim filter (S. Johnson, unpublished data, 2007), and a survey found that 93% of filters were still in use after one year.[1] However, a larger capacity or faster flow rate would better meet household's daily water requirements.[9] The Kosim filter costs GHS15.00 (US$10.36), including all parts and transportation, but PHW only charges GHS6.00 (US$4.14) in rural areas and GHS12.00 (US$8.29) in urban areas. This

reflects what people are willing and able to pay. Initially PHW stressed financial sustainability and focused on selling at higher prices to the urban middle class in Tamale. After a change in strategy, more than half of sales in the second year went to the rural poor in traditional villages. PHW sold 1,910 filters in its first two years of business. Sales increased sharply the following year after massive flooding, when 5,500 filters were supplied to flood victims through UNICEF-Ghana and Oxfam.

Polypropylene and carbon filters. Water Health Care Ltd distributes a water treatment system that is made in China and uses a combination of polypropylene fiber and carbon filters. It provides the component parts for point-of-entry water treatment systems that are used by the local sachet and bottled water industry to treat municipal water. Another local business, African Filtration Systems, markets Mission filter systems that use a polypropylene string filter, an activated carbon cartridge, and chlorine. Most components are imported from the United States, and only about 200 filters have been sold, at a price of US$45–65.

Comparative costs. As shown in Table 1, the cost of treated water in Ghana varies widely. Cloth filters distributed by GWEP and solar treatments are essentially free. Alum and Kosim ceramic pot filters are also inexpensive per liter of water treated: the water they produce is comparable in cost to the highly subsidized municipal water available from public taps in some urban areas. However, the Kosim filter requires a much larger upfront investment than alum. Even relatively expensive HWTS methods, such as imported ceramic candle filters and PUR, are less costly than buying sachet and bottled water.

Table 1. Cost of treated water to consumers in Ghana, in US dollars

Treatment method or source	Volume treated or sold		Cost per liter (in US$)
	Amount	Price	
Cloth filter	unlimited	free	0
SODIS	unlimited	free	0
Alum	80 liters	$0.02	$0.0003
Kosim ceramic pot filter	Life of filter is 3 years	$6 in rural and $12 in urban areas	$0.0004 - $0.0008
Ghana Water Company, public tap	44 liters	$0.04	$0.0009
Aquatabs (tablets to treat 20 L)	10-20 liters, depending on turbidity	$0.03	$0.0015 - $0.0030
Tanker truck			$0.0021 - $0.0044

Table 1. Cost of treated water to consumers in Ghana, in US dollars (cont.)			
Treatment method or source	**Volume treated or sold**		**Cost per liter (in US$)**
	Amount	**Price**	
Biosand filter	Life of system is 5 years	$60-$100	$0.0027 - $0.0034,* depending on construction
Vended water	20 liters 200 liters	$0.17 $0.94	$0.0047 - $0.0085, depending on quantity purchased
Imported ceramic candle filters (OK, Doulton, British Berkefeld)	Life of system is 5 years	$20-$74 for system & $2-$32 for replace-ment candles	$0.0047 - $0.0166
Mission hybrid filter and chlorine system	Life of system is 5 years	$50 for system & $15 for replacement filters and chlorine	$0.0053
PUR	10 liters	$0.07	$0.0070
Sachets, hand-tied	700 ml	$0.022	$0.0309
Sachets, factory produced	500 ml	$0.054	$0.1160
Bottled water	1.5 liters	$0.86	$0.5760
Note: This analysis was conducted in November 2007 using an exchange rate of GHS1 = US$1.08. This is the rate reflected in the table. * For treating drinking water only; cost per liter declines to $0.0009 - $0.0011 when water for washing, cooking, and other purposes is included.			

Prospects for Commercial HWTS Products

As described above (see "Northern Ghana, Household water treatment,"), surveys and market studies have found that Ghanaians, especially those in the north, recognize that drinking water is a problem and would be willing to pay a moderate amount for water treatment products. Indeed, commercial HWTS enterprises already exist at different levels of the market. Cottage industries sell hand-tied sachet water and alum balls, there are HWTS retail stores that serve the well-off, and a commercial firm is preparing to import and distribute Aquatabs nationwide.

In addition, consumer surveys have shed considerable light on how to market HWTS products in northern Ghana.[9] Companies are more likely to succeed if they:

- Emphasize health impacts when branding water treatment products.

- Rely on community sales models such as door-to-door sales, street vendors, and community-level retail outlets.
- Use price to indicate product quality.
- Market products in rural areas during harvest season, when households have greater income at their disposal.

Promotional efforts will be more effective if they recognize that health workers, friends, and social networks have greater impact on public opinion and household purchasing decisions than local officials and community leaders.

While these findings suggest that there is an opportunity to commercialize HWTS products for poor households in northern Ghana, more information—on potential market size, distribution channels, and the like—is needed to evaluate the commercial viability of such an enterprise. Interested businesses face some serious challenges. First is the technical challenge of developing products that can treat highly turbid water and that reliably remove the guinea worm vector. Second is cost. Experience with Kosim filters and Aquatabs suggest that it may be difficult to fully recover manufacturing, distribution, and promotional costs if prices are set to be affordable in rural villages. Rural households may be even less disposed to pay much for HWTS products because of the precedent set by current projects and programs which distribute these products for free or at highly subsidized prices. Third, many nonprofit and commercial distributors of HWTS products in Ghana rely on imported products or products with imported components. Developing a local industry to manufacture HWTS products at a lower cost must be a priority

III. Dar es Salaam, Tanzania

Dar es Salaam has an estimated population of about 3.5 million and is the ninth fastest growing city in the world.[11,12] Rapid growth has made it difficult to extend water and sanitation services to all residents of the city.

The country of Tanzania suffers from a variety of waterborne and water-based diseases, including various diarrheal diseases and schistosomiasis. In 2007 there were over 65,000 cases of dysentery, over 17,000 cases of typhoid, and over 2,000 cases of cholera among people of all ages. There were also more than 400,000 cases of diarrhea among children under age five.[13]

Sources of drinking water. In mainland Tanzania, two-thirds of urban households rely on piped water, although more often from a neighbor's tap than their own connection or a public tap. Another 12% rely on wells, 7% on tanker trucks or other water vendors, and 6% on surface sources. In contrast, wells (45%) and surface water (32%) are the leading sources of water in rural areas, where just 22% of households have access to piped water.[14]

The Dar es Salaam Water Supply and Sewerage Company (DAWASCO) supplies piped water to the greater municipal area. However, their service generally reaches only the planned areas of the city, where just 30% of the population lives.[15] While households can purchase a connection from DAWASCO, the cost is prohibitive for most families. DAWASCO charges households a flat monthly fee, typically Tsh20,000–30,000 (US$15-22),[§] but only makes water available to most households during severely limited hours.

A man and his son bring water home in a 20-liter jerry can typical to Tanzania.

Limited access to piped water has spawned alternative water industries. Households with a DAWASCO piped connection or a borewell often sell water to their neighbors. They may even own and lease pushcarts to water vendors. Pushcart vendors can bring in 4,000 to Tsh6,000 (US$3.00–4.40) per day, selling a 20-liter jerry can for an average of Tsh150

[§] The exchange rate used in the original Tanzania snapshot report was US$1 = 1,300 Tanzanian shillings (Tsh). However, this report uses the current exchange rate of US$1 = 1,365 Tsh to calculate the dollar equivalents of amounts given in Tsh.

(US$0.11). Large water tanker trucks serve areas of Dar es Salaam where there are no piped connections and thus no opportunity to buy water from neighbors.

Many commercial companies sell bottled water in Dar es Salaam. Prices range from Tsh200 (US$0.15) for a 350-ml bottle to Tsh1,600 (US$1.17) for a 10-liter bottle. These companies also produced and sold treated water in plastic bags until 2006, when the government banned the sale of sachet water to reduce litter. Despite the government's ban, a cottage industry continues to sell boiled water in unlabeled bags in many unplanned areas of Dar es Salaam. Roadside vendors sell a 500-mL bag of water for Tsh50 (a little less than US$.04). Vendors sell boiled water by the glass for the same price of Tsh50 in busy locations.

Household water treatment and storage. Boiling is the only common home water treatment method in Dar es Salaam. Households that do not boil their drinking water say the main reason is the high cost of charcoal. Some also mention an unpleasant metallic taste associated with boiling. In a rapid assessment of 30 households, just one treated its drinking water with WaterGuard[**] disinfectant.

Because DAWASCO supplies water during limited hours, even households with piped connections must store large quantities of water for later use. Wealthier households use electric pumps to fill 500- to 1,500-liter plastic tanks. Less affluent households store water in 20-liter buckets. Households store their drinking water in a special container, even if they do not treat it, and take extra care in cleaning it.

Every household in the rapid assessment knew that water from DAWASCO connections and borewells was not safe to drink. Most had learned about boiling and filtering water at school. They were willing to pay more for water from DAWASCO connections than from borewells: Tsh50 (less than US$0.04) versus Tsh20–30 (about US$.02) for a 20-liter bucket. However, they still did not believe that DAWASCO water was safe to drink.

HWTS and Other Water Treatment Products on the Market

Safe storage vessels. Most households and water vendors reuse locally manufactured cooking oil containers to store and transport water. Most of these containers are buckets with a snap-on lid. Some are jerry cans with a screw top and a small neck. They typically come in 10- and 20-liter sizes. Large, round plastic water storage tanks, with a capacity ranging from 200 to 5,000 liters, are also manufactured locally.

Boiling. It costs Tsh500 (US$0.37) for enough charcoal to boil 20 liters of water. Many households consider this to be prohibitive, even though the unit cost for fuel works out to be just Tsh25 (about US$0.02) per liter (see Table 2). The problem is the large upfront investment needed.

[**] WaterGuard is a chlorine-based water treatment system promoted by Population Services International (PSI) in sub-Saharan Africa. It is sold in both liquid and tablet form in Tanzania.

Chemical disinfectants. WaterGuard was the only household water treatment product observed on sale in Dar es Salaam when the snapshot report was prepared. Most respondents in the rapid assessment had heard of WaterGuard from radio and newspaper promotions. Some families had tried it and discontinued using it, largely because of the bad taste. They also expressed uneasiness about its safety and said they did not know how much disinfectant to add to the water. WaterGuard is by far the least expensive way to treat water in Tanzania (see Table 2).

Comparative costs. Treating water with WaterGuard liquid or tablets is the least expensive source of safe water in Dar es Salaam when the cost is calculated per liter. Boiling is the next most affordable option. Small quantities of water purchased by the glass or in sachets and bottles cost many times more per liter. However, consumers focus on the lump sum they need to pay for safe water, not on the price per liter. Therefore, people perceive the cost of boiling to be prohibitive, but think the price charged for water by the glass or in sachets is good.

Table 2. Cost of treated water to consumers in Dar es Salaam, Tanzania, in Tanzanian shillings and US dollars

Treatment method or source	Volume treated or sold		Cost per liter (in Tsh and US$)
	Amount	Price	
Boiled at home	20 liters	Tsh500 ($0.37)	Tsh25 ($0.02)
Treated with WaterGuard liquid*	500-1,000 liters	Tsh500 ($0.37)	Tsh0.5 - 1 ($0.004-0.0007)
Treated with WaterGuard tablet*	20 liters	Tsh20 ($0.01)	Tsh1 ($0.0007)
Sachet (boiled by vendor)	500 ml	Tsh50 ($0.04)	Tsh100 ($0.07)
By the glass (boiled by vendor)	250 ml	Tsh50 ($0.04)	Tsh 200 ($0.15)
Uhai brand bottled water	1 liter	Tsh500 ($0.37)	Tsh500 ($0.37)

* These data come from PSI-Tanzania (www.psi.or.tz/programmes_SafeWater.php).

Prospects for Commercial HWTS Products

The thriving market for water in Dar es Salaam suggests the potential for commercial HWTS products. People routinely pay for water—whether it comes from the municipal system, neighbors, vendors, tanker trucks, or in sachets and bottles—and they are willing to pay more for water they perceive to be better. Most people recognize that their water is not safe to drink. If they can afford to, they boil their water. While only one HWTS

product (WaterGuard) was observed for sale during the preparation of the snapshot report, at other times Aquatabs, locally made clay pot filters, and ceramic candle filters have been seen for sale in the markets and retail outlets of Dar es Salaam.

While a less-expensive or easier water treatment method might be welcome, efforts to market HWTS products to poor households in Dar es Salaam will face some challenges. Cost poses a major barrier. However, many small shop owners extend credit to residents who live nearby, and these credit schemes could potentially be extended to HWTS products. Another problem is that there is so little experience, commercial or otherwise, with HWTS products in Dar es Salaam. Thus, little is known about household preferences for specific HWTS products, the potential size of the market, or potential marketing strategies. Market assessments are needed to fill the information void.

IV. Cambodia

About 85% of Cambodia's 14 million people live in rural areas.[16] The average annual per capita income is about US$300, making Cambodia one of the poorest countries in the world.

While surface water is plentiful, the quality is often poor. Seasonal flooding, aggravated by deforestation, has led to increasingly degraded and unsafe water sources.[17] In 9 out of Cambodia's 24 provinces and cities, the ground water is contaminated with high levels of arsenic. Arsenic poisoning from contaminated water sources in these provinces is very common. Waterborne disease imposes a substantial burden on Cambodia. In 2002 diarrheal diseases, including cholera, typhoid, and dysentery, accounted for more than one in ten deaths (10.6%) and 345,200 DALYs lost, or 6.5% of the total DALYs lost.[2] The prevalence of childhood diarrhea is 20% in rural areas and 16% in urban areas.[18] The incidence of dengue hemorrhagic fever in Cambodia is rising, with over 34,000 cases reported and 365 deaths among the general population in the first eight months of 2007.[19]

Sources of drinking water. Around two-fifths of urban households have access to piped water, mostly through home connections. Piped water is supplied by a semiautonomous utility, the Phnom Penh Water Supply Authority, in the capital city and outlying areas. Rural households are more likely to rely on tube wells or boreholes, along with surface water sources. About one-quarter of urban households and one-third of rural households shift to rainwater during the rainy season.[18] While many private companies in Cambodia manufacture and distribute treated bottled water, they do not serve the poorer half of the population.

Household water treatment. Approximately 80% of urban households treat their water, compared with 63% of rural households. Boiling is by far the most common treatment method. About 12% of households allow the water to stand and settle prior to drinking, while just 2% use ceramic, sand, mineral pots, or other filters.[18]

Stakeholders

Government policies and programs. The Government of Cambodia developed a National Water Supply and Sanitation Policy (NWSSP) for both urban and rural areas in 2001. To increase the efficiency and effectiveness of services, the NWSSP clearly defines the roles and responsibilities of government institutions, groups of water users, NGOs, and the private sector. It encourages community stakeholders to become involved in the planning process and also encourages private-sector participation.

The Ministry of Industry, Mines, and Energy (MIME) is responsible for the water supply in all provincial towns, while the Ministry of Rural Development is responsible for safe water and sanitation in rural areas. There are continuing efforts to bring the rural water and sanitation sector under the Ministry of Health. The Ministry of Environment is responsible for environmental protection and regulation, including pollution control. In

2004 MIME developed a Drinking Water Quality Standard that outlines basic guidelines for the design and planning of water supply treatment and provides benchmarks for assessing the performance of water supply systems.[20]

Despite explicit government policies and programs, a 2006 review pointed to lack of political commitment as a major constraint on the rural water and sanitation sector in Cambodia. It also cited the lack of appropriate institutions at all levels and poor interaction between senior officials and the donor community.[21]

NGO and donor involvement. Around 40 local and international NGOs work on rural water and sanitation in Cambodia. A Water Supply and Sanitation Sectoral Working Group acts as a forum for these NGOs to share experiences and ideas, coordinate their activities, and collaborate on solutions. The Working Group also serves as a government coordination mechanism, according to a conversation with Dr. Mao Saray, the Director of the Department of Rural Water Supply (2007).

Three main donors are involved in the sector: the World Bank's Water and Sanitation Programme, the European Commission Humanitarian Office, and UNICEF. The main focus of NGOs and donors has been constructing wells to improve the microbiological safety of the water supply in rural areas of Cambodia.[22] In the past year the United States Agency for International Development has helped fund a multimillion dollar initiative to address HWTS, sanitation, and hygiene in Cambodia, Laos, and Vietnam.[23]

HWTS and Other Water Treatment Products on the Market

Rainwater harvesting. Three NGOs, Resource Development International (RDI), Hagar International, and Rain Water Cambodia (RWC), build small rainwater harvesting systems for domestic use, as well as large systems that can serve schools, health centers, and entire villages. Rainwater is relatively free from impurities, including arsenic, so clean catchments and safe storage arrangements may be all that is needed to provide safe water. In some locations, however, RDI uses clay filters or an ultraviolet (UV) system to treat rainwater before consumption. In addition to installing gutters, pipes, and storage tanks, RDI stresses regular support visits to both new and continuing users to

Many households in Cambodia harvest rainwater in large, concrete drums.

teach them how to use and maintain the system. RDI's domestic system, the Earth Tank, costs US$75[††] and holds 4,200 liters of water.

RWC works in provinces where many families live in small, thatched houses. The roofing material is not suitable for rainwater collection, and the roofs are too low to permit a gravity feed to a storage tank. Therefore, RWC provides assistance to families to build a new, larger roof above or adjacent to their house.[24] A typical 4,000–5,000 liter system for domestic use costs US$200–US$300 and lasts 15 years. Assuming each member of a five-person household consumes 4 liters per day, this works out to a cost of US$0.30-US$0.40 per cubic meter, which is equivalent to US$0.0003–US$0.0004 per liter. By the end of 2006, RWC had installed more than 500 domestic rainwater harvesting systems, as well as larger systems at 9 schools, 9 health centers, and 2 children's homes.

SODIS. The Adventist Development and Relief Agency (ADRA) introduced SODIS to Cambodia in 2004. It promotes SODIS in educational sessions for local authorities and villagers, campaigns, concerts, print materials, and provincial radio. Because the effectiveness of SODIS depends on correct use by families, ADRA provides close monitoring and follow-up. In each village, a community leader serves as a SODIS promoter and supports users. ADRA staff also make regular home visits to users. Maintaining a continuing supply of bottles poses a challenge for the sustainability and expansion of SODIS in Cambodia. ADRA's pilot projects have each involved 1,000–2,000 families. Nearly half (48%) continue to use SODIS regularly, 45% use it irregularly, and 7% do not use the system. When not supported by a strong community program, acceptance drops significantly

Bio-sand filters. A Swiss-based Christian development agency, Hagar, introduced bio-sand filters to Cambodia in 1999. Three years later, several other NGOs also began installing bio-sand filters after receiving training from Hagar. These include Cambodia Global Action, Family Health International, Asian Outreach Cambodia, and World Vision. Field staff conduct outreach education sessions in villages to assess interest in the product. Households that want a bio-sand filter send a family member to a one-day workshop to make the concrete case for the filter. They also contribute 8,000 riels (US$1.91) towards the US$50 cost of the filter. Hagar staff transport the filter to the user's house, install it, conduct monthly education sessions on maintenance, and deal with any problems that arise. They continue to make regular follow-up visits to established users every 3 to 12 months.

RDI recently began testing whether a modified bio-sand filter using iron nails could remove arsenic, which a standard bio-sand filter cannot. Nail-based filters work well for at least a year, but after that the nails may begin to lose their capacity to bind with and remove arsenic, short of the decade lifespan of biosand filters.

[††] The original Cambodia snapshot report gave many costs only in US$. Those figures remain unchanged here. When costs are given in riels, however, the amount in US$ has been recalculated using the current exchange rate of US$1 = 4,173 riels. The rate used in the snapshot report was US$1 = 4,000 riels.

Clay pot filters. International Development Enterprise (IDE) introduced ceramic clay pot filters to Cambodia in 2001.[25] The clay pot filter elements are locally manufactured in a factory run by a skilled women's cooperative, which can produce 3,000 purifiers each month. IDE has also provided technical assistance to the Cambodian Red Cross to establish a second factory, which can produce 1,000 pot filters a month.

IDE distributes its ceramic pot filters through two separate supply chains. A commercial network of over 145 retailers sells the purifier for US$8 to US$10, including an instruction pamphlet and a small scrub brush for cleaning. While the bucket and spigot last for five to six years, the ceramic filter element must be replaced every two years at a cost of US$4. The filters are promoted through television and radio, village and market demonstrations, retailers and sales agents, point-of-sale promotions, and school programs.[26] However, IDE also distributes pot filters through NGOs, which distribute them for free or at a heavily subsidized price in poor rural areas. This has given the filters a reputation as something people can get inexpensively or for free from NGOs, rather than a product that people have to buy from the market. Where IDE's two distribution systems overlap, the private sector cannot compete.

RDI entered the market for clay pot filters in Cambodia in December 2003. It has a factory in Kandal province, where it distributes the filters through NGO partners. RDI introduces the pot filters as part of a broader effort to raise awareness of hygiene and sanitation and encourage behavior change in target communities.

An independent appraisal of IDE's and RDI's programs found that approximately 2% of people using ceramic water purifiers discontinue use of the filters each month, largely due to breakage of the ceramic pot. Households were more likely to continue using the filters if they had paid cash for the purifier, used surface water as their primary source of drinking water, and engaged in related water, sanitation, and hygiene practices in the home.[17] The study recommended: more emphasis on education and behavior change to ensure correct and sustained use, wider availability of spare parts, and selling the purifiers rather than giving them away. Preliminary work on willingness to pay suggests that demand exists and full or partial cost recovery is possible.

UV systems. RDI has trialed UV systems using low-cost fluorescent lamps. Local materials, including steel, plastic, concrete, and clay, are used to construct a UV chamber. The cost per system is US$20. UV systems have several drawbacks for the Cambodian setting: they require electricity, the water must pass through a filter to remove sediment before entering the UV chamber, and the system does not remove arsenic.[27]

Small piped water systems. Several organizations have collaborated with provincial rural development committees and national government ministries to build small-scale piped water systems in 14 communities. The systems treat water with chlorine and slow sand filtration prior to its distribution. They are installed only where there is already a market for private water supplies and where users are willing and able to pay for water. While the price of the water depends on the amount of water produced and the number of

users, existing systems charge 1,700 riels (US$0.41) per cubic meter, or US$0.00041 per liter.

Prospects for Commercial HWTS Products

Commercial markets are growing strongly in Cambodia, and government policy encourages private-sector involvement in the water supply and sanitation sector. Currently, however, commercial activity is limited to selling bottled water to wealthier segments of the population. NGOs have stepped into this gap and tested a wide variety of low-cost HWTS technologies in Cambodia. Their experiences can inform commercial efforts to scale up and market promising technologies.

The majority of families, even in rural areas, boil their drinking water so the idea of treating water is widely accepted. However, little is known about the broader demand for HWTS products and people's willingness to pay for them, because the NGOs have generally:

- Distributed the products for free or at heavily subsidized prices as part of community hygiene and sanitation education programs.
- Introduced them to small pilot areas.
- Not offered families a choice of products.

This makes market assessments essential, and they have since been undertaken to gain a better understanding of the commercial potential for HWTS products.

Efforts to commercialize HWTS products for poor households in Cambodia will also face some important challenges. The success of NGO efforts may have resulted from distributing the products for free and from providing intensive education and continuing support for users—neither of which forms part of a commercial model and may, in fact, inhibit the viability of a commercial model. Demand for HWTS products may be seasonal, reflecting many households' annual shift back and forth to rainwater. There is a need to develop additional technologies that are able to remove arsenic. Alternatively, developing HWTS products that can effectively treat highly contaminated surface water would allow households to avoid arsenic-contaminated ground water. Finally, local HWTS manufacturers currently rely on artisans to produce small quantities. Scaling up production while maintaining quality control will not be easy.

V. Vietnam

Almost three-quarters of Vietnam's 85 million people live in rural areas.[28] Free-market reforms have led to significant economic growth and a decrease in poverty. However, the urban-rural income gap has increased, and there are large regional inequities.[28]

While water resources are plentiful, water is distributed unevenly across the country and over the seasons.[29] Arsenic contamination in the groundwater may pose a significant problem in the Red River Delta around Hanoi and the Mekong Delta.[30,31] In addition, as many as 13 million people may be affected by saline intrusion in coastal and delta areas.[32] There is also considerable waterborne disease in Vietnam. In 2002 diarrheal diseases, including cholera, typhoid, and dysentery, accounted for about one in eleven deaths (9.4%) and 321,100 DALYs lost, or 2.5% of the total DALYs lost.[2]

Sources of drinking water. Nearly three-quarters of urban households have water piped directly into their homes, and 19% have a well. In contrast, 63% of rural households rely on wells, which are also usually located at their homes.[33] However, the national figures obscure important regional differences. For example, there are provinces in the Mekong Delta where more than four-fifths of households rely on surface water for drinking and cooking.[32] Access to clean water sources (defined as private taps, public standpipes, purchased water, drilled wells with pumps, filtered spring water, and rainwater) ranges from less than 20% in the Central Highlands and the North West to 87% in the Red River Delta.[34]

Household water treatment. Boiling is the most common way to treat water: some estimates suggest that as many as 84% of rural households boil water before drinking.[32] Only a small fraction of the overall population regularly filters their drinking water or uses chemical disinfectants.[34] However there are a few provinces in the Red River and Mekong Deltas where filtering is common. There is also a strong tradition of using alum to treat water collected from open waterways in the Mekong Delta. Around 14% of households there also use a secondary treatment method in addition to alum, such as physical filtration, UV radiation, or chlorination.[32]

Stakeholders

Government policies and programs. One goal of the National Rural Clean Water Supply and Sanitation Strategy is to give rural residents access to at least 60 liters per day of clean water that meets national standards for personal and household hygiene use. The water would still need to be treated before drinking. To implement the strategy, the government created two successive five-year National Target Programs on Rural Water Supply and Sanitation. The current program (2006 to 2010) seeks to improve services in rural areas, raise awareness of environmental protection, and minimize the health impacts of poor water supplies, poor sanitation conditions, and pollution.[35] Program activities include the construction and renovation of water supply facilities and information, education, and communication (IEC) efforts.

The government has also established a regulatory framework in recent years. The Ministry of Health issued Drinking Water Quality Standards in 2002 and Hygiene Standards for Clean Water in 2005. In 2006, it issued checklists and guidance to Provincial Medical Centers for monitoring the quality of the water supply. This was followed in 2007 by guidelines on monitoring water in emergency situations and guidelines for government and private enterprises engaged in the production and supply of water.

The Ministry of Agriculture and Rural Development is responsible for ensuring the rural water supply. The Ministry of Health is responsible for rural sanitation, developing and issuing water quality and hygienic latrine standards, and monitoring water quality and hygienic latrines.

NGO and donor involvement. An estimated 70 organizations work on safe water and sanitation in Vietnam, including government departments or ministries, teaching and research institutes, donor agencies and programs, and local and international non-governmental organizations (NGOs). To facilitate communication among these organizations, a Water Supply and Sanitation Working Group was established in 2003.[36,37]

HWTS and Other Water Treatment Products on the Market

Rainwater harvesting. Rainwater harvesting is common in the Mekong Delta, but recent research has raised new concerns about the practice. Researchers have documented an association between uncovered rainwater storage containers, breeding of the *Aedes aegypti* mosquito, and the prevalence of dengue fever in Vietnam.[38] Further investigation is needed on how to mitigate this risk, perhaps by using screens or covers for storage containers.

Alum. Purifying surface water with alum is popular in rural areas of Vietnam, especially in the Mekong Delta and during the flood season. Alum is locally produced and readily available in markets throughout the country at a price of about 1,000 VND (around US$0.06)[‡‡] for 100 g. This amount of alum can purify more than 1,000 liters of water. On average, a family of five in the Mekong Delta uses about 500 g of alum per month, at a cost of US$0.28.

SODIS. Helvetas is introducing SODIS in the Central South Coastal region and Mekong Delta.

Chemical disinfectants. PSI introduced SafeWat disinfectant in the Mekong Delta in November 2005. SafeWat is a locally produced and distributed through a pharmacy company in each province. The project is trying to leverage private commercial markets

[‡‡] The current exchange rate of US$1 = 18,017 Vietnamese Dong (VND) is used to calculate the dollar amounts given here. The exchange rate used in the original snapshot report was US$1 = 16,000 VND.

to make the disinfectant available to lower income households. PSI advertises the disinfectant on television, displays posters in pharmacies, and produces IEC materials for direct selling. While these promotional activities have boosted sales temporarily, sales drop as soon as safe water messaging stops. The price of SafeWat is set at an affordable 4,000 VND (US$0.22) for a 150 ml bottle, which contains enough disinfectant for a family for five to six weeks. The price does not cover the cost of the promotional activities, so the project requires continuing donor support. Through July 2007, PSI sold over 194,000 bottles of SafeWat in Vietnam.

Zuellig Pharma will be responsible for distributing Aquatabs in Vietnam for the manufacturer, Medentech. Zuellig is seeking community-based partners to ensure that the product reaches the poor. Medentech plans to include promotional costs in the price of the product so that sales are sustainable. Estimates are that Aquatabs will be priced at US$0.02 for a tablet that treats 20 liters of water.

During floods and epidemics, affected communities frequently receive free water treatment products on an emergency basis. The Ministry of Health has distributed Chloramine B, while WHO, PSI, and Samaritans' Purse have distributed PuR. PuR is not officially registered in Vietnam and thus cannot yet be imported on a regular basis.

Bio-sand filters. Vietnam's National Institute of Occupational and Environmental Health (NIOEH) has developed and tested a bio-sand filter that uses locally available sand and stone (US$31) together with a pump produced in China (US$19). Users are pleased with the ease of operation and maintenance, as well as the filter's efficiency (T. Toan, unpublished data, 2007). The original NIOEH filter can be used with groundwater that has iron levels under 10 mg per liter. CERWASS, the Rural Clean Water Supply and Sanitation Devision of Vietnam's Ministry of Agriculture and Development, has introduced a similar model for groundwater with higher iron levels.

Samaritans' Purse Vietnam is piloting a bio-sand filter in Han Nam province. Households can build the biosand filtration tank themselves using local materials, but the pipe that carries the water out of the tank is supplied by Samaritans' Purse and costs about 300,000 VND (US$16.65). So far Samaritans' Purse has provided filters to about 5,000 households free of charge.

A local NGO, Water and Environment Fund, is piloting a bio-sand filter on a small scale that can treat arsenic and ammonia contamination. It combines sand filtration with plant filtration (phytofiltration).

Filters. Mineral pot filters imported from China and Korea are available in Vietnamese markets, particularly in cities and large towns. The price ranges from US$10 to $50 depending on the capacity, design, and origin of the filter. These purifiers employ a multistage filtration process to treat water that includes a ceramic filter, active carbon, and an ion exchange resin. Published data on the effectiveness of these products is lacking.

Since 2001 a small private company, Hai Van Co. Ltd, has been producing ceramic water filters in Bat Trang village, a ceramic trading village close to Hanoi. Hai Van produces approximately 15,000 ceramic filter elements each month. A single ceramic candle replacement element sells for approximately 40,000 VND (US$2.22) depending on its size and shape. Hai Van has recently begun producing flat ceramic filter elements on a demonstration basis; these are designed to replace sand and stone layers in filtration tanks.

UV systems. MEDRIX, a Seattle-based NGO, has developed and piloted a UV water treatment system that combines locally made boxes with imported lamps. The estimated total cost of the system is US$30. MEDRIX is interested in commercializing the system and is exploring the feasibility of scaling up manufacture in Vietnam and selling it more widely, initially in the Hanoi area.[39]

Reserve osmosis. Imported reverse osmosis systems are available in the market in large towns and cities. Church World Service is supporting reverse osmosis equipment for schools in Thai Nguyen province.

Prospects for Commercial HWTS Products

The prevalence of boiling and in some areas filtering and disinfecting water suggests that many households are concerned about the quality of their drinking water. Given Vietnam's thriving commercial sector and people's willingness to pay for HWTS products, there is great potential for leveraging market forces to increase access to these technologies. Indeed, families are already paying market prices for alum, ceramic candle filters, and SafeWat disinfectant, all of which are locally produced.

Despite these positive signs, however, overall use of HWTS methods other than boiling remains low. Market assessments are needed to estimate the true size of the potential market for HWTS products, identify the barriers that limit their use, and devise strategies to overcome those barriers.

Efforts to commercialize HWTS products for poor households in Vietnam will face certain challenges. Cost is an issue, especially in rural areas. Poor families generally cannot afford to use durable HWTS products. While consumable water treatment solutions are less expensive, poor families sometimes can only afford to use them during flood season. In addition, consumables are not widely available or promoted. The Mekong Delta, where people rely heavily on surface water, may need different HWTS products than the rest of the country. The SafeWat social marketing project demonstrates the need for ongoing education regarding safe water and the promotion of HWTS products. It may be difficult for commercial firms to set prices high enough to cover the cost of this kind of advertising. Finally, scaling up production of the many HWTS solutions produced locally on a small scale—such as the MEDRIX UV system, Hai Van's ceramic water filters, and some of the bio-sand filters—may be challenging, especially while maintaining quality control.

VI. Discussion and conclusions

Water is local. Important differences exist within as well as among countries. Water quality problems, such as arsenic contamination, guinea worm, and excess turbidity, tend to affect some but not all regions of a country. Likewise, rural residents have different HWTS needs than city dwellers because they tend to rely on wells and surface sources rather than piped water systems and also because their incomes are lower. Hence businesses entering the HWTS market must be prepared to vary their products and technologies, promotional strategies, and price points to meet the needs of different regions and market segments within as well as between countries.

Demand may be seasonal. In all four countries studied, water sources and water quality shift from wet to dry seasons. Households may only perceive a need to treat their water when conditions are at their worst, for example, during the dry season in northern Ghana or during seasonal flooding in the Mekong Delta.

Experience with HWTS is limited. People in all four countries generally appreciate the need to treat their water, but they know little about alternative technologies. Most households in Tanzania and Cambodia are only familiar with boiling, rural people in Vietnam generally know about boiling and alum, and most people in northern Ghana only know about cloth filters and alum. Of these three, only alum is a commercial product. This makes it difficult to ascertain whether and how much people are willing to pay for what type of products.

Commercial HWTS markets are still relatively early in their development, in general**.** The most advanced HWTS market exists in Vietnam, where local manufacturers already produce and sell ceramic filters and disinfectant, and others are planning to commercialize Aquatabs and UV systems. In Ghana and Cambodia, organizations have introduced a wide variety of HWTS technologies, but most operate on a small scale or are still in the planning stages. Few earn a profit. In Dar es Salaam, few HWTS products seem to be widely or consistently offered for sale. The limited development of the market may make it difficult to identify viable commercial partners.

Cost and affordability are important issues everywhere. Cost forms a barrier to home water treatment in all four countries. But if companies set their prices too low in an effort to reach the poor, they will not be profitable. Many current HWTS ventures in these countries do not recover production and distribution costs—let alone the cost of the intensive education and continuing promotion they rely upon to create and sustain demand. However, IDE's experience in Cambodia demonstrates that commercial distribution is feasible and can even increase continuation rates.

Scaling up small pilot projects may be difficult. Current pilot projects will have to overcome several constraints if they are to scale up. On the production side, local manufacturers in Cambodia and Vietnam rely on artisans who produce in small quantities. Increasing production while maintaining quality control will be a challenge. The lack of a supply chain for replacement parts and repairs is also a problem. On the

demand side, most pilots distribute products for free or at heavily subsidized prices. They also provide intensive education and ongoing support to users, including regular home visits. This is not a viable commercial model.

More remains to be learned. The snapshot reports collected a quick, but incomplete, sketch of the HWTS situation in these four countries. To flesh out the picture, further information is needed on a wide array of topics and issues related to the commercialization of HWTS products, including:

- The preferred attributes of drinking water, the priority households assign to safe water, and the need and prospects for safe storage vessels.
- The availability of credit (from microfinance institutions, self-help groups, local merchants, and the like) and its impact on the affordability of HWTS products.
- Consumer preferences and their willingness to pay and potential demand for HWTS products (although recent research by the Safe Water Project, in collaboration with MIT in Ghana and RTI in India, may help fill this gap).
- Sales models and supply chains for HWTS and similar products, including the factors affecting product distribution networks, such as population distribution, distances to suppliers, roads, and infrastructure.
- Current health education and promotional efforts related to safe water and HWTS products, whether conducted by government, NGOs, manufacturers, or retailers; along with the reach of mass media and other communication channels.

Market assessments and additional research are already underway to supply some of this information.

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VIII. References

[1] Peletz R. *Cross-Sectional Epidemiological Study on Water and Sanitation Practices in the Northern Region, Ghana* [masters thesis]. Massachusetts Institute of Technology (MIT); 2006.

[2] Prüss-Üstün A, Bos R, Gore F, Bartram J. *Safer Water, Better Health Costs, Benefits and Sustainability of Interventions to Protect and Promote Health.* Geneva: World Health Organization (WHO); 2008.

[3] Ghana Statistical Service (GSS), Noguchi Memorial Institute for Medical Research (NMIMR), ORC Macro. *Ghana Demographic and Health Survey 2003*. Calverton, Maryland: GSS, NMIMR, and ORC Macro. 2004.

[4] Forson M. Counting the numbers: a water & sanitation sector challenge. Presented at: MOLE XVI Conference, 7-14 June 2005; Kumasi. Ghana: UNICEF. 2005.

[5] Okioga T. *Water Quality and Business Aspects of Sachet-Vended Water in Tamale, Ghana* [master's thesis]. MIT: Cambridge, MA; 2007.

[6] Green V, Murcott S. *Household Water Treatment and Safe Storage Options for Northern Region Ghana: Consumer Preference and Relative Cost, Draft.* MIT: Cambridge, MA; 2007.

[7] Swanton A, Murcott S. *Combined Kosim Filter and Aquatabs Treatment System in Northern Region, Ghana, Draft.* Cambridge, MA: MIT; 2008.

[8] Aikhomu SE, Brieger WR, Kale OO. Acceptance and use of communal filtration units in guinea worm eradication. *Tropical Medicine and International Health.* 2000;5(1):47–52.

[9] Murcott S, Green V, Swanton A, Fitzpartick C. *Executive Summary of Key Activities and Learnings Consumer Preference and Technology Assessments: Key Activities and Learnings on Household Water Treatment and Safe Storage in Ghana.* Cambridge, MA: Massachusetts Institute of Technology (MIT); 2008.

[10] The World Bank, African Development Bank. *Millennium Development Goals (MDGs) for Water and Sanitation: Country Assessment: Ghana Report.* Washington, DC: The World Bank; 2004.

[11] 2002 population and housing census page. Official Online Gateway of the United Republic of Tanzania website. Available at: http://www.tanzania.go.tz/census/. Accessed March 27, 2008.

[12] The world's fastest growing cities and urban areas from 2006 to 2020 page. City Mayors website. Available at: http://www.citymayors.com/statistics/urban_growth1.html. Accessed March 27, 2008.

[13] Ijumba JN. Water-borne and water-related diseases in Tanzania. Presented at: Achieving Sustainable Access to Clean Water in Tanzania: Impact on Human Health, February 27, 2008; Stonybrook, New York.

[14] National Bureau of Statistics (NBS)[Tanzania], ORC Macro. *Tanzania Demographic and Health Survey 2004-05*. Dar es Salaam, Tanzania: National Bureau of Statistics and ORC Macro. 2005.

[15] Kironde JML. Access to land by the urban poor in Tanzania: some findings from Dar es Salaam. *Environment and Urbanization.* 1995;7(1):77–96.

[16] Population Reference Bureau (PRB). *2006 World Population Data Sheet.* Washington, DC: PRB; 2006.
[17] Brown J, Sobsey M. *Independent Appraisal of Ceramic Water Filtration Interventions in Cambodia, Final Report.* Chapel Hill, NC: University of North Carolina School of Public Health; 2006.
[18] Cambodia National Institute of Public Health (NIPH), Cambodia National Institute of Statistics (NIS), ORC Macro. *Cambodia Demographic and Health Survey 2005.* Phnom Penh, Cambodia and Calverton, Maryland: Cambodia NIPH, Cambodia NIS, and ORC Macro; 2006.
[19] USAID. Request for Applications USAID-Cambodia-442-08-005-RFA. Reproductive Health. Geneva: 2008. Available at: http://kenya.usaid.gov/kh/documents/Cambodia_RFA_442-08-005.pdf. Accessed May 6, 2009.
[20] Cambodia Ministry of Industry Mines and Energy (MIME). *Drinking Water Quality Standards.* Phnom Penh, Cambodia: MIME; 2004.
[21] United Kingdom Department for International Development (DFID). Review of Cambodia's rural water supply and sanitation sector. London: OPM. 2006.
[22] Ockelford J. *Cambodia Rural Water Supply and Sanitation Sector Review, Final Report.* London: Oxford Policy Management; 2006.
[23] Press Release 299 page. USAID website. Available at: http://www.usaid.gov/rdma/articles/press_release_299.html. Accessed April 24, 2009.
[24] McLennan L. *Rain Water Harvesting in Cambodia—the Approach of Rain Water in Cambodia.* Phnom Penh, Cambodia: Rain Water Cambodia; 2008.
[25] International Development Enterprises (IDE). IDE CWP NGO partnership [brochure]. Lakewood, CO: IDE. 2008.
[26] International Development Enterprises (IDE). IDE CWP NGO partnership [brochure]. Lakewood, CO: IDE. 2008.
[27] Samson M. *Overview of UV System in Cambodia.* Coventry, UK: Resource Development International (RDI); 2008.
[28] Vietnam page. Population Reference Bureau (PRB) website. Available at: http://www.prb.org/Countries/Vietnam.aspx. Accessed March 27, 2008.
[29] Water environment fund. *Environment and Life Magazine.* 2006;1.
[30] Berg M. Arsenic in drinking water: Vietnam, new focus of attention. *EAWAG News.* 2002;53:12–14.
[31] Berg M, Stengel C, Pham TK, et al. Magnitude of arsenic pollution in the Mekong and Red River Deltas—Cambodia and Vietnam. *The Science of the Total Environment.* 2007;372(2-3):413–425.
[32] Soussan J, Nha NT, Patrick KJ, et al. *Joint GoVDonor Sector Review Rural Water Supply, Sanitation and Health in Viet Nam Sector Status Report.* Hanoi, Vietnam: Asian Development Bank (ADB); 2005.
[33] Committee for Population, Family, and Children Vietnam, ORC Macro. *Vietnam Demographic and Health Survey 2002.* Calverton, Maryland, USA: Committee for Population, Family and Children and ORC Macro; 2003.
[34] Vietnam General Statistics Officer. *Result of the Survey on Household Living Standards 2004.* Hanoi, Vietnam: Statistical Publishing House; 2006.

[35] Socialist Republic of Vietnam. *National Target Program for Rural Water Supply and Sanitation (2006 - 2010).* Hanoi, Vietnam: Socialist Republic of Vietnam; 2006.
[36] Water supply and sanitation working group terms of references page. Vietnam Union of Friendship Organisations Nongovernmental Organizations (VUFO-NGO) Resource Centre website. Available at: http://www.ngocentre.org.vn/book/export/html/139. Accessed March 28, 2008.
[37] VUFO-NGO Resource Centre, The Water Supply and Sanitation (WSS) Working Group. *Water and Sanitation Sector Reference Document Overview of Organizations in Vietnam Assisting Water Supply, Sanitation and Hygiene Promotion.* Hanoi, Vietnam: VUFO-NGO Resource Centre; 2007.
[38] Queensland Institute of Medical Research. Mosquito control. 2008.
[39] Tivoli L, Lefthand C, McLaughlin L, Catherman R. UV disinfection of drinking water for the Vietnamese household: scale-up strategy for MEDRIX Vietnam. Woodinville, WA, and Hanoi, Vietnam: MEDRIX. 2007.

For more information

PATH
MAILING ADDRESS
PO Box 900922
Seattle, WA 98109, USA

STREET ADDRESS
2201 Westlake Ave., Suite 200
Seattle, WA 98121, USA
206.285.3500
info@path.org
www.path.org

To learn more about global water resources:
http://www.path.org/projects/safe_water.php