Implementation, Critical Factors and Challenges to Scale-Up of Household Drinking Water Treatment and Safe Storage Systems

Background Paper on
Household Water Treatment and Safe Storage (HWTS)
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Summary

This paper explores the current status of the adoption and sustained use of household drinking water treatment and safe storage systems, the critical factors that influence adoption and sustained use and the associated challenges to scale-up.

This paper is a DRAFT and will be revised based on comments and insights gained from the May 12 – 22, 2006 e-conference on HWTS. We welcome your input!

Table of Contents

<u>Appendices</u>

<u>Figures</u>

<u>Tables</u>

Section I – Context, Definitions and Status of HWTS

1. Introduction

Household drinking water treatment and safe storage systems comprise a cluster of innovative technologies that have come into existence since the 1990s. As a part of a class of social technologies to end poverty, these technologies have a number of powerful and appealing characteristics—they are simple, self-reliant, local, user-friendly and low-cost—suggesting that they could help solve the intransigent problem of safe, clean water for all. If they do make a contribution to the goal of global safe water, they will do so because they empower users, especially women and children, who bear a disproportionate burden of the unsafe drinking water crisis. Like the 20th century search for a polio vaccine or the 21st century search for a cure for HIV/AIDS or cancer, the motivation driving HWTS research and development is a search for a common, social good, and an instatement of a basic human right. However, as a solution that necessitates household-by-household adoption and sustained use, a commercial, bottom-line objective is also essential. Yet, if commercial products, such as computers, cell phones or Internet use can "go exponential," then practical actors and dreamers alike may also inquire: "Can safe, clean water and the associated clean water technologies also be taken to scale?" If the answer is "Yes," HWTS will be part of the mix.

2. Diffusion of Social Technology Innovations and Technologies to End Poverty

Diffusion is the process by which an innovation is "communicated through certain channels over time among members of a social system." Diffusion of an innovation is a two-way exchange, a communication process. Technology, correctly understood, is not only hardware—the tool that embodies the material or physical object—but "matter and energy" / "hardware and software" (Rogers, 2003), so in this respect, technology and its diffusion are intimately linked to communication. Social technology innovations are innovations whose primary aim is a social, common-good objective, with a financial or profit objective as a subsidiary or parallel aim. Technologies to end poverty are a subset of social technology innovations targeted at bringing a basic level of well-being to the 4.8 billion people earning $1/day (20% global population) to $2/day (60% global population). HWTS social technologies are innovative not only in the conventional sense of "new hardware," but they incorporate hardware and software, and seek to realize a global social objective of clean water for all.

New technologies have three dissemination levels: knowledge, use[1] and commercialization. Conventionally, these stages are:

> Needs/Problem Identification → Research and Development → Commercialization → Diffusion and Adoption → Consequences

[1] The term "use" means both adoption (short-term or daily use) and sustained use (long-term use for one year or more). Adoption, sustained use and related terms are discussed more fully in Section 11 – Social Behavioral Factors and Section 16 – Monitoring and Evaluation.

An interesting characteristic of the HWTS technologies cluster is that adoption and sustained use have frequently occurred in advance of widespread commercialization. One reason is because technology transfer involves a communication process (the software side) that travels faster than physical hardware. Another reason is because the commercial side is not guaranteed—the market for HWTS products includes the very poor people. While those who earn $1/day or $2/day have enormous purchasing power as a group, their demand for HWTS is not guaranteed because of a paucity of funds on the individual level. Fortunately, the market for HWTS also includes the travel and tourism industry, the disaster relief industry, militaries, allied agencies and their clients. In fact, these markets, together with middle class markets in India, China and other developing countries, may provide the biggest opportunities for HWTS products and services, potentially also capable of subsidizing/creating incentives for purchases by the poor depending on how programs are structured and implemented.

3. Water Quality, "Safe" Drinking Water and Water Treatment and Storage

A short introduction to water quality and safety helps set the context. Water quality can be defined by three broad categories—microbiological, chemical and physical/aesthetic attributes, as shown in Figure 1. Safe drinking water, as defined by the World Health Organization *Guidelines for Drinking Water Quality*, does not represent "any significant risk to health over the lifetime of consumption, including different sensitivities that may occur between life stages."

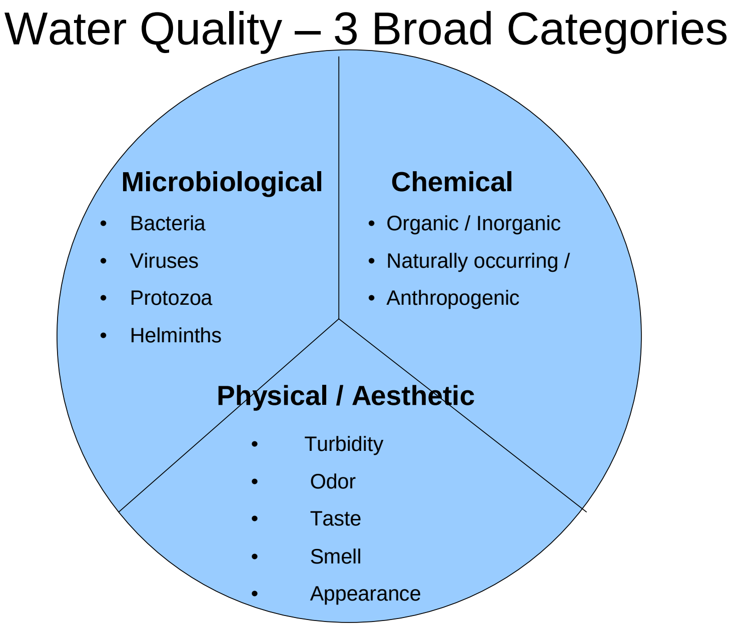

Figure 1: Three Broad Water Quality Categories

Microbiological and chemical waterborne contaminants are those potentially most likely to affect human health. Microbiological contaminants can have immediate effects on human health by causing infectious diseases, such as diarrhea. Diarrhea kills an estimated 1.8 million people each year and is the third leading cause of death among infectious diseases after respiratory infections and HIV/AIDS. It ranks ahead of tuberculosis and malaria (WHO, 2005). As stated in the WHO Guidelines: "Infectious diseases caused by pathogenic bacteria, viruses, protozoa and helminths [worms] are the most common and widespread health risk associated with drinking water" (WHO, 2004). Chemical contaminants, in contrast, tend to have human health impacts that manifest over longer time periods, perhaps years or decades. The physical/aesthetic characteristics of water are very important from a consumer's point of view insofar as they determine patterns of behavior/use, but they are secondary from a human health point of view.

HWTS systems are designed to address water contaminants in one or some of these three broad categories. HWTS innovations have principally focused on microbiological contaminants because infectious waterborne diseases, as indicated above, are the single most important class of water quality concerns globally. This paper reports on HWTS systems that have explicitly been designed to address microbiological contamination. Meanwhile, even as research continues to push the frontier and to explore systems that do it all, no single HWTS technology is or will ever probably be a perfect solution. Rather, each system will likely always have its advantages and limitations.

4. Piped and Non-Piped Water Supply and Distribution Systems, Transmission Routes for Contaminants and a Multiple Barrier Approach

For the purposes of global data collection and monitoring, the UNICEF/WHO Joint Monitoring Programme maintains national and global datasets of "improved" and "unimproved" water supplies, as shown in Table 1[2].

Table 1: WHO/UNICEF Joint Monitoring Definition of Improved Water Supply

Improved	**Unimproved**
* Household connection	* Unprotected well
* Public standpipe	* Unprotected spring
* Borehole	* Vendor provided water
* Protected dug well	* Tanker truck water
* Protected spring	
* Rainwater collection	

Another way of conceptualizing water supply is in terms of piped vs. non-piped systems, as shown in Figure 2.

[2] Improved vs. Safe: WHO/UNICEF indicates that improved sources are those that are likely to provide safe water such as household connections, boreholes, etc. Unfortunately, the information currently available does not allow us to establish the relationship between access to safe water and access to improved sources. WHO and UNICEF are currently working to demonstrate this relationship.

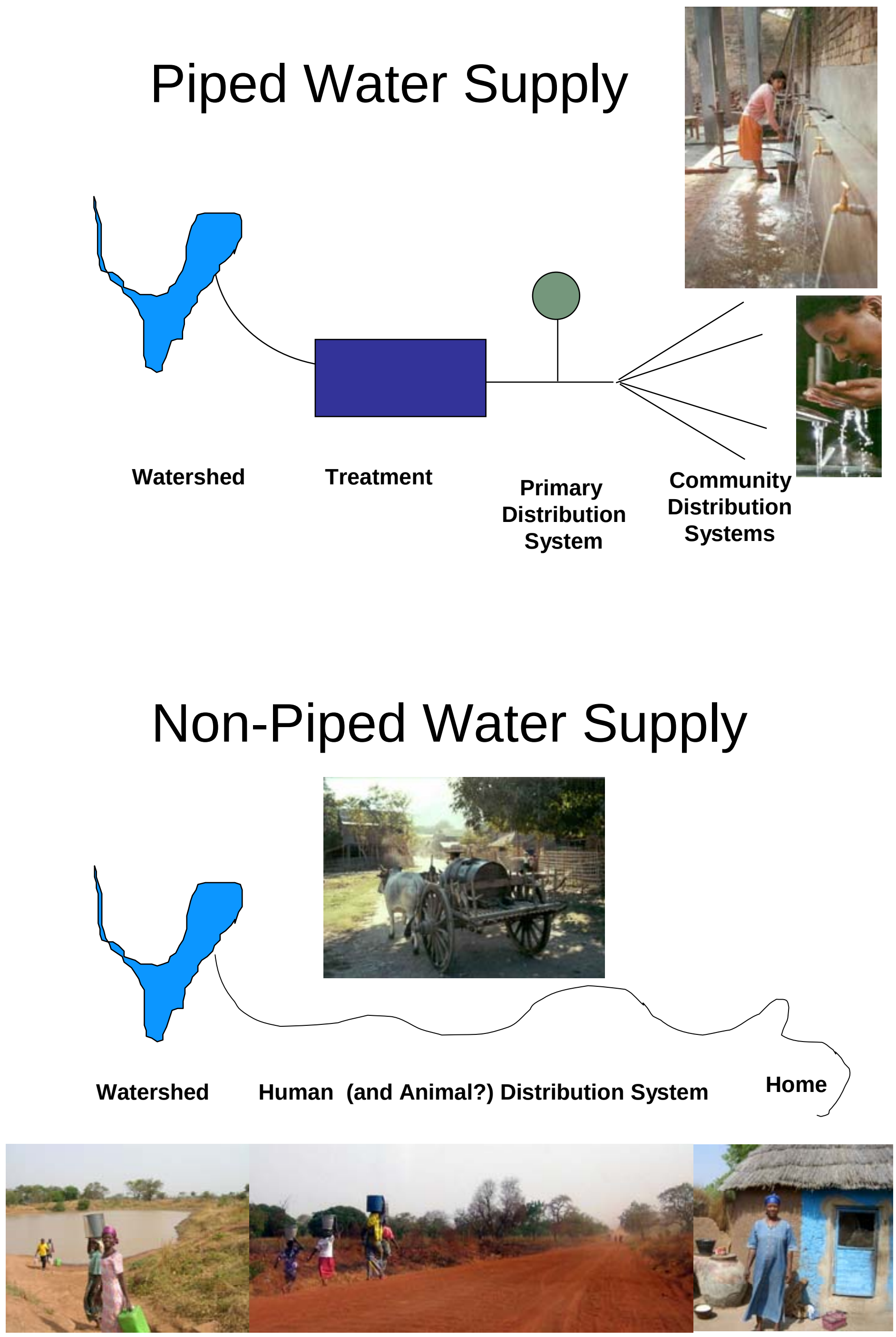

Figure 2: Piped and Non-Piped Water Supply

Water supply begins with rainwater, which is accessed directly via rainwater harvesting or indirectly either from surface water sources such as lakes, rivers or streams or from groundwater sources. A piped supply, as shown in Figure 2, typically takes water from the source, puts it through a distribution system that involves some form of treatment, and then distributes it to public stand-pipes or household taps. A non-piped water supply takes water from the source via a human-mediated transport system, either carried manually or conveyed by some kind of vehicle such as an animal cart, a bike or a tanker truck to the home.

Water and public health professionals do not think in terms of a single public health barrier to microbiologically contaminated drinking water, but of a “multiple barriers approach.” Barriers that protect microbiological water quality can occur in each of these stages:

- Watershed (source) protection
- Treatment: centralized and decentralized
- Piped distribution: safe distribution to the public stand-pipe or home compound
- Non-piped, community and household distribution: safe transport from the source to the point-of-use
- Safe storage: reservoirs, community and home storage

As expressed in the WHO *Guidelines for Drinking Water Quality* (2004):

Securing the microbial safety of drinking water supplies is based on the use of multiple barriers, from catchment to consumer, to prevent the contamination of drinking water and to reduce contamination to levels not injurious to health. Safety is increased if multiple barriers are in place, including protection of water resources, proper selection and operation of a series of treatment steps and management of distribution systems (piped or otherwise).

The drinking water source or water exiting a treatment plant may provide a safe and potentially disinfected supply, but water may become re-contaminated through distribution and storage, if it is touched by unclean hands, dirty cups or dippers or if it is held in contaminated or uncovered storage vessels. Safe household water management means maintaining or improving the microbiological quality of the water through collecting, distributing/transporting and storing in the home. In this context, HWTS offers a new protection barrier.

5. HWTS Technologies

Safe household water management to protect against microbiological contamination begins with safe storage. Safe storage is defined as a standard-sized container with (1) a narrow mouth or opening, (2) a lid and (3) a tap to access to the stored water and to prevent contact with hands, cups or dippers. Some studies have shown the benefit of water storage containers possessing these design characteristics. Yet other factors, such as storage time, water temperature, airborne particulate concentrations, inadequate hand washing and food preparation using stored water may also contribute to unsafe water in the home.

Disinfection is "the deliberate destruction or inactivation of disease-causing microorganisms." A frontal attack approach to disinfection is to destroy or inactivate the microbes, which can be accomplished by applying one of the following disinfection methods:

- Chemical: chlorine and chlorine compounds, ozone, iodine, certain metals (e.g. silver and copper)
- Physical
    - UV light
    - Heat (boiling, pasteurization)

    - High pH
- Exposure to electromagnetic, acoustic or particle radiation

However, a deeper, theoretical understanding recognizes that microbes attach to particles in water. Thus to eliminate microbes, the first step is to remove particles. Particles are commonly measured as turbidity. While turbidity is listed as a physical or aesthetic characteristic in Figure 1 and not as being inherently harmful to health, particles are essentially food and shelter for microbes. Therefore, if water is clear with few or no particles, it may be rendered microbially safe when treated solely by a disinfection step. Many water supplies, especially those from surface water sources, should include a particle removal step plus a disinfection step to be safe microbially.

One other important factor is that some microorganisms, such as *cryptosporidium, giardia, vibrio cholera* and guinea worm, have high resistance to conventional chemical disinfectants, such as chlorine, but are removed or reduced by filtration and coagulation-flocculation, which are the two most common particle removal processes. These processes, whose principle objective is particle removal, can also be considered a disinfection method in the broadest sense.

With this household water management, water quality and treatment background in mind, the cluster of HWTS systems that are the focus of this paper, i.e. those HWTS systems that address microbial water contamination, are categorized as follows:

Safe Storage
- Safe storage containers (standard size container with a narrow mouth or opening, lid and tap to access water)

Disinfection-Only Technologies
These processes destroy or inactivate many, but not all, pathogens:
- Boiling
- Household chlorination and safe storage
- Solar disinfection (SODIS)
- Ultraviolet (UV) lamp

Particle Removal Technologies
These processes remove particles and may (or may not) remove certain microbes:
- Cloth filtration
- Ceramic filters
    - Candle filters
    - Potters for Peace filtron-type "pot" filters
- Biosand filters
- Coagulation/precipitation only

Adsorption
- Charcoal
- Hybrid adsorption with carbon
- Resin-based

Membrane Processes

- Membrane
- Reverse osmosis

Whereas particle filtration involves micro-sized particles, membrane processes include microfiltration, ultrafiltration, reverse osmosis and nanofiltration at macromolecular and ionic size ranges. State-of-the-art membrane systems are common in developed country applications, both in treatment plants and in point-of-use/point-of-entry home systems. Some technologies are being applied commercially in developing countries.

Two or Three Processes Combined (Hybrid) Systems (Particle Removal + Disinfection + Aesthetics)

Combining particle removal with microbe destruction or inactivation accomplishes multiple objectives.

- Coagulation/flocculation + disinfection (e.g. PUR)
- Filtration + chlorine disinfection + aesthetics (e.g. Gift of Water – Haiti)
- Filtration + disinfection + aesthetics (e.g. Pure-It – Hindustan Lever)

A fact sheet has been developed for each individual technology categorized above (see Appendix 1) that provides general information about the technology for educators and promoters, users and the general public.

6. Status of Implementation of Major HWTS

General Overview

A wide range of HWTS options exists, and this paper intentionally focuses only on those HWTS applications that are beyond early stage research, development and small-scale pilot applications. These are called here, major HWTS, and have been:

- Communicated to key social groups and networks—lead users, opinion leaders, water health professionals, others and applied in daily practice by users affected by potentially unsafe drinking water and associated waterborne diseases

  and/or
- Implemented in multiple countries

  and/or
- Attained some level of commercialization

A generalized picture of major HWTS implementation is illustrated schematically in Figure 3:

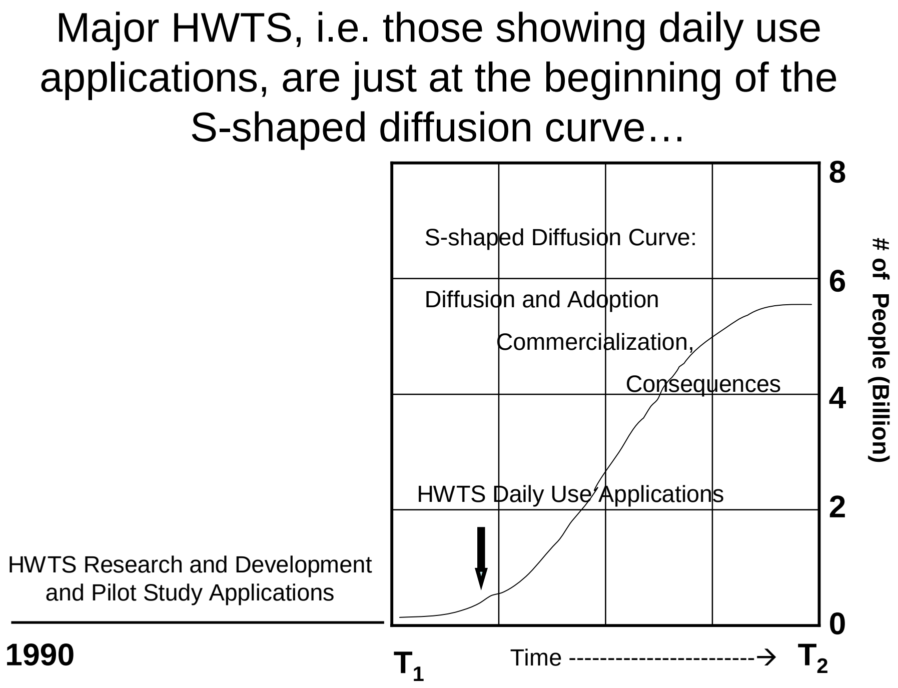

Figure 3: Generalized Schematic of the Status of Implementation of Major HWTS

Although isolated research, development and applications of HWTS as a solution for contaminated drinking water in developing countries existed prior to the 1990s, Figure 3 shows that HWTS research and development and pilot HWTS applications started during the 1990s. Pioneering work included the studies and implementation programs of the Centers for Disease Control / Pan American Health Organization (household chlorination), the Swiss Technical Institute-EAWAG (SODIS), Potters for Peace-Nicaragua (ceramic filtration), University of Calgary (Biosand), Proctor and Gamble (PUR) and others. The time represented by "T1" is about AD 2000, roughly concurrent with the declaration of the United Nations Millennium Development Goals. Starting at "T1", major HWTS begin daily use applications. The curve represented on the right half of Figure 3 is a generalized curve showing how innovations diffuse generally. If HWTS diffusion follows this generalized pattern, the number of units will increase dramatically, and billions of people will adopt and make appropriate, daily use of such systems. Figure 3 shows a hypothetical 5+ billion people with HWTS at time "T2."

Given that most of these technologies are no more than 10-20 years old, most implementation efforts have occurred for 10 years or less. The extent of dissemination is praiseworthy but has barely scratched the surface in terms of need (one to many billions of people, depending on whose estimate you use), and it has not achieved anything like computer, cell phone or Internet use proportions.[3] Regarding present status, the extent of major HWTS application is wide (53 countries) but not deep (low percentage coverage) relative to the total population in need of safe drinking water.

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[3] For purpose of comparing HWTS diffusion to cell phone diffusion, cell phones were first offered to American consumers in 1983. In the first decade, 130 million were sold. During the second decade, 1.1 billion were sold worldwide. (Rogers, E., 2003. p. 259)

Our best knowledge of major HWTS implementation comes from two sources:

1. A 2005 survey[4] conducted by the Implementation Working Group of the WHO International Network to Promote Household Drinking Water Treatment and Safe Storage (the "Network").
2. Commercial Companies Implementing HWTS, based on information available on the Web and other published sources.

WHO Network Implementation Working Group Survey

The WHO Network, founded in 2003, is the largest public-private partnership focused on HWTS applications. More than 85 organizations are currently affiliated with the Network, representing the following sectors:

- NGOs: 30 percent
- Private sector / commercial: 20 percent
- Public sector / government: 10 percent
- International organizations: 10 percent
- Academic institutions: 17 percent
- Professional associations: 8 percent
- Religious organizations: 5 percent

A 2005 survey provided on the WHO Network's website invited responses from organizations implementing HWTS. To date, 39 implementing organizations, from the various sectors shown in Figure 4, have replied.

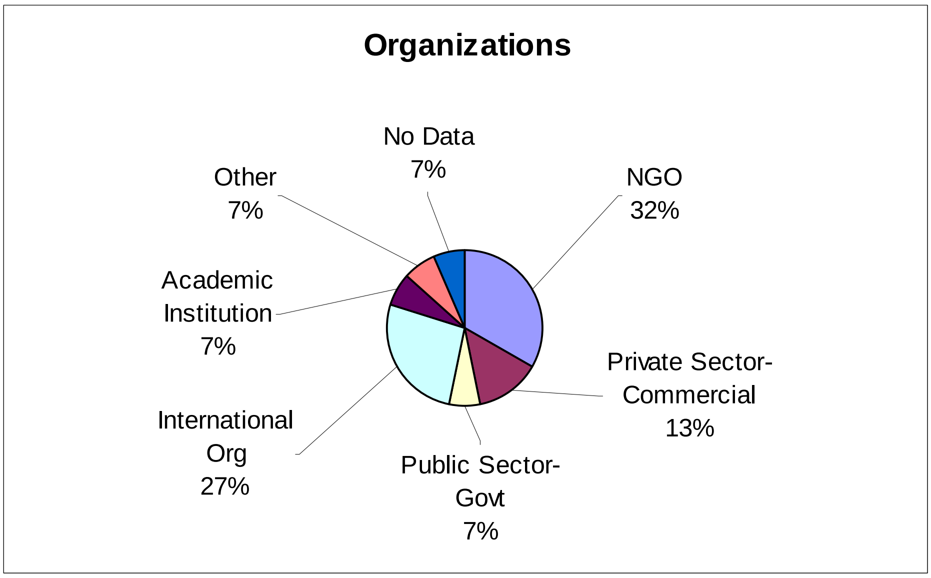

Figure 4: Sectors Represented by the Organizations Responding to the 2005 WHO Network Implementation Working Group Survey

[4] http://www.who.int/household_water/implementation/en

This survey shows the extent of HWTS coverage by major technologies, countries of implementation and estimated number of beneficiaries:

- Eight different major HWTS technologies are represented: safe storage, boiling, household chlorination, solar disinfection, two different types of ceramic filters – candle filters and pot filters, biosand filters and combined systems, including coagulation + chlorine disinfection and filtration + disinfection. (See global maps and HWTS Fact Sheets in Appendix 1).
- The 53 HWTS implementation countries are: Afghanistan, Argentina, Bangladesh, Benin, Bhutan, Bolivia, Brazil, Burkina Faso, Cambodia, Cameroon, Columbia, Congo, Dominican Republic, Ecuador, El Salvador, Ethiopia, Ghana, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, India, Indonesia, Kenya, Lao People's Democratic Republic, Madagascar, Malawi, Mali, Mexico, Mozambique, Myanmar, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Peru, Philippines, Rwanda, Senegal, Sierra Leone, South Africa, Sri Lanka, Thailand, Togo, Uganda, United Republic of Tanzania, Uzbekistan, Vietnam, Zambia and Zimbabwe.
- About six million individual beneficiaries. (Note: many respondents did not provide numbers of beneficiaries, and so this number is a low estimate.)

Global maps illustrate the the extent of implementation. Based on the WHO survey responses, these maps show the global implementation of HWTS according to specific technology, according to the number of beneficiaries, and according to the number of technologies or projects per country.

Financing an implementation method can be done, broadly speaking, in three ways:
1. Charitable donations (partly or wholly subsidized)
2. Cost-recovery, where the product is sold for profit or at breakeven, but where an organization provides subsidies that cover part of the costs, such as promotion, staff salaries, etc.
3. Commercially, in a "for-profit" enterprise

These financing approaches reflect how different organizations that participated in the survey implement HWTS schemes. As shown in Figure 5, of the 34 survey respondents, 35 percent were engaged in commercially marketing their HWTS product, most of whom (65 percent) used social marketing methods. Additionally, 50 percent used a charitable model. (NB: The survey allowed the respondent to check multiple boxes, and therefore individual organizations could indicate multiple methods of implementation.)

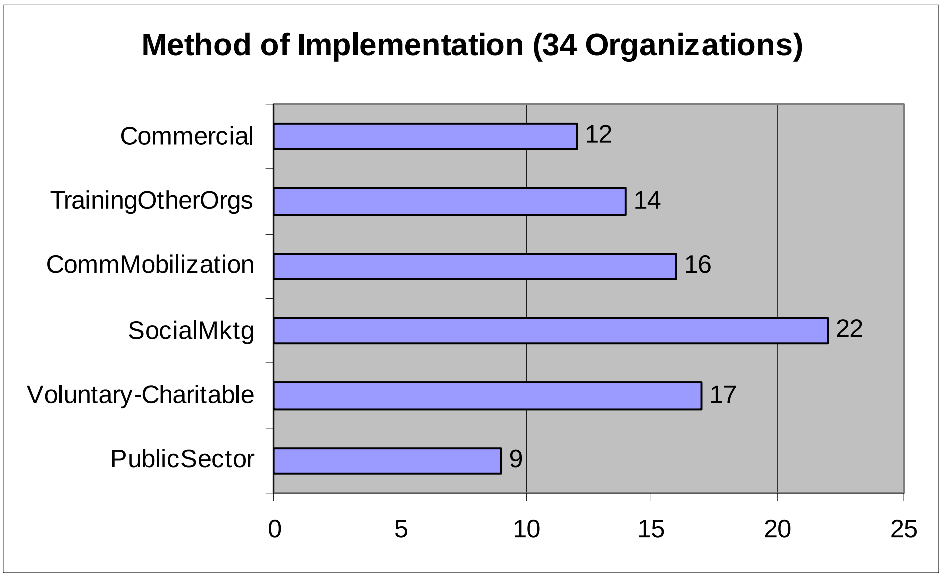

Figure 5: Method of HWTS Implementation (n=34 organizations)

Worldwide Commercial HWTS Enterprises[5]

The global production of commercial HWTS units (exclusive of Canadian, European, UK and US companies, except where their major markets are in the developing world) is briefly described in the section below. For further information, the reader is referred to the accompanying Worldwide Commercial HWTS Enterprises Summary Table, given as Appendix 2.

Household Chlorination

Several technologies are closely related: 1) adding liquid solution or powdered/granule chlorine to water or 2) adding chlorine tablets. Household chlorination is being marketed by six companies, including three from India (Aquatech Dosing Systems, Crompton Greaves Familigard and Get Water Solutions Chlorination), one from S. Korea (Keosan's KISS 2000) and one from Ireland (Medentech Aquatabs), and one from the USA (Arch Chemicals). These are less expensive than Proctor and Gamble's PUR (see below) and average about $.25 per sachet. In general, these companies lack the commitment P&G has made to social marketing, but their efforts are still considerable.

Ultraviolet (UV) Disinfection

The commercial UV market breaks into roughly four sectors according to price. The least expensive model involves a single UV light source plus transformer and electric cord which together sells at retail for $10 – $25. It presumes the end-user has an appropriate storage container and an electricity source. Only one company currently produces a unit for this market,

[5] The author wishes to acknowledge the technical and editorial assistance of Klaas van de Ven in reviewing this section; Basic Water Needs Foundation, Prins Hendrikstraat 31 6828 GN Arnhem, the Netherlands E-mail watersafe@hetnet.nl

Zhejiang Purimate Water Technologies Model DP208 (China) for $10. Zhejiang is prepared to produce 5,000 units per month with a minimum wholesale purchase of 50 units; this product has been ISO 9001 certified.

The next lowest priced UV units range from $50 – $100. Four Indian companies have products in this range: Ace Hygiene UV Pureflow 3 Stage for $92, Kenstar Inellibloc for $93, Moniba for $87 and Usha Brita for $71. Usha Brita is an interesting product because although it is manufactured in India.

The third price range from $101 – $150 includes the following companies from India: Ace Hygiene UV, Aquagruard I Nova Classic, Bajaj Electricals (UV Plus), Eureka Forbes (Aqua Flo, Aqua Guard Classic, Aqua Guard Classic Compact, Aqua Flo Designs), Kenstar (WP9703) , Konark Waterdoc (UVXL), Moniba Anand (UV Storage Purifier models), Simfony (Big Flat #1), Usha Brita (Waterguard Digital); one from Brazil, M&M; and one from the USA, Water Health International (household model).

The fourth price range from $151 – $200 is supplied by the following Indian companies: Alfaa (E Water 3 Stages, Compact), Eureka Forbes (Aqua Guard Classic Compact, Pump, Booster), Usha Brita (Waterguard Digital). Hanovia UV of England probably also fits into this price range.

The fifth price range is for elite or commercial use and only has four identified suppliers: Konark Unique, Moniba Anand (Online Purifier cum Cooler "n" Heater, 562) and Water Health International (Commercial System).

From this partial assessment of pricing structures (all prices of all manufacturers were not ascertained), the data suggests that the $101 – $150 and $150 – $200 price ranges are the most targeted markets at present. The ranges below these may represent real business opportunities.

Particle Removal

In terms of particle removal processes, the following commercial technologies exist:

- Ceramic filters (pore size between 0.2 and 1 micron): remove bacteria and protozoa; little or no virus removal without modification of current systems
- Sand filtration: well-designed models remove bacteria and parasites
- Ultra-filtration (pore size about 0.02 microns): removes bacteria, protozoa, parasites and viruses

Cloth removal technology is probably under-represented with only one company (Sinolink from China) that produces a cloth filter with activated carbon.

Ceramic candle filters are by far the largest product in this field. Countries and number of companies indicate level of commercial activity: Bolivia (1), Brazil (2), China (24), India (9), Malaysia (1), Pakistan (1), Poland (1), Portugal (1), S. Korea (5), Switzerland (1), Taiwan (2), USA (1), Vietnam (1) and Great Britain (1). Prices per individual filter are remarkably competitive. Bulk price for a container load of Stefani candles without silver impregnation from Brazil is $0.65. Stefani manufactures 5 million candles per year (Van der Ven, K, 2006). Cost per candle filter ranges from $5 – $10. Two candle filter systems range from $18 – $30. One anomalous unit, priced at $98, is made in S. Korea. The lower cost ceramic filters use a two-container plastic or metal system with one to three candles in the upper container.

India – Ceramic Candle Companies
The manufacturing volume in India of ceramic candle filters – typically of white kaolin clay - is approximately 18 million ceramic filters per year (Van der Ven, K, 2006). Most Indian ceramic candles are cheap ($0.90 – $1.30) and of poor quality. The main problem is that the manufacturing process involves putting white cement between the cap and the ceramic candle, which causes cracks and leaks. Quality control often does not exist.

Most Indian candle filter companies outsource candle manufacturing but put their brand name plastic or metal cap on it and package it. Some brands are Videon, Butterfly, Usha Brita, Sai Water Equipments and Ravi Exports. A major player is OK industries (www.okinds.com).

One high-quality brand is the Domit filter from Rajaniklat in Kolkata. This filter has a non-leaking seal and is silver impregnated. These candle filters have been tested in Auroville with excellent results. Domit Filter manufacturing capacity is 15,000 candles per month and the price is quite high ($1.90/candle). Pelikan is another high-quality Indian candle, purchased in the marketplace in Nairobi, Kenya (Franz, A., 2005). The manufacturer is as yet unidentified.

Ceramic pot filters are represented by several commercial/NGO manufacturers, one from Nicaragua (Potters for Peace), two from Cambodia (IDE-Red Cross and Resources Development Institute), one from Ghana (Ceramica Tamakloe) and one from the USA (Pure Water 4 All). The Nicaragua filter sells for $7, the IDE ceramic pot filter sells for $7 – $12, and the Ceramica Tamakloe system sells for $15 – $20.

Biosand filters are manufactured commercially by six companies: three from India (Aquatech, Get Water Solution, Konark Waterdoc), one from Bangladesh (Canadian International Water Purification Bangladesh Filter) and two from the USA (Pure Water for the World Water Filter and Safe Water Institute BioSand Water Filter). Retail prices have not been ascertained. Selecting, sifting and preparing local sand and gravel for this process depend on the dollar value of local production time and other inputs.

Adsorption

Activated carbon is the largest product in this field, including four Chinese companies (Jorden Hardware, Ningbo Qinyuan, Sinolink and Solutions Water Tech), four Indian companies (Aquatech, Get Water Solutions, Godrej & Boyce and Konark Water Doc), two Singapore companies (Delfina International and Intraco), four South Korean companies (Jinkwang, Komosa, Microfilter and Wonyang), one Taiwanese company (Caware International) and one company from the United Arab Emirates (Tawrid). Prices are usually at least double that of plain candle filters.

Iodine-based disinfection: iodine resin-based technologies to eliminate bacteria from drinking water by iodine-based inactivation are an interesting option since the low cost models are comparable in price to ceramic candle filtration. Four Indian companies manufacture these units: Eureka Forbes (3 in 1, $55 – $66), Konark Waterdoc (Respura, $51 – $100), Singer (Aquarius II, $111), Usha Brita ($48), and Zero B (Puristore, $32 and Purilline $103).

<u>Hybrid Adsorption with Carbon</u>

Integrated filters: many ceramic candle filters are filled with activated carbon to remove chlorine and to improve taste. However, the capacity for the carbon to remove chlorine is much less than the capacity of the ceramic filter to remove bacteria. Another more expensive approach is to use an activated carbon filter and a ceramic filter separately.

This hybrid combination of ceramic candle filtration and carbon filtration is more popular than plain carbon filtration. China is well represented in this field with 32 manufacturers, with a low retail price of $15.50 (Shenzhen Angel) making this technology attractive. South Korea has five manufacturers, Malaysia has three and India, Japan, South Africa, Singapore and Taiwan each have one.

UV combined with ceramic and carbon filtration units are another hybrid manufactured in China (Ningbo Flyhawk Electrical). Infrared combined with ceramic and carbon filtration is manufactured in three countries: China (G R Tech), Singapore (Pink of Health) and Taiwan (Porce Well Enterprise). Prices are over $100.

<u>Membrane Processes / Reverse Osmosis</u>

Membrane ultra-filtration is represented by three Chinese manufacturers (Aucuma Alamo Water Refiners, Shenzhen Chengdalai Industrial, Shenzhen Litree Purifying Tech), two Malaysian manufacturers (Hezong Trading, World Wellness Network), one Indian manufacturer (Eureka Forbes) and one Korean manufacturer (Kovit). Prices have not been ascertained.

Reverse osmosis (RO) is represented by 40 manufacturers which clearly dominate the field. Their distribution by country is revealing: China (16), India (8), Malaysia (2), S. Korea (4), Singapore (1), Taiwan (7) and UAE (1). Prices for units range from $100 – $150 to over $300. A high-end RO product (RO + ceramic/charcoal multiple hybrid) is manufactured in Taiwan (Japin International) for $1,400.

<u>Two or Three Process Combined (Hybrid) Systems</u>

Hybrid combinations on the low end include the following: filtration (sometimes), activated carbon + disinfection (Konark Water Doc Systems; P&G, PUR; and Sharp Engineering Works UV, Disinfection, Coagulation, Flocculation) and involve some metal salt precipitant + chlorination. P&G is socially marketed. Another hybrid is filtration + disinfection, combined with aesthetics (Pure-It, India from Hindustan Lever, $36 consumer price). It is not socially marketed.

PUR
P&G is one of the first global corporations to enter the market with a household drinking water

treatment product for developing countries, disaster relief and other markets. To date, P&G has invested some $25 million into developing and distributing its PUR water-purifying sachets. The company's only not-for-profit division was created for PUR sachets but operates with a business model.

P&G efforts to make PUR available started with test markets in Guatemala, Philippines and Pakistan. Test market results indicated that repurchase rates of 5-13 percent were not sufficient for a sustainable business. Also, P&G learned that consumer behavior change is difficult and necessitates new marketing approaches.

P&G's Safe Drinking Water Program is currently focused in two areas: emergency relief to provide PUR at cost to emergency relief groups and social marketing to provide PUR to local NGOs who distribute the product using a business approach but in a break-even, not-for-profit model for P&G.

Social marketing allows P&G to enter a market in places where it is too risky for commercial entry. It uses a sustainable business plan to cover all costs after an initial investment to introduce the product, and it provides future opportunities for P&G entry with other products.

P&G is engaged in national-scale efforts to make PUR available in Haiti, Dominican Republic, Malawi, Pakistan and Uganda through social marketing and in Western Kenya through small women's groups. P&G is seeking partners to expand efforts for both emergency relief and for sustained social markets.

P&G has worked in partnership with a number of organizations, including the WHO International Network to Promote Household Drinking Water Treatment and Safe Storage. They have created the Safe Drinking Water Alliance with USAID's Global Development Alliance:

- USAID/P&G funding and technical support
- Population Services International (PSI) social marketing
- CARE emergency relief
- Johns Hopkins University - Center for Communication Programs monitoring & behavior change (Algood, G. 2005)

Other Combined Hybrid Systems: a new hybrid recently being marketed by three companies in S. Korea (Biocera, Maha and Korea Rapidfit) is silver impregnated foam or ceramic balls. It appears to be socially marketed.

Filtration + ozonation disinfection is another hybrid technology that averages over $100 and is produced by companies in the following countries: China (2), India (4), Malaysia (1), Singapore (1) and S. Korea (3).

Summary

In summary the commercial HWTS technologies can be arranged into pricing gradations that have associated markets:

- Under $1.00 for chlorination, SODIS

- $10.00 and under for ceramic pot filters, ceramic candle filters, silver impregnated foam or ceramic balls and low-end UV (China)
- $15.00 – $20.00 for biosand filters, ceramic candles and carbon filtration (Shenzhen Angel, China) and resin adsorption units
- Above $20 for UV, iodine resins, membrane ultra-filtration, reverse osmosis and hybrid systems

These results demonstrate that more efficient manufacturing methods may substantially reduce the manufacturing cost of many of the HWTS technologies and will bring to market a variety of solutions suited to the needs of millions of low- income families.

Section II – Critical Factors that Influence the Adoption and Sustained Use of HWTS Innovations

7. Critical Factors

This section proposes a set of critical factors that influence the rate of adoption[6] and sustained use of HWTS innovations. This is a suggested or hypothesized set of critical factors that may include some that turn out to be insignificant or omit others that may have been overlooked. Readers are invited to respond with their experience of this set of critical factors in order to refine our collective understanding.

The classic investigation of critical factors in the adoption and diffusion of innovations is the work of Everett Rogers (2003). Rogers has identified variables, perceived attributes, which determine the rate of adoption of innovations, as shown in the first box of Figure 6. They are: (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability and (5) observability. He indicates that these explain about half of the variance in the rate of adoption. An expanded set of variables (boxes 2 – 5 of Figure 6), is said to explain 49 – 87 percent of the variance in rate of adoption of an innovation (Rogers, E. 2003). While Rogers's research focuses on innovations generally, much of this research is retrospective, and none of it pertains explicitly to HWTS.

[6] By rate of adoption we mean "the length of time required for a certain percentage of members of a social system to adopt an innovation." (Rogers, p. 221)

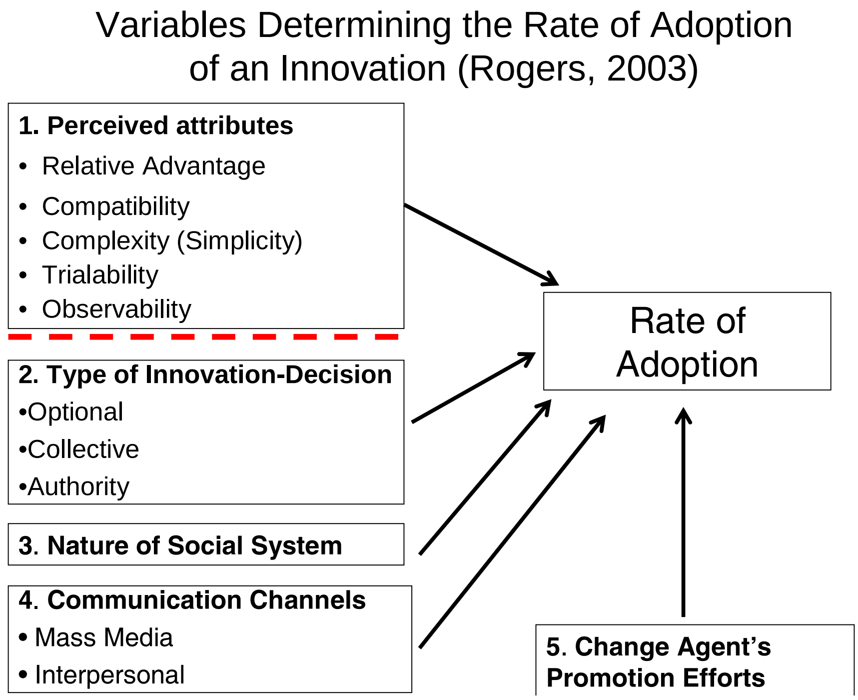

Figure 6: Variables Determining the Rate of Adoption of an Innovation (Rogers, 2003)

Public Health Communication / Social Marketing Framework

Public health communication and social marketing provide a theoretical framework within which to situate the adoption and sustained use of HWTS. The field of public health communication is at the interface of public health and social marketing and represents a special subset of social marketing activities.

Definitions of social marketing differ. Whereas some emphasize the social mission over the profit motive, others explicitly embrace the double bottom line of social and financial goals. Social marketing came into existence as a discipline in the 1970s, when Philip Kotler and Gerald Zaltman recognized that commercial marketing techniques could be adapted to better convey public health messages (Weinreich, N., 2006). Up to that point, health communication in the U.S. had consisted mainly of public service announcements delivered top-down from public health professionals to an audience. ("Smoking is bad for your health;" "Seat belts save lives;" and "Remember, only you can prevent forest fires.") Social marketing evolved during the latter decades of the 20th century, recognizing that one could sell ideas, attitudes and behaviors in addition to products. This shift, in turn, led to a major focus on the customer and the needs and desires of the target audience. Social marketing has since been widely applied in international health campaigns, such as in promoting contraception or oral rehydration therapy (ORT). Today, social marketing takes a range of institutional forms.

A widely used framework for the commercial "marketing mix" identifies the "4 Ps" – product, price, place, and promotion – as critical factors influencing the rate of adoption of a product or idea.[7] As applied to HWTS:

- **Product** is the water treatment option and the entire package of benefits that delivers value (physical product, brand, pre-sales education and training, post-sale technical support and service, financing plan, company reputation and convenience).
- **Price** means affordability to the user.
- **Place** involves the distribution channels, the product accessibility (including spare parts) and the entire supply chain.
- **Promotion** is the communication strategy, including the integrated use of advertising and public relations, media events and person-to-person marketing, i.e. all activities that increase the product's visibility and desirability.

The "4 Ps" cover the commercial terrain. Some see social marketing as mixing in additional "Ps" to the commercial soup. The four social "Ps" include partnership, public, policy and purse strings. The social "Ps" can be generically described as follows:

- **Partnership** makes is happen at scale and sustainably.
- **Policy** is often needed to support long-term change.
- **Public** includes both internal groups (those involved with approval or implementation of the program) and external groups (target audience and secondary groups, such as policy makers).
- **Purse strings involves the fact that** most social organizations obtain their funding from foundations, government grants or private donations and are answerable to these supporters. (Weinreich, N., 2006).

In this paper, we set forth four commercial "Ps" and four social "Ps" and hypothesize that these eight variables, and several dozen additional ones are potentially responsible for the adoption and sustained use of HWTS innovations. These factors are organized thematically:

- Commercial
- Social marketing
- Technical verification
- Social/behavioral
- Leadership, education and social networks
- Financial
- Installation, operation and maintenance
- Manufacturing and quality control

In some instances, these variables have already been extensively studied for general innovations. In several instances, they have been studied specifically in relation to HWTS. The approximate 30 factors tentatively hypothesized here are described and explored qualitatively and offered as points of discussion and further investigation. Within some of the themes, case studies are provided to illustrate a salient point.

8. Commercial Factors

[7] The "4 Ps" are a simplified, popular aggregation of a set of 12 activities defined in N.H. Borden in "The Concept of the Marketing Mix," *Strategic Marketing Management.* Harvard Business School. Boston, Ma. 1991.

Products: These have been identified in Section 5 and covered by individual Fact Sheets in Appendix 1. This cluster of technologies presents a diverse range of attributes, capabilities and methods of application. Because low-income customers have rarely been offered HWTS product choices (See *Nepal Consumer Perception Study* below as a notable exception), it is not clear whether one or several products are more appealing to customers.

Price: Price is a critical factor in adopting the use of HWTS or any product. Thus, accurate price information is necessary.

In 2005, researchers visited 11 different NGO HWTS implementation programs in Kenya (Baffrey, R. 2005) and compiled the prices, as paid by program beneficiaries and consumers of the several commercially available products, i.e. ceramic candle filters, household chlorine and PUR, as shown in Table 2:

Table 2: Retail Prices of HWTS in Kenya

Water Treatment Process	HWTS Systems	Retail Price to User ($)	Annual O&M Price ($)
Disinfection Only			
	Household Chlorination only ($0.60/500 ml bottle) [1]	$7.00	$3.60
	SODIS ($0.16) [2]		$6.40
Particle Removal			
	Ceramic Candle Filter (Pelikan brand @ $2/candle)	$13.00	$4.00
	Biosand Filter	$13.00	$0.12
	Coagulation / Flocculation Only ($0.01/10 L) [3]		$14.60
	Safe Storage -Modified Clay Pot	$6.00	
Combined Systems			
	Coagulation/Flocculation + Chlorine Disinfection ($0.05/10 liters treated) [4]		$73
	Filtration + Disinfection + Aesthetics + Storage	$19.00	$3.60

[1] Assumes $0.60/500 ml bottle lasting about two months per family = $3.60/year; 125 20-L jerry cans per 500 ml bottle.
[2] Assumes 40 two-liter bottles per family per year @ $0.16/bottle (KSH 12/bottle) Typical practice is significantly less.
[3] Assumes $0.01/coagulant dose treating ten liters, requiring four treatments per day per family x 365 days per year = $14.60. In practice, the amount used would likely be lower.
[4] Assumes $0.05/sachet treating ten liters, requiring four sachets per day per family x 365 days per year = $73. In practice, the amount used would likely be lower.
[Exchange Rate: KSH 75 = $1.00]

Prices were computed based on the assumption of an average family size of five to six and a minimum daily requirement of 7.5 liters per person per day necessary for drinking and cooking (Howard, G. and Bartram, J, 2003). This comes to about two 20-liter jerry cans of water per family per day for drinking and cooking. It is substantially higher than estimates of use given by specific HWTS project proponents, so these values represent liberal estimates of water quantity consumed daily, although still modest amounts compared to water consumption levels in high income countries.

In Northern Region, Ghana, the Pure Home Water social business is selling its HWTS product line at market prices, as shown in Table 3.

Table 3: Retail Costs of HWTS in Northern Region, Ghana

	Retail Price (US$)	O&M (US$)
Ceramic pot-shaped filter (full payment purchase)	$19.00	$6.67
Ceramic pot-shaped filter (on credit purchase)	$20.00	$6.67
Modified clay pot safe storage container w/ ½" brass tap (40L)	$8.50	
Plastic safe storage container w/ ½" brass tap (50 L)	$8.50	
Biosand filter (with 50L plastic bucket)	15.00	
SODIS		$0.11

To compare these methods, the Net Present Value is computed using data from Tables 2 and 3, assuming a ten percent discount rate and a product lifespan of five years, as shown in Table 4:

Table 4: Net Present Value of HWTS (rounded to nearest dollar, assuming a ten percent discount rate and a five year product life)

Water Treatment Process	HWTS Systems	Net Present Value (5 years)
	Safe Storage -Modified Clay Pot (40L) or Plastic Safe Storage Container (50 L)	$9
Disinfection Only		
	Household Chlorination only ($0.60/500 ml bottle) + safe storage container	$21
	SODIS ($0.16/bottle)	$24
Particle Removal		
	Ceramic Candle Filter (Pelikan brand)	$28
	Ceramic Pot Filter (Filtron brand in Ghana)	$44
	Ceramic Pot Filter (Filtron brand in Cambodia) [1]	$25
	Biosand Filter (plastic, 50 L size)	$13

	Biosand Filter (concrete – 60L) [2]	$32
	Coagulation / Flocculation Only ($0.01/10 L) [3]	$55
Combined Systems		
	Coagulation/Flocculation + Chlorine Disinfection ($0.05/10 liters treated) [4]	$277
	Filtration + Disinfection + Aesthetics + Storage	$33

[1] Alternate ceramic pot filter NPV price, based on data from Cambodia
[2] Alternate biosand filter NPV price, based on data for concrete biosands from Nepal

Table 4 is also an Excel spreadsheet with the Net Present Value (NPV) formula already built in. This spreadsheet allows users to substitute their own HWTS price estimates and compute and show NPV comparisons. The spreadsheet and several other specific price information sets on HWTS are provided in Appendix 3.

Place: Place is a potential critical factor in successfully implementing HWTS. If profit were the driving factor, marketers selling a ceramic water filter in Ghana would sell in the capital city of Accra. However, Pure Home Water entrepreneurs have a social good as their bottom line. Thus, their marketing efforts are focused in Northern Region, where rates of diarrheal disease and guinea worm are high. Northern Region is ten hours from Accra over bumpy roads. Ceramic filters produced in the capital have breakage rates of 20 to 50 percent by the time they arrive. This example clearly shows how place is a critical factor. Similarly, it takes many hours to travel from the capital city of Kathmandu to the Terai region of Nepal. Some local NGOs promote the Biosand filter, which can be constructed locally, using locally available materials. A final example comes from Mombasa and neighboring Kwale District. Pharmacies in Mombasa stock the household chlorination product WaterGuard and experience brisk sales, especially when their customers learn of the product from radio and TV announcements. In neighboring Kwale, most people cannot afford radios, and village kiosks have limited sales of the same WaterGuard product. Thus, place can influence HWTS use on many levels.

Promotion: The communication marketing plan includes the integrated use of advertising and public relations, media events and person-to-person marketing, which are all activities that increase product visibility and desirability. A convenient mnemonic for the set of activities comprising the promotion/communication plan is the "6 Ms" model:

- Market – to whom is the communication addressed?
- Mission – what is the objective of the communication?
- Message – what are the specific points to be communicated?
- Media – which vehicles will be used to convey the message?
- Money – how much will be spent in the effort?
- Measurement – how will impact be assessed after the campaign? (Dolan, R. 1997)

Media outlets provide one communication channel. Interpersonal communication is another channel with potential wide applicability for HWTS. Consumers can learn about products through direct marketing, through retail promotions and/or through trade promotions..

9. Social Marketing

Partnership: Partnerships are thought to enable wider diffusion than individual organizations working in isolation. We have already mentioned the five-year WHO International Network to Promote Household Drinking Water Treatment and Safe Storage as an 85 member organization, public-private partnership working toward commonly defined goals and objectives, outlined in an overarching strategy. Visit http://www.who.int/household_water for more information on the Network.

Policy: Government policies and regulations can significantly impact HWTS use. For example, a religious NGO in Haiti was implementing a combined system of filtration and chlorine disinfection. When bureaucratic delays and political instability blocked the shipment in customs, the liquid chlorine with a limited shelf life—especially when exposed to sun and high temperatures—became inactive. Thus, government policies can be critical in supporting or undermining product availability, viability and quality.

Publics: HWTS implementing organizations have multiple "publics" and must target different audiences to be successful. Internal groups include funders, producers, distributers and program managers. External groups include targeted users and secondary groups such as policy makers. Each group can play a significant role in successful uptake of HWTS.

Purse strings: Most organizations implementing HWTS obtain their funding from foundations, government grants or private donations and are answerable to these funders. Funders play a critical role in diffusing HWTS technologies.

10. Technical Verification

A health-based innovation must be efficacious to be promoted effectively. This is done by randomized epidemiological health impact studies and product verification trials both in the lab and in the field.

Health Impact Studies

The reduction in incidence of diarrhea from HWTS interventions is well-documented in earlier works. K.J. Nath et al (2006) reviews many major studies on the health impact of HWTS and summarizes by saying "the evidence shows that provision of safe water alone at the household level can reduce diarrhoeal and other enteric diseases by 6 – 50 percent, even in the absence of improved sanitation and other hygiene measures." Nath et al (2006) go on to say that health impact "varies considerably from one community to another depending on a variety of technology-related as well as site-specific environmental and demographic factors."

Product Technical Performance (ETV Process – Sobsey)

As an innovative cluster of technologies undergoing rapid invention, reinvention and application in a wide variety of geographic and demographic contexts, a large and growing diversity of HWTS products exists. (See fact sheets in Appendix 1) These products are promoted by private individuals, inventors, NGOs, religious organizations, commercial enterprises and governments. The efficacy of some products is well-documented and of other products is unknown and undocumented.

A WHO-directed technology verification process is underway to establish health-based performance targets for HWTS and to prescribe protocols to verify the capacity of these technologies to achieve those health targets. This is part of WHO's rolling revision of the 3rd Edition *Guidelines on Drinking Water Quality*. While this process progresses and is an essential precondition to ethical, quality-assured implementation, detailed discussion of it is beyond this paper's scope. The HWTS technology verification process and protocols can provide more information. See hhwater@who.int.

11. Social / Behavioral

Most people do not embrace an innovation on the basis of scientific studies but rather rely on subjective evaluations conveyed through a social process involving interpersonal communication channels. Several groups of social scientists from Academy for Educational Development (AED), Johns Hopkins Center for Communications Programs (CCP) and the Swiss Technical Institute (ETH –EAWAG) have sought to identify the critical social/behavioral factors that specifically relate to successfully adopting HWTS.

The Nepal Consumer Perception Study

The Nepal *Consumer Perception Study* (HIP, 2006) considered four different HWTS interventions: boiling, SODIS, ceramic candle filter and chlorination. Interviews were also conducted in the Parsa District with biosand filter users (e.g. the *Kanchan*™ Arsenic Filter), but this system was not formally included in the study for logistical and security reasons.

The *Consumer Perception Study* identified a set of eight characteristics as the basis for evaluating user's acceptance of the different options:

- Taste
- Smell
- Appearance
- Temperature
- Acceptability to family members
- Effort, convenience and maintenance
- Perceived effectiveness
- Perceived value

The Nepal study did not statistically rank these eight variables, but rather qualitatively ranked the different systems based on mothers' perceptions. After the mothers were trained and given a specific HWTS method to use for one month, they saw a demonstration of all four methods and were asked their opinions as to which method they preferred.

The results showed that householders perceived water that was clear, free of visible turbidity, dirt and sand, and to a lesser extent, free of bugs, insects and absent of an objectionable smell as "good and fit to drink." All HWTS methods were accepted and carried out correctly and with relative ease. The ceramic filter was the most preferred HWTS method across the range of attributes; respondents especially liked its ease of use. Notably, the ceramic filter was the least effective technically (it did not successfully meet its claim to remove microbial contamination) and was not a preferred method among the mothers in terms of affordability. However, although perceived effectiveness was included, neither actual technical performance nor affordability were among the eight characteristics measured by the survey. Chlorination was the second most preferred method. Mothers accepted chlorination but objected to the smell of the treated water. SODIS and boiling were satisfactory to consumers, however those who tried SODIS sought a method that was not dependent on weather conditions and expressed concern about the unavailability of bottles at study locations. Boiling was the least preferred method because it made water warm and unpleasant to consume, especially during the hot summer months.

Johns Hopkins Studies

Researchers at Johns Hopkins University Center for Communication Programs have also carried out formative research on HWTS and identified psychosocial factors as key to water treatment behavior. In June 2005, experts gathered to identify outcome variables and intermediate variables of HWTS behavior. Appendix 4 provides two tables: Table A presents the result of the discussion regarding behavioral outcomes; and Table B presents some variables that need to be measured and their role in predicting consistent behavior.

Through formative research the Johns Hopkins team has identified and compared attributes of water treatment technologies and assessed their effect on water treatment behavior. Methods compared include boiling, chlorine solutions and PUR. Findings show that mothers valued the following attributes in water: clear, taste, safe, easy to use and natural.

The critical psychosocial factors identified in the Hopkins studies are:

Cognitive

- Knows that water source is not safe for drinking and that safe water prevents diarrhea
  Agrees that water that looks clear may not be good for drinking
- Agrees that water needs to be treated even when it comes from tap
- Agrees that chlorine-based treatment products are safe
- Agrees that (the technology) is effective in making water safe for drinking
- Agrees that one can make the time to treat water at home
- Agrees that water treatment is a priority
- Thinks that others in the community treat their water consistently

Emotional

- Confident in treating water herself
- Likes the taste of treated water
- Sense of satisfaction by providing treated water for all members of the household

Social
- Social influence and support (others have recommended to treat water)
- Advocates water treatment to others in the community

Derived from this and related investigations, including a review of the literature on water treatment (Figueroa and Kincaid 2002), the Johns Hopkins researchers have developed a predictive model, as shown in Figure 7, and tool for measuring these psychosocial variables. Publication is forthcoming (Figueroa, M., E. 2006 -- personal communication).

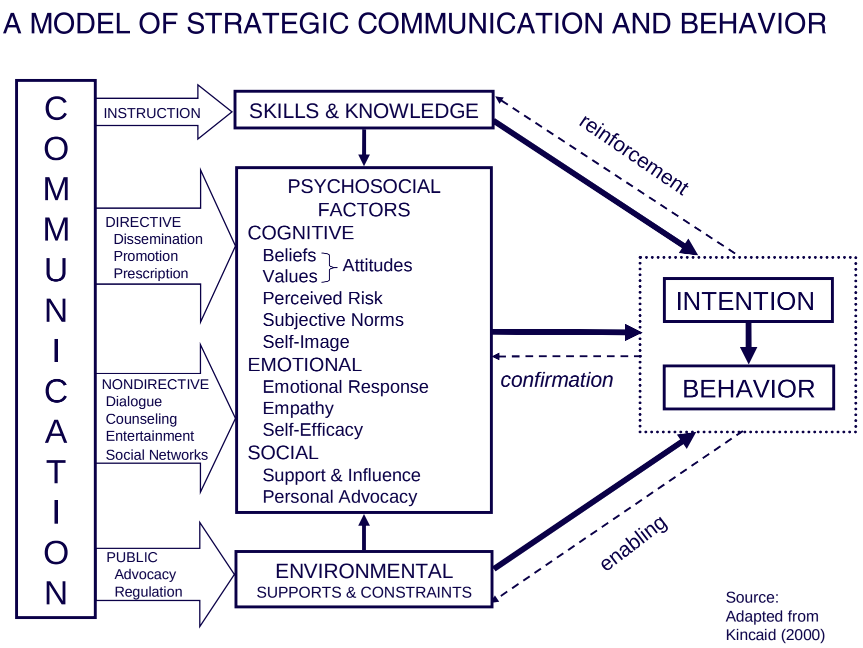

Figure 7: A Predictive Model of Communication and Change

Swiss Technical Institute Study

Moser, Heri and Mosler of the Swiss Technical Institute (ETH) investigated *Determinants of the Diffusion of SODIS* on the individual and social factors that influence the adoption of SODIS. The researchers carried out a multiple regression analysis to gain knowledge of what factors were most influential. Their regression shows that these factors are:
- Habits (degree of automatic behavior)
- Total number of people that had seen using SODIS
- Conviction that SODIS is safe to drink
- Vulnerability (self-perceived risk to suffer from diarrhea)
- Conviction that SODIS is the least time-consuming method to treat water

They conclude that habits and social influence are the first and second most important predictive variables respectively (Moser, S. et al, 2005). These studies show a broad cluster of variables associated with the behavioral aspects of HWTS.

12. Leadership, Education/Awareness and Social Networks

The software variables of leadership, education and social networks are widely acknowledged in theory as critical ingredients in successful HWTS program implementation. This often breaks down in practice due to the common error in program initiation to fund and count the hardware side of implementation and to overlook or neglect the software aspect. The critical role of leadership, education and social networks in successful HWTS implementation is well-illustrated in the story "A Tale of Two Districts in Peru" presented in Appendix 5.

13. Financial

While price has already been discussed in the context of the "4 Ps," a cluster of variables beyond price encompasses other financial aspects of HWTS adoption and sustained use, including:

- Willingness to pay
- Availability of credit and microfinance
- Aid, subsidies and incentives

Willingness to Pay

"What can the poor afford?" is the first of two topics of the Academy for Educational Development-hosted e-conference on Household Drinking Water Treatment and Safe Storage. Willingness to pay can be gauged by various means. Contingent valuation or willingness to pay surveys are methods that attempt to elicit individual preferences for a product or service. A handful of formal or informal investigations into what the poor can afford to pay for various HWTS products have been conducted. The story "Unwillingness to Pay for Household Drinking Water Treatment and Safe Storage" (Appendix 7) gives an informal glimpse into some of these issues.

Availability of Credit and Microfinance

The cost of many HWTS, while low cost from a global north perspective, is still a major investment for someone earning $1 – $2/day. For the poor, a critical factor in the affordability of a HWTS system may be the availability of credit or microfinance. Experience in several countries has shown that the availability of credit and microfinance stimulates the market for HWTS. Nonetheless, if poor people are already paying for water, sometimes at a price much higher than those receiving piped supplies, a HWTS system will not likely be their first need.

One surprising finding of a recent study in Nepal was that although it had been presumed that microfinance institutions (MFIs) preferred NOT to lend for non-income-generating activities such as HWTS products, after interviews with several MFI and microfinance NGOs, it was discovered that the lack of money to lend was the main barrier (Frey, S. et al, 2006).

Aid, Subsidies and Incentives

The three broad financing approaches to HWTS are: (1) charitable gifts (partly or wholly subsidized), (2) cost-recovery (breakeven) and (3) commercial (for profit) enterprises.

Most HWTS implemented through NGOs are, with some notable exceptions, operating according to charitable or cost-recovery models, not as for profit enterprises. The role of subsidies for social technology uptake is often hotly debated. Some say subsidies are necessary because people cannot afford to pay the full cost for a HWTS product. Others say subsidies distort the market and prevent successful commercialization of the product.

Arguments FOR Subsidies:

- People cannot wait to get safe water. They must have a HWTS now. Without a subsidy, they simply cannot afford the product.
- Subsidies will allow HWTS to penetrate into villages. Over some time, demand will be created.
- The difference between the willingness to pay, and the full cost is not so huge. A small subsidy can solve this problem. Why waste time and money setting up other approaches? Just give the subsidy.
- Even if an NGO breaks even on HWTS sales, it still cannot recover full costs of NGO staff time, travel, overhead, etc. Full-cost recovery is a myth.

Arguments AGAINST Subsidies:

- If people in village A know that the people in village B are receiving subsidies, then people in village A will wait for their turn to get a subsidy. They may wait for years and not be willing to buy the HWTS. People may become too passive.
- A subsidy will distort the true supply and demand balance. People may buy a HWTS because it is cheap, not because it is the best for them.
- Donors, instead of users, become the social entrepreneurs' clients.
- Subsidies are not sustainable in the long term (adapted from: Ngai, T., 2005).

Although little research exists on subsidies as related to HWTS, many case studies have examined subsidies in related fields. A good example is the dissemination of improved cook stoves in rural India, estimated to be nearly 30 million, at a rate of 2 million per year – through both government-controlled, subsidy-driven programs and demand-driven, entrepreneur-based profitable enterprises. (Shastri, C.M et al, 2002; Bhogle, S., 2003).

While subsidies for HWTS are widely in use, incentives are, thus far, infrequently applied. Incentives are rewards—cash or other inducements, such as free give-aways—to motivate actions, in this case, the purchase of HWTS. A voucher system is a way an incentive could be applied to HWTS.

14. Installation, Operation and Maintenance

Whether disseminated as charity, distributed during emergency relief, sold as a subsidized government or NGO product, or purchased commercially, the single most critical factor in adopting and sustaining use of any given HWTS product may be its successful installation, operation and maintenance (O&M). If users do not receive proper installation and O&M

instruction at start-up, and if personal instruction or technical support is not available when a problem arises, users will express their dissatisfaction and stop using the system.

Simple installation, operation and maintenance brochures, flyers, posters and stickers often accompany HWTS promotion, distribution and sales. Different HWTS products reflect different degrees of technical expertise in terms of their installation and O&M instructional information. Several typical examples of instructional materials are given in Appendix 8.

Installation

Some HWTS systems reduce costs to consumers by enabling the user to assemble and/or install the product themselves, often following some training workshop. Minimal instructional materials may need to accompany the product.

Operation

Operational instructions for a HWTS product should:
- Be expressed in a standardized format
- Be written in the local language
- Include pictorial and textual schemes
- Indicate methods that are safe for all users at all skills levels

The product should:
- Be easy to operate
- Operate and perform its function regardless of water volume fluctuations, weather conditions, reasonable changes in pH and temperature range
- Not make the water toxic or unpalatable
- Ensure any chemical concentrations are minor
- Provide residual protection against possible recontamination or some other measure of disinfection efficacy
- Be adaptable to local conditions and variations

Maintenance

Maintenance is the first step towards long-term sustainability and use. The activity of maintenance itself should be safe, easy to perform and not excessively strenuous or tedious. Maintenance should be able to be performed by young and old alike, if given the proper instruction.

Maintenance instructions should be:
- Be expressed in a standardized format
- Be written in the local language
- Include pictorial and textual schemes
- Communicate clearly the duration between cleanings, which should be a conservative and precise
- Include extra items needed to perform maintenance

- Specify typical life of product and its parts, any parts needing replacement should be specified and obvious to the user
- Indicate location of spare parts distributors
- Indicate clearly how to dispose of waste materials

These comments sketch out key points. The National Sanitation Foundation International Standard /American National Standard Institute (NSF/ANSI) has a standard NSF/ANSI #53 for Drinking Water Treatment Units on Health Effects (2004). The NSF/ANSI #53 Chapter 8 on "Instruction and Information" provides a bench-mark for the provision of instructions on installation, operation and maintenance. An excerpt is provided in Appendix 9. The HWTS implementation community would benefit from a dialogue on this topic.

15. Manufacturing - Quality Control

Quality control in the manufacturing process is a key element in assuring consumer confidence that their HWTS system is providing them with safe water.

The Swiss Katadyn Ceramic Candle Filter is one of the original commercial HWTS products, the patent for which dates back to the 1940s. Katadyn's "Ceradyn" and "Gravidyn" products are targeted for the outdoor recreational and the emergency relief market. With Katadyn's reputation and cultural association with Swiss precision and excellence, the water purification candle filter products have established themselves as leaders in their class. Their two-vessel plastic containment system, into which the candles are mounted into the upper vessel, disassembles to fit neatly one into the other, with the lid on top. This allows for shipment as a closed unit, while enabling contents, such as grains or other foods or medicines to be enclosed and safely stored, avoiding the expense of shipping dead space, for example, during transport in emergency air shipments.

The Hong Phuc Company Ltd. of Vietnam has made an exact replica of the containment system. Comparing the two reveals no visible differences. But when used, the Hong Phuc candles are not of the same high quality as the Swiss Katadyne.

Table 5: Comparison of Katadyn and Hong Phuc Ceramic Candle Filter Systems

	Capital Cost ($)	O&M Cost ($)
Katadyn (sold in Bolivia)	$21	$8 for 2 candles
Katadyn (sold in the USA)	$150	$50 each
Hong Phuc	$5	$1

A quality product is not necessarily a high-cost product. One of the better candle filters tested by Franz (2005) in Kenya was one of the least costly products.

Section III – Challenges and Future Directions

16. Gaps and Challenges to Scale Up

“Mixed Messages” – Improved Water Supply vs. HWTS

Topic 2 of the HIP-hosted E-Conference asks “How do programs promote HWTS and ensure that government continues to supply improved drinking water sources. This topic raises the question of whether access to improved water supply and HWTS are compatible interventions. For years, experts have advocated using improved water supplies. That message has been heard and comprehended. Moreover, the MDG Goal 7 Target 10 is based on improved water supplies. We risk confusing the very people we seek to serve with what appears to be mixed messages on what constitutes safe water.

One response to the mixed message challenge is to understand that a single barrier cannot protect the public from microbiologically contaminated drinking water. Multiple barriers are needed. And everyone, even those without access to an improved water supply (i.e. a household piped connection, public standpipe, borehole, protected dug well, protected spring or rainwater collection) deserves multiple barrier solutions. Thus, the debate should not be: improved water supply vs. HWTS, but rather, both options should be available because HWTS offers another necessary protective barrier.

O&M Challenge

All treatment requires O&M ,and the problems with O&M are well-known. Pickford (1977), in comments pre-dating widespread HWTS options, writing in the context of community water treatment systems, argues that:

> Whenever water is provided for low-income people in developing countries, there should be the minimum possible treatment, and the best supply is one that needs no treatment at all. The trouble with treatment is that it needs looking after. If the treatment process, however simple it may be, does not receive adequate attention, it will not function properly. Inadequate attention may, in fact, lead to a positive danger to public health… It is therefore important that all possible sources of water should be considered. A distant reliable source involving a long pipeline but needing no treatment may well be cheaper in the long run than a nearby source whose waters require a great deal of treatment to make them suitable.

These comments also pertain to and serve as a challenge to those seeking to promote HWTS. Have all safe source options been pursued? Will the HWTS function properly? What community-based supports and safe-guards are in place to regularly instruct, support and monitor correct use? Could HWTS, malfunctioning or misused, even be a danger to public health?

Cost-Effectiveness of HWTS and Effects of Subsidies

Documentation is lacking on the cost-effectiveness of HWTS and on how well HWTS work in an unsubsidized environment. For example, in an evaluation of the household chlorination program using Chlorin in Zambia, price was given as the most frequently cited reason for discontinuance (USAID 2004). Data are needed both from the consumer perspective (Are these products affordable to the poor? to the middle class in developing countries?) and from the programmatic perspective (Can higher priced sales to the middle class offset lower priced sales to the poor?). If HWTS are not cost-effective, cost-recovery and financial sustainability are major challenges. Moreover, we know that several programs disseminate HWTS as direct donations or at highly subsidized prices. The effect of subsidies and the concomitant market distortions are a barrier to commercial operations. This subject has not been adequately studied or documented.

Lack of Information on Combined Systems Implementation and Integration of HWTS into Other Programs

Several major HWTS currently implemented, for example, many ceramic filters, the biosand filter and cloth filters, do not completely protect against microbial contamination. For safe drinking water, these systems should be used in combination with a disinfection technology, such as chlorination, solar or UV disinfection. However, combined systems add an additional layer of complication for the user. And, with some exceptions (e.g. PUR, Gift of Water Program) good documentation is lacking on programmatic experience with successful combined systems implementation and scale-up.

Similarly, information is lacking on experiences that integrate HWTS with other water, sanitation, hygiene, health and non-health programs. While research has shown the efficacy of HWTS interventions, whether synergies are created with combined interventions is not yet well understood.

Monitoring and Evaluation

Water Quality Monitoring Tools – Need for Simple, Low-Cost Methods

Consumer confidence that a product is delivering the expected quality is critical to building acceptance in a new innovation. Consumers must trust that the product performs as advertised and that the water it delivers is not only tasty but safe. Typically, assurance is guaranteed in two ways: by technology verification prior to dissemination and by subsequent monitoring. In the case of HWTS, many low-end and NGO/socially marketed products have been introduced without being properly verified technically. As described in Section 6, products are already in markets and homes in at least 53 countries. Thus, ensuring water quality can be tested inexpensively at home—a second line of defense.

Some simple, low-cost microbial water quality test methods are already available for use in the community or home. Some products, such as household chlorination, lend themselves well to very simple testing. Considerable literature on HWTS field testing methods is available.[8] Simple, low-cost water quality treatment methods are the focus of a recent EU-funded "Preparatory Study."[9]

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[8] See, for example: http://web.mit.edu/watsan ->documents ->student theses, Chian Siong Low (Nepal 2002), Amber Franz (Kenya 2005), and Claire Mattelet (Ghana 2006).

[9] For more information contact Dr. Stephen Gundry, Stephen.Gundry@bristol.ac.uk.

Programmatic Monitoring and Evaluation Tools

Daily or short-term behavior-related variables have been described in Section 11 and presented in Appendix 4) In addition to these short-term behavioral variables, we also need agreement on common metrics for long-term program monitoring and evaluation. Several different sets of long-term monitoring and evaluation variables have been suggested:

Small and medium-sized government or NGO programs might consider monitoring long-term HWTS sustained use levels after the model of Kenya Water and Health Organization (KWAHO) in their SODIS program in Kibera, Nigeria. A clear indication of sustained use, referred to by KWAHO as acceptance level, is shown in Table 6:

Table 6: Acceptance Level (Variables Used by KWAHO in SODIS Program in Kibera, Kenya)

Item	Number or Ratio	Percent (%)
Total target households	20,000	
Number of households reached (or trained) / total target households	9,000/20,000	45%
Regular users / number households reached (or trained)	8,000/9,000	88%
Irregular users / number households reached (or trained)	110 / 9,000	3%
Non-users / number of households reached (or trained)	780 / 9,000	9%
Overall acceptance level = regular users / total target households	8,000 / 20,000	40%
Acceptance level / total number of households reached (or trained)	8,000 / 9,000	89%

Standardized definitions of regular user, irregular user, non-user and time component would help sharpen this approach. Also needed is a variable for long-term use, which we suggest calling rate of sustained use.

- Rate of Adoption (ROA)

$$= \frac{\text{\# of households using HWTS system after 1 month}}{\text{\# households reached (or trained)}}$$

- Rate of Sustained Use (ROSU)

$$= \frac{\text{\# of households using HWTS system after 1 year}}{\text{\# of households reached (or trained)}}$$

(Adapted from "Long Survey" applied in Kenya by Baffrey,R. and Murcott,S. June, 2005)

Rate of Adoption and Sustained Use: The WHO Survey described in Section 6 considered, but ultimately did not include, a variable on rate of adoption and rate of sustained use. One data collection complication for these variables is that certain products, such as household chlorine and PUR, are recurrent purchase products, where other systems, such as a ceramic filters or Biosand filters are one-time purchases. For example: The SWS may have sold 1.6 million units of its household chlorine product WaterGuard per ten million population in Zambia, whereas a local ceramic filter may have only sold 10,000 ceramic filter systems and an additional 100,000 replacement candles per 31 million population in Kenya. Despite the different numbers, the two different sales rates may have reached the same number of people.

These variables may work for NGO programs where "reached" or "trained" means that the HWTS product has been communicated through interpersonal channels. However, if the HWTS product is communicated through mass media and commercial enterprises, a market-based measure of success may be needed.

Market Penetration[10]

Commercial HWTS implementation will likely not invest the time or labor in a long-term follow-up such as undertaken by KWAHO to show success. For commercial enterprises, market penetration is a better, cheaper and clearly understandable measure of success.

- Market penetration (for one-time purchase HWTS units)

$$= \frac{\text{total number of units of product sold}}{\text{total population of the given country}}$$

- Market penetration (for recurrent purchase HWTS products)

$$= \frac{(\text{total \# units sold}) / (\text{total \# units for 1 year's safe water})}{\text{total population in the given country}}$$

Example: Assume 1.8 million bottles of chlorine are sold in Zambia in one year. It takes 12 bottles per year to provide safe water for one household (based on volume of bottle, concentration, etc). Population of Zambia = 10 million, therefore:

$$\text{Market penetration} = \frac{1.8\text{ M} / 12}{10\text{ M}} = 0.015$$

Thus, chlorine is reaching about 150,000 people.

Sharing Best Practices of Interventions at Scale

Currently, the information gap in terms of best practices of HWTS interventions at scale is big. This is true for NGO and agency programs and commercial activities. For example, the NGOs and agencies implementing HWTS have not yet met, individually or collectively with industry experts in point of use water treatment, particularly those from China, India and other developing countries where large capacity and HWTS markets are emerging.

[10] This section is based on email exchanges between Rob Quick (CDC) and Susan Murcott (MIT) – March 2005.

17. Summary and Recommendations

The strategic goals of the WHO International Network to Promote Household Drinking Water Treatment and Safe Storage put forward in 2003 are appropriate recommendations to those implementing HWTS in 2006. A sixth recommendation has been added to the five original goals to make information on tools and best practices widely available through the Internet. It is likely that the USAID/HIP hosted e-conference on HWTS will generate more recommendations.

1. Include HWTS in the portfolio of water, sanitation and hygiene and other health programs and incorporate sanitation and hygiene promotion into HWTS projects.
2. Implement HWTS programs in several countries.
3. Document and publish the results of HWTS programs at scale that have been evaluated using consistent and accepted program effectiveness criteria, specifically to agree on common metrics on daily use behavioural variables and on long-term adoption and sustained use variables.
4. Use local human resources, materials and facilities to implement projects and to build local capacity.
5. Develop strategies and practices for effective commercial and social marketing that assure customer satisfaction.
6. Make available a range of tools for program implementers, including tools for:

- Selecting HWTS systems
- Formative research
- Global HWTS mapping and monitoring
- Marketing and promotion
- Supporting local scale-up – microfinance, subsidies, incentives
- Developing common metrics to compare adoption and sustained use
- Documenting best practices

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