DEVELOPMENT OF PROGRAM IMPLEMENTATION, EVALUATION, AND SELECTION TOOLS FOR HOUSEHOLD WATER TREATMENT AND SAFE STORAGE SYSTEMS IN DEVELOPING COUNTRIES

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ABSTRACT

Over the past six years, the MIT Department of Civil and Environmental Engineering's Master of Engineering program has undertaken various projects involved with the design and implementation of a wide range of household drinking water treatment and safe storage (HWTS) systems. Projects have been conducted in Nepal, Haiti, Nicaragua, the Dominican Republic and Peru, with the current year's project team focused on Kenya. These individual and team projects have brought the overall HWTS program to a point where program implementation practices are now of great interest. The primary objective of this thesis is to generate program implementation and selection tools to aid in the implementation of HWTS systems for local communities in developing nations. The tools generated are presented as two separate components: (1) a HWTS implementation organization survey and (2) a HWTS technology selection tool.

The HWTS implementation organization survey is intended primarily for information collection on currently implemented HWTS programs, but is also applicable for pre-implementation scenarios. In late 2004, in collaboration with the Implementation Working Group of the WHO International Network to Promote Household Drinking Water and Safe Storage ("The Network"), the MIT team developed a draft implementation organization survey. During January 2005, this survey instrument was vetted and iterated through interactions with eleven different HWTS implementing program groups working in five of Kenya's seven provinces and one area, who are applying eight different HWTS technologies: household chlorination, solar disinfection, boiling, ceramic candle filtration, concrete BioSand filtration, combined flocculation/disinfection, defluoridation with bone char, and the modified clay pot.

The HWTS technology selection tool is meant to aid stakeholders in the choice of the most appropriate HWTS technology, or combination of technologies, for a given potential implementation area. The tool utilizes parameters such as target population and water source to generate a score specific to each of the HWTS technologies and to effectively rank each of the technologies in terms of applicability to a given target area. Research collected by the MIT team during the January 2005 Kenya trip served as the primary basis for the allocation of scores for each of the parameters utilized.

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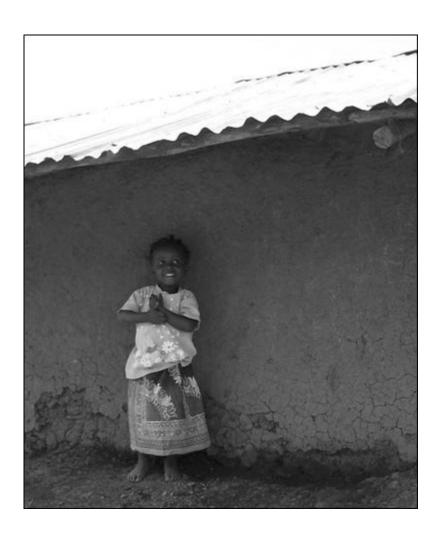


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LIST OF ABBREVIATIONS

WHO IWG

Agronym	Full Name
Acronym ACK	Anglican Church of Kenya
AIDS	Acquired Immune Deficiency Syndrome
ANSI	American National Standards Institute
CAWST	Centre for Affordable Water and Sanitation Technology
CBOs	Community-Based Organizations
CCS	Christian Community Services
CDC	Centers for Disease Control and Prevention
CDN	Catholic Diocese of Nakuru
CEE	Civil and Environmental Engineering
DFID	British Department for International Development
EPA	Environmental Protection Agency
GDP	Gross Domestic Product
GDWQ	Guidelines to Drinking Water Quality
HDPE	High Density Polyethylene
HIV	
HWTS	Human Immunodeficiency Virus Household Water Treatment and Safe Storage
IMF	International Monetary Fund
ITN	International Training Network for Water and Waste Management
KWAHO	Kenya Water for Health Organization
MCLs	Maximum Contaminant Levels
MDGs	
MDWL	Maximum Drinking Water Level
MIT	Maximum Drinking Water Level Massachusetts Institute of Technology
NETWAS	Network for Water and Sanitation, International
NGOs	,
NSF	Non-Government Organizations National Science Foundation International
PAHO	
PET	U.S. Pan American Health Organization
PSI	Polyethylene Terephthalate
PVC	Population Services, International
	Poly-Vinyl Chloride Social Marketing Initiative of Vanya
SMIK	Social Marketing Initiative of Kenya Solar Disinfection
SODIS	
SWAK	Society for Women and AIDS in Kenya
SWS	Safe Water System United Nation's Environmental Programme
UNEP	United Nation's Environmental Programme
UNHCR	United Nations High Commissioner for Refugees United National International Children's Emergency Fund
UNICEF	United Nations International Children's Emergency Fund
USAID	U.S. Agency for International Development
UV	UltraViolet
VAT	Value-Added-Tax
WHO	World Health Organization

World Health Organization Implementation Working Group

CHAPTER 1 – INTRODUCTION AND BACKGROUND

Over the past six years, the Massachusetts Institute of Technology (MIT) Department of Civil and Environmental Engineering's Master of Engineering program has undertaken various projects involved with the design and implementation of a wide range of household drinking water treatment and safe storage (HWTS) systems. Projects have been conducted in Nepal, Haiti, Nicaragua, the Dominican Republic and Peru, with the current year's project team focused on Kenya. These individual and team projects have brought the overall HWTS program to a point where program implementation practices are now of great interest.

The primary objective of this thesis is to generate program implementation and selection tools to aid in the implementation of household water treatment and safe storage systems for local communities in developing nations. The tools generated are presented as two separate components: (1) HWTS program implementation organization survey and (2) a HWTS technology selection tool. The implementation organization survey is to be utilized primarily for information gathering on currently implemented HWTS programs. The technology selection tool is meant to aid stakeholders in the choice of the most appropriate HWTS technology, or combination of technologies, for a given potential implementation area.

This chapter serves as an introduction and background for the thesis. Sections 1.1 and 1.2 provide an introduction to the global water crisis, emphasizing the role of household water treatment programs in addressing issues pertaining to water quality at a household level. Sections 1.3 and 1.4 provide site-specific information on Kenya, focusing on the country's current water situation. And finally, Sections 1.5 and 1.6 provide information on the objectives, research plan, and methodology of the thesis.

1.1 The Global Water Crisis

Water is fundamental for human health and survival. Adequate water availability and quality are key components to alleviating poverty in developing nations. Unfortunately, the right to safe water is not recognized for a large portion of the world's poorest citizens as at least 1.1 billion people lack access to water and 2.6 billion people lack adequate sanitation (WHO/UNICEF JMP, 2000). This has been identified as "a silent humanitarian crisis that each day takes thousands of lives, robs the poor of their health, thwarts progress toward gender equality, and hamstrings economic development, particularly in Africa and Asia (United Nations Millennium Project, 2005)".

1.1.1 The Millennium Development Goals

In September of 2000, the United Nations issued a set of "Millennium Development Goals" (MDGs) meant to address the most pressing issues faced by the world at that point in time. Of these goals, the seventh specifically addressed the issue of environmental sustainability and in doing so set as a target to "halve, by 2015, the proportion of the world without sustainable access to safe drinking water and basic sanitation".

Although the MDGs were formulated in 2000, the baseline for most of the MDG targets, including those for water and sanitation, has been set at 1990. Subsequently, 2002 is considered the halfway mark towards achieving the 2015 MDG deadline. Consequently, a mid-term assessment report was produced jointly by World Health Organization (WHO) and United Nations International Children's Emergency Fund (UNICEF), providing coverage data for 1990 and 2002 at national, regional and global levels and an analysis of trends towards 2015 (WHO/UNICEF JMP, 2004).

In regard to the worldwide drinking water target, the mid-term assessment report prognosis a relatively accurate one. The report indicated remarkable progress from 1990 to 2002, with the proportion of people with access to improved drinking water sources increasing from 77 to 83 percent. This accounts for a total of 1.1 billion people benefiting from increasingly safe and sanitary drinking water sources. Although these numbers project that the Millennium Development Goal will be met on a global level, it is tempered by the fact that certain regions of the world are still struggling to provide improved drinking water sources to currently unserved populations. One such region is sub-Saharan Africa which, despite having an increase in coverage from 49 to 58 percent, is still projected to fall short of reaching the Millennium Development Goal of 75 percent coverage by 2015. Factors cited as contributing to the impeded progress in the region are population growth, political instability, and low priority given to water and sanitation. One solution proposed for this region is the "decentralization of responsibility and ownership providing a choice of service level to communities, based on their ability willingness to pay". (WHO/UNICEF JMP, 2004)

A geographic representation of the data presented in the report is provided in Figure 1.1.

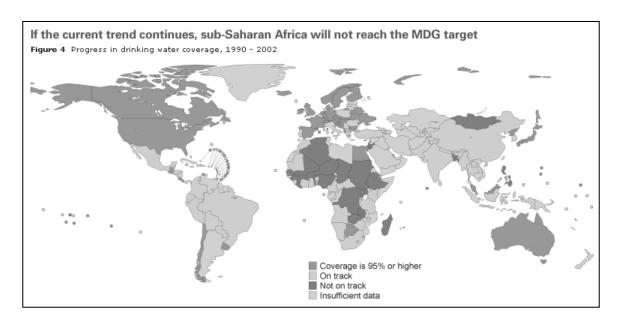


Figure 1.1 – Progress in Drinking Water Coverage, 1990-2002 (Source: WHO/UNICEF JMP, 2004)

According to the report, Kenya experienced a 17 percent increase (45 to 62 percent) in water coverage during this period, indicating that the country was well on its way to achieving the MDG target.

It must be noted that increase in coverage is defined as the percentage of the population using "improved" drinking water sources, the definition of which is shown in the table below. Although "improved" drinking water technologies are determined as those more likely to provide safe drinking water than those characterized as "unimproved", these sources still do not include any definition of safe drinking water or any specific measurement of water quality and may be misleading to that extent.

Table 1.1 – Categorization of "Improved" versus "Unimproved" Drinking Water Sources

Improved drinking water sources	Unimproved drinking water sources
Household connection	Unprotected well
Public standpipe	Unprotected spring
Borehole	Rivers or ponds
Protected dug well	Vendor-provided water
Protected spring	Bottled water
Rainwater collection	Tanker truck water

(Source: WHO/UNICEF JMP, 2004)

Addressing the concern of safe drinking water requires that population growth also be taken into account. The report indicates that despite a tremendous number of people gaining access to improved drinking water sources per year, reported at 90 million, an average population growth of 80 million people per year only results in a net total increase of 10 million per year. The report also cites a tremendous discrepancy in the proportion of populations being served between urban and rural areas of developing nations. In sub-Saharan Africa, for instance, the disparity between populations in urban and rural areas is reported at 37 percent. This indicates that a greater focus on rural areas in developing nations is needed to be able to attain the 2015 target. (WHO/UNICEF JMP, 2004)

1.1.2 Water-Related Disease

Microbial contamination of drinking water sources is a problem affecting many developing nations around the world. The use of polluted water for drinking and bathing is a principal pathway for infection by diseases that kill millions and sicken more than a billion people each year (World Bank, 1992). Unsafe water is implicated in many cases of diarrheal disease. Approximately four billion cases of diarrhea each year cause 2.2 million deaths, mostly among children under the age of five. This is equivalent to one child dying every 15 seconds, or 20 jumbo jets crashing every day. The most widespread contamination of water is from disease-bearing human and animal wastes, typically detected by measuring fecal coliform levels. Human wastes pose great health risks for the many people who are compelled to drink and wash in untreated water from rivers and other surface water sources (World Bank, 1992).

There are four categories of water-related diseases that are based on the route of transmission: waterborne diseases, water-washed diseases, water-based diseases, and insect vector-related diseases. The definition of these categories is presented in Table 1.2.

Table 1.2 – Water-Related Diseases

Category	Definition	
	Caused by ingestion of water contaminated by human or animal feces or	
Waterborne Diseases	urine containing pathogenic bacteria or viruses; including cholera,	
	typhoid, amoebic and bacillary dysentery and other diarrheal diseases.	
Water-washed	Caused by poor personal hygiene and skin or eye contact with	
Diseases	contaminated water; including scabies, trachoma and flea, lice and tick-	
Diseases	borne diseases.	
Water-based	Caused by parasites found in intermediate organisms living in	
Diseases	contaminated water; including dracunculiasis, schistosomiases, and other	
Diseases	helmuths.	
Insect Vector-related	Caused by parasites found in intermediate organisms living in	
Diseases	contaminated water; including dracunculiasis, schistosomiases, and other	
Diseases	helmuths.	

(Source: Bradley, 1977)

Developing nations suffer the most from these diseases. In fact, of the 37 major diseases in developing countries, 21 are water and sanitation related (USAID, 1993).

1.2 Household Water Treatment and Safe Storage (HWTS) Technologies

In industrialized societies, the provision of safe water has typically been accomplished through the use of community-wide systems such as centralized water treatment plants and piped distribution networks. Unfortunately, the installation of these utilities is oftentimes not cost-effective in developing nations. Funds are typically not available, nor are the technical capabilities required for operation and maintenance. New alternative strategies are urgently needed to address the world's current water crisis. One such alternative is the promotion and implementation of household water treatment and safe storage (HWTS) technologies. Although the ultimate goal of any community should be achieving the highest level of water service possible, household systems give an immediate and sustainable solution to the provision of safe water at the household level.

Household water treatment acts on the principle that water can be contaminated at various stages prior to use. A pristine water source can become microbially contaminated by improper transport, storage, and use practices in the home. By treating water immediately before intended use, the possibility of contamination is significantly lessened. Household treatment is implemented in combination with safe storage, sanitation, and hygiene in order to achieve maximum benefits to the household. Safe storage refers to storing water in protected containers that restrict physical access prior to use. Sanitation, although not emphasized in this document, is also recognized as a vital component in reducing disease in developing nations. Safe water is not as effective if it is not implemented in conjunction with proper sanitation. Hygiene is also important in this regard as improper hygiene practices, such as inadequate hand-washing, can also lead to the spread of disease in the household. Unlike water and sanitation, which are mostly addressed by the presence of physical systems in the home in conjunction with education and awareness, hygiene is principally implemented through proper education and awareness.

1.2.1 HWTS Availability and Performance

There are a wide range of HWTS technologies available that are relatively inexpensive and require little if any technical skill for operation and maintenance. Each technology has specific strengths and limitations in certain implementation scenarios. Technologies vary in cost, availability, and performance. A brief description of currently available HWTS technologies is provided in Chapter 2.

There is a growing body of literature and research available on most of the individual HWTS technologies. One important report is by Mark Sobsey (2002) for the World Health Organization's Water, Sanitation and Health Programme. The report, entitled "Managing Water in the Home: Accelerated Health Gains from Improved Water Supply", attempts to describe and review each of the various available HWTS systems. The report provides a scientifically sound and supportable basis for identifying, accepting, and promoting HWTS technologies so that programs in support of the implementation of household water treatment and storage can be developed and disseminated elsewhere (Sobsey, 2002). In Sobsey's report, over-population, urban-growth and expansion, periurban settlement, deforestation, global change, and increased coverage of the earth's surface with impervious materials are cited as specific factors that are increasing the potential of fecal contamination of drinking water sources. The document further indicates that the current global numbers reported for populations lacking access to safe drinking water are conservative, and that the actual situation is much worse than described. This is due to several simplifying assumptions made in regard to distribution, transport, and practices at the household level. The author argues that even with "effective" distribution systems, there is still a large potential for contamination in distribution systems due to inadequate maintenance, in addition to the potential of contamination at "protected" sources. Furthermore, practices during transport and storage of water at individual homes are not accounted for. These practices may not adequately protect water from contamination at this level. The author argues that education regarding hygienic practices during transport and at the home are necessary to protect water sources at the household level. (Sobsey, 2002)

Some critical findings of the report are presented in the following tables.

Table 1.3 – Physical Methods for Water Treatment at the Household Level

Method	Availability & Practicality	Technical Difficulty	Cost ^a	Microbial Efficacy ^b
Boiling or heating with fuels	Varies ^c	Low-Moderate	Varies _c	High
Exposure to Sunlight	High	Low-Moderate	Low	Moderate
UV Irradiation (lamps)	Varies ^d	Low-moderate	Moderate-high ^d	High
Plain Sedimentation	High	Low	Low	Low
Filtration ^e	Varies ^e	Low-Moderate	Varies ^e	Varies ^f
Aeration	Moderate	Low	Low	Low ^g

Source: Sobsey, 2002

^a Categories for annual household cost estimates in US dollars are less than \$10 for low, >\$10-100 for moderate and >\$100 for high.

b Categories for microbial efficacy are based on estimated order-of-magnitude or log10 reductions of waterborne microbes by the treatment technology. The categories are <1 log10 (<90 percent) is low, 1 to 2 log10 (90-99 percent) is moderate and >2 log10 (>99 percent is high).

^c Depends on heating method as well as availability and cost of fuels, which range from low to high.

^d Depends on availability of and type of lamps, housings, availability and cost of electricity, as well as operation and maintenance needs (pumps and system cleaning methods).

^e Different filtration technologies are available. Some (e.g., membrane filtration) are recommended for emergency water treatment). Practicality, availability, cost and microbial efficacy depend on the filter medium and its availability: granular, ceramic, fabric, etc.

f Depends on pore size and other properties of the filter medium, which vary widely. Some are highly efficient (>>99 percent or >>2log10) for microbial removals.

Table 1.4 – Chemical or Physical-Chemical Methods for Water Treatment at the Household Level

Method	Availability & Practicality	Technical Difficulty	Cost ^a	Microbial Efficacy ^b
Coagulation-Flocculation or Precipitation	Moderate	Moderate	Varies	Varies ^c
Adsorption (charcoal, carbon, clay, etc.)	High-Moderate	Low-Moderate	Varies	Varies w/ adsorbent ^d
Ion exchange	Low-Moderate	Moderate-High	Usually High	Low/Moderate
Chlorination	High-Moderate	Low-Moderate	Moderate	High
Ozone	Low	High	High	High
Chlorine Dioxide	Low	Varies ^e	High	High
Iodination (elemental, salt or resin)	Low	Moderate-High	High	High
Acid/base treatment w/citrus juice, hydroxide salts, etc.	High	Low	Varies	Varies
Silver or Copper	High	Low	Low	Low
Combined systems: chemical coagulation-flocculation, filtration, chemical disinfection	Low-Moderate	Moderate-High	High	High

Source: Sobsey, 2002

In addition to the important study by Sobsey, six years of studies have also been conducted on a wide-range of these technologies at MIT by the Master of Engineering Program as well as studies on individual technologies by a number of other researchers (e.g. Wegelin, Mintz, Quick, etc.). These MIT studies combine field research as well as controlled laboratory studies and are discussed further in Section 1.2.4.

^g Aeration (oxygenation) may have synergistic effects with other water treatments, such as solar disinfection with sunlight or with other processes that may oxidize molecular oxygen.

^a Categories for annual household cost estimates in US dollars are less than \$10 for low, >\$10-100 for moderate and >\$100 for high.

b Categories for microbial efficacy are based on estimated order-of-magnitude or log10 reductions of waterborne microbes by the treatment technology. The categories are <1 log10 (<90 percent) is low, 1 to 2 log10 (90-99 percent) is moderate and >2 log10 (>99 percent is high).

^c Varies with coagulant, dose, mixing and settling conditions and pH range.

^d Microbial adsorption efficiency is low for charcoal and carbon and high for some clays.

^e On-site generation of gas is difficult but chemical production by acidifying chlorate or chlorite is simple if measuring devices and instructions are provided.

1.2.2 HWTS Implementation

There is currently a proactive approach aimed at implementing HWTS technologies throughout the globe both by local governments and non-government organizations (NGOs) such as the Centre for Affordable Water and Sanitation Technology (CAWST), CARE, and Potters for Peace. In addition to this, there is also a tremendous involvement on the part of international aid organizations such as MEDAIR and the UNICEF as well as national agencies like the Centers for Disease Control and Prevention (CDC). Also among these organizations is the World Health Organization, which is actively attempting to "accelerate health gains to those without reliable access to safe drinking water" through the promotion of HWTS technologies. The WHO has established the International Network for the Promotion of Safe Household Water Treatment and Storage (The "Network"), in collaboration with the United Nations, bilateral agencies, private sector companies, NGOs, and research institutions such as MIT (WHO, 2005). The network format optimizes flexibility, participation and creativity to support coordinated action. Gaining clearer insight into a number of organizations implementing these HWTS technologies in Kenya through the use of a survey instrument is one important focus of this thesis.

Local governments in developing nations are recognizing the efficacy of these technologies and have begun to include HWTS systems in policy considerations. For instance, the Government of Nepal, along with several local and global organizations involved with health and sanitation, has embarked upon programs aimed at addressing the treatment of both arsenic and microbially contaminated drinking water. Several project teams working in partnership with the Massachusetts Institute of Technology Master of Engineering Program in the Civil and Environmental Engineering (CEE) Department have, over the past fours years, been collaborators in the development of household water treatment technologies for individual homes located in these affected regions

1.2.3 The WHO Implementation Working Group

The Implementation Working Group (IWG) of the World Health Organization (WHO) "Network," has committed to undertaking the following activities in Year 1 (2004-2005):

IMPLEMENTATION TASK LEADERS **INTERESTED MEMBERS ACTIVITY** 1a. Create Web-based tool for S. Murcott (MIT) CDC, IDE, MIT, Ministry of Local HWTS technology and program Government-Kenya - City Council of options, organized according to Nairobi (CCN) (need more info Dr. key parameters Nynku), SANDEC (need more info), UNICEF, USAID, UNC 1b. Create Web-based database of implementation experience of IDE, MIT, Ministry of Local the Members Government-Kenya -City Council of Nairobi (CCN), Medentech (provision of data), P&G, SANDEC (provide

Table 1.5 – WHO IWG Activities of Existence

IMPLEMENTATION ACTIVITY	TASK LEADERS	INTERESTED MEMBERS
		data), National Nurses Assoc. of Kenya (NNAK) (provide data), Nursing Council of Kenya (NCK) (need more info for final decision)
2a. Develop agreed common guidance and approaches for technology verification	B. Gordon (WHO)	Anglican Church, AIT, BushProof, CDC, CAWST, IDE, LSHTM, MIT, MedAir, Practica, Samaritan's Purse, UNICEF, UNC
2b. Create Web-based tool for sharing technology verification methodologies and results		CDC, Emory, IDE, MIT Ministry of Local Government-Kenya - City Council of Nairobi (consumer of this information), UNICEF, UNC
2c. Develop agreed common guidance for evaluation, including both impact evaluation for health, water quality, and behavior/use as well as program implementation evaluation	B. Gordon (WHO)	CDC, CAWST, Emory, IDE, KWAHO, JHU, LSHTM, MIT, Ministry of Health-Gov't of India, Ministry of Local Government-Kenya, City Council of Nairobi-Kenya, DOH/MOPH-Thailand, MOH-Kenya, Nursing Council of Kenya (NCK) (behavior/use, program implementation, evaluation), Practica, Rotary, USAID, Water Resources Management Authority
3. Develop tool for formative research	J. Borrazzo and R. Rainey (US AID)	IDE, JHU, LSHTM, National Nurses Assoc. of Kenya (NNAK), PSI, USAID
4. Develop tool for estimating programmatic costs	Rick Rheingans (Emory) and Tom Clasen (LSHTM)	CDC, Emory, JHU, LSHTM, USAID, WSP-Africa
5. Develop program and business development checklist	S. Murcott (MIT)	CAWST, IDE, MIT, PSI, Practica, USAID

Source: WHO IWG, 2004

The table also includes the "task leaders" assigned to complete each activity and the member organizations of the network that stand to benefit from each activity. Primarily of interest to this thesis is Activity 1b: *Create Web-based database of implementation experience of the Members*.

In order to develop a good Web database of implementation experience it was determined that a thorough survey of a set of implementing organizations was called for. Throughout the development of the survey, IWG network members were asked for input on the survey; once received, input was incorporated in various iterations. The survey, initially a 36-page document, was significantly narrowed in scope and detail through these iterations and is now in its eighth version containing only 19 pages. The survey acts as a collection instrument on which the Web-based tool is based. The Web-based tool has the primary function of providing an efficient vehicle by which HWTS implementation organization data may be entered, collected, and referenced. The 19-page survey has been further refined and iterated into a "short form" version comprised of only four pages which feeds into a database that serves as a resource for HWTS program implementation. This Web-based tool is discussed further in Chapter 3.

1.2.4 MIT Master of Engineering Theses on HWTS Development

The Master of Engineering Program at MIT has produced a number of theses¹ that have addressed the research development and implementation of household water treatment technologies. These theses have focused in the implementation of these systems in Nepal, Haiti, Nicaragua, the Dominican Republic and Peru. The theses target different facets of technologies and programs that address the issues or water and sanitation at a household level. It is upon these documents that a solid base for this thesis has been established, taking into account not only the technologies produced but also the typical problems and successes experienced during the introduction of these technologies to native communities.

The current year's (2005) project team focused on Kenya and the research and development of certain promising HWTS technologies such as household chlorination, SODIS, ceramic candle filtration, combined flocculation-disinfection, and the modified clay pot. Specific research conducted by members of the project team is summarized briefly as follows:

 Brian Loux and Amber Franz were stationed at the Ministry of Water's Pollution Control Division in Nairobi. Loux developed and tested modified solar disinfection systems. Franz performed testing on several locally available brands of ceramic water filters. Franz examined flow rate, turbidity removal, and bacterial removal for each of the filters while in Kenya. (Loux, Franz, 2005)

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¹ These theses are available to the public through the MIT Civil and Environmental Engineering Web portal on water and sanitation projects in developing countries and may be accessed through the following link: http://web.mit.edu/watsan.

- Pragnya Alekal and the business team, Ellen Sluder, Jody Gibney, Mark Chasse, and Rachel Greenblat worked with SWAK (Society for Women and AIDS in Kenya), CARE Kenya, and PSI (Population Services, International) in Kisumu. Alekal performed household surveys and tests with regard to chlorine disinfection (Waterguard®) and coagulation/flocculation products (PuR®). The business team evaluated the business and marketing operations of organizations distributing Waterguard and PuR. (Alekal, Chasse et al, 2005)
- Suzanne Young and Mike Pihulic visited various pottery organizations in and around Homa Bay in an attempt to document the pot-making process and develop a standardized safe storage container that could be used with disinfection products. Young and Pihulic worked with the CDC and CARE-Kenya. (Young, Pihulic, 2005)

The largest portion of the past theses has focused on the country of Nepal. Work in Nepal dates as far back as 1999 with over 30 Masters of Engineering students, MIT Sloan Business School students, and faculty members and staff contributing to projects in the region. As reported by the department, projects have ranged from site investigation and assessing water quality at project sites to the evaluation and testing of existing technologies, to researching and developing low-cost household water treatment technologies, to business analysis and scaled-up implementation of these technologies. Field sites include the Kathmandu Valley and the Terai Region. Technologies have addressed water quality issues such as arsenic as well as microbial contamination with specific technologies being developed or evaluated such as ceramic filtration, chlorine disinfection, slow sand filtration, and solar disinfection. These technologies are similar to those being implemented by numerous organizations around the world for similar communities in developing nations.

Of the projects in Nepal, several focus not only on the specifics of the actual technology, but also take into account other non-technical factors that are required to implement these technologies successfully. These works include considerations regarding distribution, marketing, pricing, and willingness-to-pay of consumers as well as other impacts in regards to social acceptance, education, training, and overall sustainability. The works also included suggested methods for monitoring and evaluation of technologies once they had been successfully implemented. Furthermore, certain methods utilized for gathering research data for these works have been excellent sources for developing the survey instrument used for this project.

1.3 Background on Kenya

1.3.1 Population and Demographics

The following are key statistics on population and demographics in Kenya obtained from the 2004 World Factbook of the Central Intelligence Agency:

• Population: 32,021,856

• Age Structure:

0-14 years: 40.6 percent (male 6,575,409; female 6,430,218)
 15-64 years: 56.5 percent (male 9,126,847; female 8,962,905)
 65 years and over: 2.9 percent (male 399,050; female 527,427)

• Median Age:

total: 18.6 yearsmale: 18.5 yearsfemale: 18.7 years

• Growth Rate:1.14 percent

Birth Rate: 27.82 births/1,000 population
Death Rate: 16.31 deaths/1,000 population

• Infant Mortality Rate:

total: 62.62 deaths/1,000 live births
 male: 65.55 deaths/1,000 live births
 female: 59.6 deaths/1,000 live births

• Life Expectancy:

total population: 44.94 years

male: 44.79 years*female*: 45.1 years

• Fertility Rate: 3.31 children born/woman

• HIV/AIDS – Adult Prevalence Rate: 6.7 percent (2003 estimate)

• HIV/AIDS – People Living with Aids: 1.2 million (2003 estimate)

Kenya is experiencing a net migration out of the country of 0.1 persons per 1,000 population (World Factbook, 2004). According to the United Nations High Commissioner for Refugees (UNHCR) Global Appeal 2005, the country is home to some 232,333 refugees from neighboring countries. Data from the UNHCR report is presented in the following table.

Table 1.6 – Data of Refugees in Kenya

Country of Origin	Population
Somalia (refugees)	151,002
Sudan (refugees)	58,135
Ethiopia (refugees)	10,630
Other refugees	8,816
Asylum-seekers	3,750
Total	232,333

Source: UNHCR, 2005

The country is experiencing up to 150,000 deaths from HIV/AIDS (Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome) per year (World Factbook, 2004). According to conversations with the Ministry of Health, this is a marked improvement from the HIV/AIDS situation in years past. Although no specific numbers were issued by the Ministry during these conversations, the Ministry indicated that strong health programs and awareness creation were the primary reasons for the reduction in HIV/AIDS related deaths per year.

The people of Kenya can be divided into four language groups and 42 tribes (Kenya Embassy, 2005). These tribes are categorized into the following ethnic groups: Kikuyu 22 percent, Luhya 14 percent, Luo 13 percent, Kalenjin 12 percent, Kamba 11 percent, Kisii 6 percent, Meru 6 percent, other African 15 percent, and non-African (Asian, European, and Arab) 1 percent. The two official languages of the country are English and Kiswahili. Religion in the country is composed of the following: Protestant 45 percent, Roman Catholic 33 percent, indigenous beliefs 10 percent, Muslim 10 percent, and other 2 percent (World Factbook, 2004). The adult literacy rate, defined as the percent of the population over 15 years of age that can read or write, is 81.5 percent (UNDP, 2001).

1.3.2 Location, Climate, and Natural Resources

Kenya is located in Eastern Africa, bordering the Indian Ocean. The country is also bordered by Ethiopia and Sudan to the north, Somalia to the east, Uganda to the west, and Tanzania to the south (Figure 1.2). The country has a total area of 582,650 square kilometers, with a total land boundary of 3,477 kilometers and a coastline of 536 kilometers.



Figure 1.2 – Map of Kenya (Source: University of Texas at Austin, 2005)

The climate varies from tropical along the coast to arid in the interior. The terrain consists of low plains in the east rising to central highlands bisected by the Great Rift Valley with a fertile plateau lying to the west. Elevations range from 0 meters above mean sea-level at the Indian Ocean to heights of 5,200 meters above mean sea-level inland at Mount Kenya.

Natural resources consist of gold, limestone, soda ash, salt, rubies, fluorspar, garnets, wildlife, and hydropower (World Factbook, 2004).

1.3.3 Government and Economy

Kenya was recognized as a republic in 1964 and is currently lead by President Mwai Kibaki and Vice President Moody Awori. The country is divided into seven provinces and one area: Central, Coast, Eastern, North Eastern, Nyanza, Rift Valley, Western, and the Nairobi Area. Nairobi is the country's capital.

Kenya is considered the regional hub for trade and finance in East Africa. Unfortunately the country has been plagued with problems of endemic corruption resulting in several suspensions of loans granted to the country by the International Monetary Fund (IMF). Listed below are some select economic information obtained from 2004 World Factbook of the Central Intelligence Agency:

• Gross Domestic Product (GDP): \$33.03 billion

• GDP – real growth rate: 1.5 percent

• GDP – per capita: \$1,000

• Population below Poverty Line: 50 percent

Inflation Rate: 9.8 percent
Labor Force: 11.45 million
Unemployment Rate: 40 percent

1.4 Kenya's Water Crisis

About 31 percent of Kenyans receive their drinking water from a pipe (household or communal tap); while 37 percent obtain water from an open spring, stream, or river. The rest obtain water from wells, water vendors or other sources (Central Bureau of Statistics, 2004). In 2002, it was estimated by the World Health Organization that 38 percent of Kenyans lacked access to safe drinking water with this number increasing to 54 percent in rural areas. Reportedly 31 percent of the population has to travel more than half an hour to fetch water (WHO, 2004).

Water scarcity is also an impending problem for the country. Droughts and inadequate rainfall have lead to a deficit in renewable freshwater resources. This scarcity has dire consequences to the health and financial well-being of the nation's people as a large portion of the economy is highly dependent on water-intensive livelihoods such as agriculture and livestock. Kenya is recognized by the United Nation's Environmental Programme (UNEP) as being a "water scarce" nation, meaning that average supplies of available freshwater per capita fall below 1,000 cubic meters per year. This is emphasized further in Table 1.7 which compares Kenya's renewable water supply to other African nations.

Table 1.7 – Comparing Water Stress Index for the Nile Basin States

Country	Available	Available	WSI
	Renewable Water	Water per Capita	(Water Stress Index)
Egypt	58.10	936	11
Sudan	154.00	5,766	2
Ethiopia	110.00	1,950	5
Kenya	30.20	1,112	9
Uganda	66.00	3,352	3
Tanzania	89.00	2,964	3
Rwanda	6.30	1,215	8
Burundi	3.60	594	17
	Standard Hydrological Indicators		

Source: Ohlsson, 1998

The water stress index factor utilized above was developed as part of a case study on the Nile Basin. The index is based on the UNDP Human Development Index, which takes into account factors such as life expectancy (as a proxy for general level of development), educational attainment (as a proxy for institutional capacity) and real GDP per capita. Combined with standard indicators for water scarcity, the index serves as a measure of how "water-stressed" a nation is. The higher the index the more water-stressed a nation is considered to be; as noted in the table, Kenya has the highest value behind only Egypt and Burundi.

Water stress has a direct impact on water quality. In facing conditions of limited water supply, people normally acquire water from the most accessible and readily available sources. Unfortunately, these sources may be highly turbid and contaminated surface water sources. This leads to a higher probability of contracting diseases and further heightens the role of household water treatment. During the Kenya field visit in January 2005, a wide range of water sources such as springs, boreholes, rivers, lakes, rainwater harvesting, public standpipes, and piped networks were observed as being utilized to varying extents. These sources were oftentimes the most accessible to the populations in these areas. Water quality issues ranged from high turbidity and cholera outbreaks in Machakos to fluoride contaminated groundwater in Nakuru. Without a proper and renewable source of water, it is very likely that these water issues will only intensify in the future.

Problems of water supply and quality are further exacerbated in rural versus urban areas. Approximately 90 percent of the urban population in Kenya has access to improved water sources, while only 45 percent of the rural population has access to improved water sources (UNICEF, 2002). Some issues pertaining to Kenya's urban-rural divide are discussed further in subsequent chapters.

1.5 Objectives

The primary objective of this thesis is to generate a program implementation organization survey and a HWTS technology selection tool to aid in the implementation of household water treatment and safe storage systems for local communities in developing nations. The implementation survey and technology selection tool is intended to take into account all facets of program implementation and is designed with inherent flexibility in order to be used by local communities as well as global agencies, organizations, and enterprises involved in program implementation.

Ideally, the development of the survey and selection tool requires a comprehensive evaluation of current HWTS implementation practices in as many developing nations as possible. However, for the purposes of this thesis, HWTS program implementation research was conducted in Kenya alone. For instance, the implementation survey aimed to summarize and gain insight into as many of the country's currently available HWTS technologies as possible, as well as into the agencies involved in their implementation, identifying current and past problems and successes faced in program implementation.

Initial areas of interest and questions posed for the overall framework of the project consisted of the following:

- 1. **Implementation**: Has your organization been effective in implementing household water treatment systems? What are common problems encountered in regard to these specific areas: role of training and education, correct use of HWTS systems, logistics, financing, role of local and national government, local communities and culture, non-profit organizations and aid agencies, job creation, monitoring and data collection and management, locally available materials and resource for construction and repair, available skills, management, and timelines? What are the challenges in scaling-up the projects?
- 2. **Operation and Maintenance**: What has been the long-term effectiveness of these projects? Is operation and maintenance being performed regularly and properly?
- 3. **Social Acceptability**: Do users like these HWTS methods?
- 4. **Technical Performance**: Did these systems perform in the household the ways they are intended?
- 5. **Improvement**: What improvements could be made to the general implementation process?
- 6. **Evaluation**: What are reasonable criteria for judging if systems are truly effective? Are there monitoring and evaluation programs/systems in place that can track the progress of these systems?

7. **Financial and Human Resources**: What is the role of other agencies in the implementation process? Are the resources of these agencies utilized to their full potential? What roles do local governments play in the implementation process? What roles do businesses play in the implementation process?

These questions were subsequently organized, condensed, and categorized into sections that comprise the implementation survey and were also considered in the development of the technology selection tool.

The accumulation and review of information on these areas alone may serve to aid in overall program implementation; however, a more exact application of compiled information was warranted and subsequently addressed in the development of the implementation survey and technology selection tool, which are briefly introduced in the following sections and then described in detail in Chapters 3 and 5 respectively.

1.5.1 The HWTS Implementation Organization Survey

The HWTS implementation organization survey is to be utilized primarily for gathering information on currently implemented HWTS programs.

The survey consists of the following sections:

- General Information
- Implementation Program / Product Description
- Target Population and Current Water Use Practices
- Resource Availability
- Education and Training
- Funding
- Operational Monitoring
- Target: Health Outcomes
- Target: Water Quality
- Target: HWTS System Performance
- Target: Behavior/Use (Social Acceptability)
- Costs
- Other Types of Approaches and Questions
- Final Thoughts
- Publications

The survey is currently in its eighth version, is 19 pages long, and requires one to two hours to conduct.

1.5.2 The HWTS Technology Selection Tool

The technology selection tool is meant to aid stakeholders in the choice of the most appropriate HWTS technology, or combination of technologies for a given potential implementation area. In this context, all of the data collected in Kenya using the implementation survey have aided in the creation of the selection tool. Some of the parameters considered by the tool are listed as follows:

- Target Population
- Water Source
- Water Use Practices, Access, and Transport
- Occurrence of Disease
- Local Government
- Presence of Implementing Organizations
- Presence of Local Community Groups
- Presence of Schools
- Presence of Health Clinics
- Infrastructure
- Economic Considerations

A more comprehensive list and discussion of the parameters considered for the HWTS technology selection tool are provided in Chapter 5.

It is an inherent assumption that through the selection of a proper technology, overall program implementation will have a much greater chance of being effective and successful. It is anticipated that such a tool will have several applications specific to the beneficiaries, be they organizations, business, or HWTS users. The tool is designed with an inherent flexibility to allow for its use by both local communities as well as global agencies, organizations, and enterprises involved in program implementation. It is also intended that the said tool be modified incrementally in the future to suit different goals and types of program implementation.

Finally, it is pertinent to emphasize these objectives within the current context in Kenya. As Kenya is the specific focus of the research conducted for the project, all objectives mentioned were made with the current parameters of Kenya in mind. This required that the bulk of the technologies and agencies evaluated be those currently present and applicable to the country. Subsequently, the selection tool developed is geared more for use by local communities in Kenya, although an effort was made to make the tool applicable to a wide range of communities in developing nations.

1.6 Research Plan and Methodology

Research for the project has been accomplished through the following approach: (1) a review of current literature and past MIT Master of Engineering projects focused on HWTS program implementation, (2) development of a survey instrument with potential global applicability, to collect information on HWTS program implementation, (3) pretesting of the survey instrument through phone interviews, (4) conducting interviews using the survey instrument with Kenyan agencies involved in the implementation of various HWTS technologies, (5) survey refinement through eight iterations to improve this as an instrument for information gathering in regard to program implementation, and (6) development of a technology selection tool.

1.6.1 Preliminary Research

As a starting point, a comprehensive review and analysis of available literature and past MIT projects focused on program implementation was performed. The purpose of the literature review was to provide background information that assisted in the development of the survey instrument. For instance, the Master of Engineering Program in the CEE Department of MIT has produced several theses that have touched upon factors to be considered in the implementation of household water treatment technologies. The information contained in these theses is valuable in that several important variables have been identified in the selection and review of these HWTS systems, such as social acceptance, financial viability, performance, and ease of operation and maintenance. Several relevant MIT Master of Engineering theses were reviewed in reference to general obstacles encountered during the HWTS implementation process. Observations in regard to the execution of these technologies were consolidated for consideration in the future implementation of other programs. Apart from this, a large number of publications on the current state of global water supply and sanitation and the applicability of household water treatment were reviewed.

The survey was initially developed with the intent of acquiring comprehensive data regarding available HWTS technologies from an assortment of agencies. The term "agencies" actually encompasses all organizations, universities, enterprises, and local and national government entities that might be involved with the promulgation of HWTS technologies. Agencies were selected based on whether or not they were implementing household water treatment and other similar systems, either on a global and/or a local scale. Such global agencies of interest were the CDC, CARE, CAWST, Potters for Peace, and UNICEF. In addition to this, it was also intended that the survey be applied to private companies such as Procter & Gamble, who produce technologies such as PuR® water purification sachets.

It was intended that the survey be utilized on the aforementioned agencies prior to the site visit to Kenya. It was determined that this would be beneficial both in order to gain insight into the effectiveness and uniformity of the survey as well as to gather preliminary data prior to hitting the ground. Unfortunately, time constraints allowed for only a limited use of the survey on agencies prior to the site visit. That being said, the survey was modified to a certain extent using phone interviews conducted with two organizations implementing HWTS technologies. These interviews served to correct vague questions and themes and hone in on the specific information considered most important and readily available. These interviews are discussed further in the next section.

1.6.2 Pre-Testing Through Phone Interviews

Prior to the site visit to Kenya, the "long form" of the survey was tested through interviews with two WHO IWG members: Ron Rivera of Potters for Peace and Camille Dow Baker of the Center for Affordable Water and Sanitation Technology (CAWST). Mr. Rivera is deeply involved with all facets of one particular ceramic water treatment technology: The Potters for Peace "Filtron". Mr. Rivera is particularly active with the training and development of pottery workshops in a number of developing nations throughout the world. Ms. Camille Dow Baker, CAWST's Chief Executive Officer, is a professional engineer with over 20 years of senior management experience as well as several years of experience leading a non-profit organization. CAWST is involved primarily with the implementation of the BioSand filter technology.

The initial 36-page survey instrument was subsequently streamlined to 17 pages in anticipation of time constraints in the field. Upon modification, the final version of the implementation survey is in a condition to effectively collect data in a more efficient and clear manner for use by future researchers and organizations implementing HWTS technologies.

1.6.3 Field Research

After revising the survey based on input received during pre-testing, the implementation survey was utilized for data collection during the site visit to Kenya. Local agencies and international organizations with local branches in the country were visited personally to conduct interviews. General methods of program implementation were observed through site visits that occurred in the same time period as the interviews. A list of the agencies and organizations visited in Kenya during January 2005 is as follows:

Organization Technology Location Population Services International (PSI) Nairobi Waterguard Nairobi (Headquarters) Mombasa Waterguard Mombasa, Coast Prov. Network for Water and Sanitation (NETWAS) Ceramic Candle Filter Nairobi (Headquarters) Kenya Water for Health Organization (KWAHO) **SODIS** Kibera District, Nairobi Nairobi Maseno, Western Province **EcoSan Toilets** Maseno, Western Prov.

Table 1.8 – HWTS Implementation Organizations Visited in Kenya

Organization	Technology	Location
Kenya Ministry of Water Resources	Boiling / Chlorination	Nairobi (Headquarters)
Kenya Ministry of Health	Boiling	Nairobi (Headquarters)
MEDAIR / BushProof	BioSand Filters	Machakos, Eastern Prov.
World Vision International (WVI)	Safe Water System	Nairobi (Headquarters)
Anglican Church of Kenya (ACK)	SODIS	Eldoret (Headquarters)
Catholic Diocese of Nakuru (CDN)	Defluoridation Filters	Nakuru, Rift Valley Prov.
Society for Women and Aids in Kenya (SWAK)	Waterguard / PuR /	Kisumu (Headquarters) /
	Modified Clay Pots	Western Prov.
CARE-Kenya	Safe Water System /	Kisumu (Headquarters) /
	Modified Clay Pots	Western Prov.

The interviews were conducted by the author, Robert Baffrey, and his colleague, Jill Baumgartner, a student with the Harvard School of Public Health. Interviews were primarily conducted jointly by the author and Ms. Baumgartner, although there were instances when the interviews were conducted by only one person. Typically, the interviews were recorded by hand or through the use of a tape recorder.

CHAPTER 2 – HWTS TECHNOLOGIES

A brief introduction to HWTS technologies was provided in Chapter 1; in this chapter a brief description of these technologies is provided. A more detailed discussion of these HWTS technologies, including maintenance procedures, costs in Kenya, and respective advantages and disadvantages of each technology are included in Appendix A.

Only the technologies researched in the site visit to Kenya are included here as these are the primary technologies of interest and hence those considered in the HWTS technology selection tool developed in Chapter 5. These technologies are household chlorination (Section 2.1), solar disinfection (SODIS) (Section 2.2), boiling (Section 2.3), ceramic candle filtration (Section 2.4), BioSand filtration (Section 2.5), combined flocculation/disinfection (Section 2.6), defluoridation with bone char (Section 2.7), and the modified clay pot (Section 2.8).

2.1 Household Chlorination (Waterguard®)

Beginning in the early 1990s, the Centers for Disease Control and Prevention (CDC) and the U.S Pan American Health Organization (PAHO) developed the "Safe Water System" (SWS). The SWS consists of three parts: 1) household disinfection of drinking water supplies using a low concentration sodium hypochlorite solution; 2) safe water storage; and; 3) behavior change via water, sanitation, and hygiene education (CDC, 2005). Of concern in this thesis is the first component of the system, referred to throughout the document as "household chlorination".

Household chlorination is one of the HWTS technologies that has been adapted from treatment typically utilized for large-scale community-wide systems. Disinfection of drinking water or wastewater refers to the destruction of disease-causing organisms. Disinfection does not necessary result in the complete sterilization of a water supply but rather in the destruction of bacteria, viruses, and amoebic cysts, the principal organisms responsible for waterborne disease (Sullivan, 2002). Disinfectants, such as chlorine, destroy these organisms by several means, including damage to cell walls, alteration of the cell membrane, destroying selective permeability, alteration of the colloidal nature of the protoplasm, causing protein denature, and the inhibition of enzyme activity (Metcalf & Eddy, 1991).

Chlorination for large scale systems may include "primary disinfection" which addresses the initial elimination of water-borne-pathogens and "secondary disinfection" which is required to prevent the recontamination of waters. If previously treated waters are allowed to sit for extended periods of time, chlorine residual often dissipates, allowing the water to once again be susceptible to contamination by micro-organisms. In a household setting this may occur if households are too small to consume the dosed amount of treated water in adequate time, requiring the retreatment of drinking water after 24 hours in order to ensure water safety.

Chlorine dose efficacy is typically measured in terms of concentration and contact time. In general, the longer the contact time up to a certain maximum the greater the level of disinfection. Similarly, the higher the concentration of chlorine available for disinfection, the greater the level of disinfection up to a certain maximum. Other factors can affect the efficiency of chlorine disinfection, such as pH, temperature, and turbidity of the raw water.

Population Services International (PSI) markets the branded household chlorine product Waterguard® in Kenya. The organization works closely with the CDC.



Photo 2.1 - Waterguard® Bottle

2.2 Solar Disinfection (SODIS)

Solar Disinfection (SODIS) uses 1-2 liter PET (Polyethylene Terephthalate) plastic bottles and energy from the sun to disinfect water. The bottles are filled with water, shaken to induce aeration with oxygen, and left in the sun for one to two days prior to use depending on latitude, cloud cover, and a number of other factors. Microbially contaminated water is disinfected by ultraviolet (UV) light and by thermal disinfection as a result of this process. Studies show that various bacteria of serious concern in different populations are reduced extensively when exposed to solar radiation (Sobsey, 2002).



Photo 2.2 – SODIS bottle in Mathuru, Kenya (2005)

The technology was pioneered in the late 1970s by Acra *et al.* at the American University of Beirut, Lebanon, who sought to find an inexpensive disinfection method for oral rehydration solutions (Acra *et al.*, 1984). SANDEC/EAWAG (Swiss Federal Institute for Environmental Science and Technology) started to investigate the SODIS process in 1991. Their findings were encouraging and field-tests where launched to include several countries: Columbia, Bolivia, Burkina Faso, Togo, Indonesia, Thailand, and China (EAWAG/SANDEC, 1998). The most compelling aspects of this technology are the low investment costs of plastic bottles and the disinfection energy that is provided free of charge by the sun. (Flores, 2003)

The organizations implementing the technology in Kenya are the Kenya Water for Health Organization (KWAHO) and the Anglican Church of Kenya (ACK).

2.3 Boiling

Boiling or heating of water with fuel has been used to disinfect household water since ancient times. It is effective in destroying all classes of waterborne pathogens and can be effectively applied to all waters, including those high in turbidity or dissolved constituents. Although some authorities recommend that water be brought to a rolling boil for one to five minutes, the WHO Guidelines for Drinking Water Quality recommend bringing the water to a rolling boil as an indication that a high temperature has been achieved (WHO, 2004). These boiling requirements are likely to be well in excess of the heating conditions needed to dramatically reduce most waterborne pathogens, but observing a rolling boil assures that sufficiently high temperatures have been reached to achieve pathogen destruction. Although boiling is the preferred thermal treatment for contaminated water, heating to pasteurization temperatures (generally 60 degrees Celsius) for periods of minutes to tens of minutes will destroy most waterborne pathogens of concern. However, unless temperature monitoring is possible, caution is recommended in attempting to pasteurize waters at non-boiling temperatures. (Adapted from Murcott and Kilonzo, 2005)

The boiling approach is already commonly used throughout developing nations of the world and may be considered the most basic form of water treatment. Implementation of the technology is performed through simple awareness creation. In Kenya, the Ministries of Health and Water are the primary organizations disseminating knowledge about boiling as an effective method of water treatment.

2.4 Ceramic Candle Filtration

A number of ceramic filters are currently available in a wide range of shapes, sizes, and applications. Among the most popular of these are the candle and pot filters. What makes these filters "ceramic" is the material from which these are composed, namely clay, and the process by which these are made, namely through molding and firing. The filters are constructed from a mixture of clay, water, sand, and combustible material such as sawdust or rice husk. The mixture is formed into the desired shape (candle, pot, disk, etc.) and subsequently fired at high temperatures (about 900 degrees Celsius) for a prolonged period of time. During the firing process, combustible materials in the mixture are removed, leaving pores in the filter media. These pores serve to obstruct the flow of micro-organisms as raw water is passed through the filter.

These filters can have secondary objectives such as odor removal and taste improvement of the filtered water. Materials such as activated carbon or silver nitrate are sometimes added to the mixture to provide additional treatment and possibly some disinfection.

There are a variety of filters commercially available on international and local levels. The primary countries currently manufacturing these ceramic candle filter technologies are the United Kingdom, India, China, and Brazil. Ceramic candle filter elements are typically part of a system comprised of two containers, one on top of the other with the candle filter being located in the upper vessel. Raw water is poured into the top container, flowing through the filter element, and collected as treated water in the bottom vessel. Vessels can be made of steel, plastic, or clay and are oftentimes fitted with spigots to avoid recontamination.





Photo 2.3 – Kisii Ceramic Candle Water Filter (left) and British Doulton Filter (right) (Source: http://www.kentainers.com/kentainers/waterfilters.html>)

The organization implementing the ceramic candle filter technology in Kenya, and interviewed by the project team, is the Network for Water and Sanitation (NETWAS). It should also be mentioned that a large number of different brands of these filters are commercially available in Nairobi, therefore it is also fair to say that the technology is being implemented by some businesses in the country that were not included in the research conducted for this thesis.

Research on these ceramic candle filters was conducted in Kenya by Amber Franz, a fellow MIT Master of Engineering student and Kenya team member. During the time spent in Kenya, Franz performed testing of several locally available brands of ceramic water filters. Franz examined flow rate, turbidity removal, and bacterial removal for each of the filters while in Kenya. The following table presents some results of the research conducted (Franz, 2005):

Table 2.1 – Summary of Data Obtained for Each Brand of Filter Tested

	Turbi Remova	•	Flow Rat	e (L/hr)	Total Col Remova		E. coli Rem	noval (%)	
Filter	Kenya	MIT	Kenya	MIT	Kenya	MIT	Kenya	MIT	Cost (\$)
AquaMaster	98.3	88.6	0.093	0.160	99.835	99.6	99.995	99.95	10.00
Doulton	98.3	92	0.235	0.546	99.831	99.0	99.993	99.7	40.00
Stefani	98.8	93.1	0.101	0.241	99.694	97.5	99.967	97.6	2.25
Pelikan	98.3	97.3	0.182	0.203	99.982	99.6	99.985	99.9	2.00
Pozzani	97.1	89.9	0.101	0.180	99.653	95.6	99.769	93	20.00

Adapted from: Franz, 2005

2.5 BioSand Filtration

Dr. David Manz of the University of Calgary, Alberta, driven by the desire to help the developing world find a better way to purify drinking water, developed a simple, cheap and effective filtration system based on the concept of slow sand filtration (Legge, 1996). The result of these investigations was the BioSand Filter, an intermittently operated slow sand filter specifically designed for use by poor people in developing countries. The filter operates by gravity; being open to the atmosphere at both ends, the water flow is determined by the elevation differences at the influent and effluent ends of the filter. Particle removal occurs both at some depth and at the surface of the filter media (Pincus, 2003).

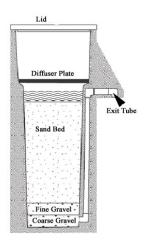


Figure 2.1 – Schematic of BioSand Filter

The actual filter bed consists of medium sand above a layer of coarse sand which in turn lies above a layer of gravel in which the lower portion of the effluent pipe is located (Figure 2.1). The BioSand filter contains a lid on top and a diffuser plate which is typically a sheet of wood, plastic, tin, or concrete with holes drilled in a grid pattern. The diffuser plate spreads water evenly over the surface of the sand, minimizing disturbance of the *schmutzdecke*. The filter media is typically enclosed in either a plastic or concrete casing.

Microbial contamination is partially removed on account of the *schmutzdecke*, a thin biological layer at the water/sand interface that is thought to eliminate pathogens in the influent water. Subsequently, a design parameter for the systems is a five centimeter layer of standing water, above the top layer of sand, which allows adequate oxygen diffusion to the biological layer during periods in which the filter is not being used. Other assumed removal mechanisms are bacteviory (death of influent bacteria), adsorption, and mechanical straining. (Pincus, 2003)

The filter has achieved wide-scale implementation. Various church groups and NGOs, including Samaritan's Purse and the Center for Water and Sanitation Technology (CAWST), have installed more than 57,500 BioSand filters in more than 28 countries worldwide, including Haiti, the Dominican Republic, Nepal, Nicaragua, Mozambique, and Kenya (CAWST, 2005). The organizations implementing the technology in Kenya are the NGO "BushProof", together with Samaritan's Purse and MedAir.



Photo 2.4 – Concrete BioSand Filter in Machakos, Kenya (2005)

2.6 Combined Flocculation/Disinfection (PuR®)

Combined flocculation and disinfection pertains to a two-pronged approach to water treatment in which large suspended particles are first coagulated and settled out prior to the elimination or inactivation of water-borne pathogens. Flocculation is the process by which particles agglomerate into larger particles, this is achieved by the addition of a chemical coagulant which causes adsorbtion of particles to one another creating "flocs" which progressively gain enough mass to settle down to the bottom of the water storage vessel. Disinfection is then achieved through the same process discussed in the section pertaining to household chlorination.

On the household level this process has been researched and marketed by Procter and Gamble (P&G), which has developed a sachet registered under the brand name PuR®, comprised principally of ferrous sulfate as the chemical coagulant and calcium hypochlorite as the household chlorination product. PuR® was developed as part of a collaborative effort between P&G and the Centers for Disease Control and Prevention.

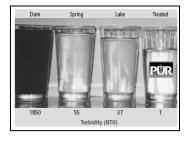


Photo 2.5 – Procter and Gamble's PuR

The product uses the same ingredients as applied in municipal water systems; but it is reverse engineered to effectively be a mini water treatment plant in a sachet. The product's efficacy is easily demonstrated through visible signals that water is cleaner; it also performs much better than simple chlorination in applications to turbid water. PuR® is also capable of reducing metals (e.g. arsenic, lead), pesticide contaminants (e.g. DDT) and other organic chemicals (P&G, 2005).

A single sachet of PuR® purifies 10 liters of drinking water. The sachet is cut open and the contents are poured into a bucket filled with 10 liters of water. Jerry cans are not appropriate, as water cannot be stirred properly. The contents are manually mixed rapidly with a large, clean spoon, then allowed to precipitate and settle for five minutes. Next, the 10 liters of water are decanted by pouring into a second safe storage container which has been covered by a piece of cloth or clean cotton material. After 20 minutes, the water is safe to drink. The sludge that has collected in the bottom of the first bucket can be discarded into a latrine.

PuR® is marketed in Kenya, Uganda, Haiti, Pakistan, Philippines, Guatemala and Morocco. In Nyanza Province, PuR® has been introduced by the Society for Women and Aids in Kenya (SWAK).

2.7 Defluoridation with Bone Char

Bone char filtration technology is different from the rest of the technologies presented in this document due to the fact that it addresses chemical (i.e. fluoride) contamination rather than microbial contamination of raw water. Fluoride is a naturally occurring contaminant which can cause dental and skeletal fluorosis upon consumption. Both diseases can be life-long afflictions.

Bone char has been determined to be a medium capable of absorbing high amounts of fluoride. In order to produce this absorbent medium, animal bones are fired at high temperatures, removing organics, and then crushed to produce the said "bone char". In the site visit to Kenya, the Catholic Diocese of Nakuru had done extensive research on the bone char process. After crushing, the bone char is sieved to select sizes, processed further, and then installed in tall cylindrical water storage tanks through which raw water passes. These vessels may range in size from community-scale to household-scale applications. A bone char filter is simple to operate and has high efficiency.



Photo 2.6 – Bone char filter media (2005)



Photo 2.7 – Community-scale defluoridation filter (2005)

2.8 The Modified Clay Pot

The modified clay pot is different from the various HWTS technologies presented in that it addresses safe storage and not water treatment. This is not to imply that the technology is any less important in the overall process of household treatment and storage. The aforementioned CDC Safe Water System includes the provision of a safe water storage vessel. This vessel is constructed of plastic and was designed to be easily transportable, from both a bulk transportation and manual transportation standpoint, durable, and restrictive in terms of access by children and human contact. The same philosophy is utilized by the modified clay pot, only this case makes use of locally available resources, such as clay and indigenous ceramic craft traditions instead of plastic molding.

Traditional clay storage pots (Photo 2.8) are widely used throughout developing nations. These pots are hand-crafted from clay and fired in kilns. The pots typically possess large openings to provide access to water through the use of a calabash or cup. Users enjoy these containers because of the evaporative cooling effect they have on the stored water. These vessels are effective in storing water but provide limited protection from microbial contamination.



Photo 2.8 – Traditional Clay Pot

These traditional vessels are the basis for the design of the modified clay pot (Photo 2.9), which utilizes similar production processes while improving upon design to include a narrower opening, lid, spigot, and a wider base to reduce the potential of the vessels tipping over. The vessel also has a space at the bottom, below the spigot, to retain sediment. The form, color, and function of the modified clay pots are essentially identical to the traditional ones.



Photo 2.9 – Modified Clay Pots (2005)

Whereas a number of countries have elected to use the CDC's HDPE (High Density Polyethylene) plastic safe storage vessel, the preference in Kenya for traditional clay vessels led to the changes discussed above (CARE, 2003). Pottery shops in Nyanza are producing the "modified clay pots" at the Oriang Women's Pottery Group in Homa Bay and at the SWAK-affiliated workshops in Siaya and Asembo. Aside from SWAK, CARE-Kenya is also actively involved in the implementation of this technology.

CHAPTER 3 – HWTS IMPLEMENTATION ORGANIZATION SURVEY

3.1 Introduction

In late 2004, in collaboration with the Implementation Working Group of the WHO International Network to Promote Household Drinking Water and Safe Storage ("The Network"), the MIT team developed a draft HWTS program implementing organization survey. During January 2005, this survey instrument was vetted and iterated through interactions with eleven different HWTS implementing program groups working in five of Kenya's seven provinces and one area, who are applying eight different HWTS technologies: household chlorination (Waterguard®), solar disinfection (SODIS), boiling, ceramic candle filtration, concrete BioSand filtration, combined flocculation/disinfection (PuR®), defluoridation with bone char, and the modified clay pot. The resultant survey instrument is intended primarily for information collection of currently implemented HWTS programs, but is also applicable for pre-implementation scenarios. The targets considered: Health Outcome, Water Quality, Technology Performance and Behavior/Use, are those identified by either the World Health Organization (WHO) 3rd Edition Guidelines for Drinking Water Quality and/or the Implementation Working Group of the WHO Network. Additionally, another potential target, "Costs" (Finances and Economics) has also been included in the survey instrument.

Throughout this chapter, the survey will be discussed section by section with special attention focused on the evaluation methodologies or "targets" utilized to structure the survey. Sections will be discussed with respect to information collected and effectiveness in the field, and specifically as it pertains to experiences conducting the survey in Kenya.

The complete "long" version of the survey version 8 has been included in Appendix B.

3.1.1 Amount of Time Required to Complete Interviews

Several organizations such as KWAHO, BushProof/MedAir, and SWAK answered the entire survey in approximately one to two hours. Other organizations were receptive to the survey but were limited by time constraints and were only asked to answer the questions deemed most important by those conducting the surveys. Oftentimes, organizations would simply give interviewers background data on their respective HWTS program (paper or electronic copy), and subsequently ask the interviewer to return to them if there was any additional information required that was not covered by the data given. On more than one occasion, it was necessary to leave a copy of the survey with the organization for completion at a later time.

Without adequate time the survey could not be completed effectively. This was not an overwhelming concern as the survey was intended to be used in scenarios where time is readily available. In developing a survey with the intent to comprehensively evaluate a HWTS program or technology, it was not expected that the survey be conducted in a short amount of time. Conditions in Kenya were not conducive to the survey as at least thirteen organizations across the country were visited in only three weeks; oftentimes the team found itself having to conduct both the interview and a site visit in only one afternoon. When sufficient time was allowed, the interview was conducted in an efficient manner.

3.1.2 Clarification Required for Survey Questions

Questions were typically straightforward and clear although some did require clarification in order to be comprehended fully. The survey did warrant some knowledge of HWTS systems and implementation practices from the standpoint of both the interviewer and the interviewee. In order to know what information to ask for, the interviewer had to have a clear comprehension of the technologies and the targets being used to monitor program implementation; however, it is not expected that this would pose a hindrance to the use of the survey by others as only a relatively short period of time and effort would be required to train an interviewer on how to conduct the survey. The effectiveness of any survey depends on the knowledge of the person being interviewed; the same is true for this survey. To the extent that the interviewee has an intimate knowledge of the HWTS program in question to that extent the survey will be effective.

3.1.3 Additional Notes on Interviews Conducted

Specific parts of the survey were tailored to organization members having different responsibilities in HWTS implementation. In this case the interviewer needed to interview two separate parties to gain a comprehensive evaluation of the organization. For instance, in interviewing the NGO BushProof the team interviewed both the head of the organization in Kenya, Ms. Cleo Weisent-Brandsma, and the two technicians, Simon Mwangangi Nutiku and David M. Kilonzo, who were responsible for implementation of the technology in the field. Ms. Weisent-Brandsma was the source of overall information on the organization while the technicians supplied detailed information on the construction and implementation of the technology in the field.

The survey required some flexibility on the part of the interviewer. It was most effective when two people were conducting the interview as one could record answers while the other took the lead in asking questions. The use of an audio recording device also served to make the interview process more efficient.

It must also be mentioned that the survey was modified into a version for use on a household level. The team did not originally intend to conduct household surveys but thought it pertinent to have a survey on hand should the opportunity to interview households arise. The household survey was used on about fifteen households in Machakos and Mathuru and, like the organization-based survey, held up relatively well and took about 45 minutes to complete. This household-based survey is discussed further in Section 3.6.

3.2 Background Sections

The following sections of the survey aim to gain general background information on the organization and technologies on which information is being collected.

3.2.1 General Information

Questions Included in Section:

1 General Information

The following section has the purpose of determining basic background information on the organization. Obtain simple answers to these questions as most will be tackled in more detail in later portions of the survey.

Date and Time:

Location:

Name of interviewer:

1.1

Interviewee Name/Position:

Organization:

Address:

Telephone(s):

Fax:

Email:

Website:

1.2 Type of organization: (e.g. Non-Governmental Organization (NGO), Business, Government, Agency, Academic Institution, Other?)

1.3 Organization's general history and mission statement?

For the following questions (1.4 and 1.5) we need only ask briefly about these topics and explain that the topics will be addressed in more detail at a later section of the survey.

- 1.4 Organization's specific goals with regards to implementation of one or multiple HWTS systems?
- 1.5. How does your organization measure progress towards these specific goal(s)? What specific tools, programs, and methodologies do you employ?
- 1.6 Number of staff members working on HWTS implementation?

Intent of Section:

The primary intent of this section is to facilitate the management and sorting of the surveys conducted. This section records the interviewer, date, time, and location of the survey.

In addition to this, Questions 1.1 to 1.3 address general background information on the organization on which data is being collected, specifically contact information, organization type, and the organization's general goals and mission statement.

Questions 1.4 to 1.6 are questions that are actually addressed in a more detailed manner in later sections of the survey. The questions are presented to gain a preliminary idea of the HWTS technologies being implemented by the organization along with the evaluation methodologies utilized and number of staff members working on the program. These questions have two purposes: (1) to help the interviewer assess how to go about conducting the rest of the interview and (2) to provide some preliminary information on those subjects that may be utilized should time be cut short to conduct later portions of the interview.

If the interviewer can gain some insight into the technologies being implemented and the evaluation methodologies employed, then he/she may conduct the rest of the interview more efficiently since there is a better idea of what questions to focus upon. Also, if time is cut short, as was the case in several of the interviews in Kenya, the interviewer already has some information on the essential topics addressed in later sections of the survey.

Problems Encountered and Potential Improvements:

There were no problems encountered in this section of the survey. One suggestion to the interviewer might be to obtain the information on this section prior to the actual interview. A large portion of this information is readily available through sources such as the Internet and passing this section would expedite the survey and allow the interviewer to move on to other more important sections.

3.2.2 Implementation Program/Product Description

Questions Included in Section:

2 Implementation Program / Product Description

The following section has the purpose of obtaining information specific to the program or product being implemented. .

- 2.1 HWTS Implementation Program/Product Name:
- 2.2 Brief (1-2 sentences) Description:
- 2.3 Why did your organization select this HWTS technology for implementation (as opposed to other community-wide technologies)?

- 2.4 Who brought this technology to your attention?
- 2.5 Where is the HWTS technology manufactured? Who distributes it?
- 2.6 Where do you obtain technical support for this HWTS technology?
- 2.7 Baseline Conditions:

Describe the current setting in which the program is being undertaken.

I Region or Primary Community	
II Predominant Exposure Scenario existing	Water: ³
in the program setting before introduction of	a. Not Improved
the program	b. Improved
	c. Regulated
	Sanitation:4
	a. Not Improved
	b. Improved
	c. Full Coverage
III Month and Year of commencement of	Month
program	Year
IV Start-up and Post-Start Up Periods	Start-up began
•	Post-start up (ongoing) period began
	Program terminated
	Program ongoing

³ Joint Monitoring Program definitions (http://www/wssinfo.org/en/122_definitions_en.html:

2.8 HWTS Implementation Program/Product Details:

To date, several types of HWTS systems have had randomized, controlled epidemiological studies performed to provide evidence of their efficacy. These are: solar disinfection (SODIS), household chlorination (the "Safe Water System"), combined flocculation/disinfection (PuR), cloth filtration (for guinea worm eradiation) and certain types of ceramic filtration (ceramic candles manufactured by Berkefeld or Katadyn). Identify if your organization is using one of these five HWTS approaches or another type of system. Identify HWTS based on the dominant treatment process(es)

II HWTS system(s) described	1. Safe Storage	
by its/their dominant	2. Sedimentation and other pre-treatment approaches	
treatment process(es)	3. Coagulation/Flocculation	
	Examples:	
	* Iron Salts	
	* Alum Salts	
	* Natural polymers	
	4. Particle Filtration	

[&]quot;Not improved water" = unprotected well, unprotected spring, vendor provided water, tanker truck water

[&]quot;Improved water" = household connection, public standpipe, borehole, protected dug well, protected spring, rainwater collection

⁴ *Joint Monitoring Program definitions:*

[&]quot;Not improved sanitation" = service or bucket latrines (where excreta are manually removed), shared and public latrines, latrines with an open pit

[&]quot;Improved sanitation" = connection to a public sewer, connection to a septic system, pour-flush latrines, simple pit latrine, ventilated improved pit latrine

	Examples:	
	* Cloth	
	* Ceramic water filters (candles, pot, disks)	
	* Sand	
	* Intermittent household slow sand filters	
	5. Absorption	
	Examples:	
	* Granular activated carbon	
	* Activated alumina or other metals	
	6. Membrane Processes (microfiltration, ultrafiltration,	
	electrodialysis, nanofiltraton, reverse osmosis)	
	7. Disinfection	
	Examples	
	* Boiling	
	* Household Chlorination (the "Safe Water System")	
	* Solar Disinfection (SODIS)	
	* Other UV Disinfection Systems	
	* Other disinfection methods	
	8. Combined (multiple process) HWTS Systems	
	Examples:	
	* Combined flocculation/disinfection (e.g. PuR)	
	* Rough filter + granular activated carbon filter +	
	chlorine	
	* Ceramic candle + sand + chlorine disinfection	
	9. Other	
	Storage vessel	
	Education to encourage adoption or use of HWTS	
	Hygiene instruction (independent of HWTS)	
	Sanitation intervention	
	Water supply intervention	
	Marketing	
	Other (describe)	
IV Predominant	Public (i.e., government or NGO-funded program)	
Dissemination Model /	Quasi-Commercial (social marketing)	
Method of Implementation	Commercial	

- $2.9\ Provide\ a\ more\ detailed\ description\ of\ the\ HWTS\ (optional):$
- 2.10 Extent of current implementation (locations and number of units):

I Number of persons in the program.	persons
II Number of households include in the program.	households
III Average number of persons per household included in the program.	persons/household
IV Maximum coverage assuming no increase in fixed costs and 80% utilization	persons

2.11 What role do other organizations play in the implementation of the program/product? In your opinion, how important is the relationship to other organizations to program success?

Intent of Section:

The primary intent of this section is to obtain information specific to the technology and program being implemented.

Questions 2.1 through 2.6 are included to obtain information on the HWTS technology being implemented. Important information being asked for is how the technology was selected, where the technology is manufactured/distributed, and from whom technical support for the technology is received. It is important to determine how the technology came to the organization's attention and why it was selected over other technologies. This feeds into information on the overall dissemination of the technology on a global scale. Furthermore, it is also important to determine where the technology has come from and how technical assistance is being provided, both of which are aspects that contribute to overall program efficacy.

Question 2.7 addresses the implementation program, specifically the baseline conditions of the target area. The question is given in the form of a table adapted from a "Cost Assessment for Selected Household Water Treatment Interventions" by Tom Clasen and Laurence Haller (Clasen and Haller, 2004). The table asks for information on the target area in regards to pre-implementation water and sanitation conditions. These conditions are based on those defined in the WHO/UNICEF Joint Monitoring Program MDG Mid-Term Assessment Report, classified into unimproved, improved, and regulated. This information is detailed further in the "Target Population and Current Water Use Practices and Concerns" section of the survey and is included here to gain only a preliminary understanding of available water and sanitation service in the area. Additionally, the table also obtains information on the period in which the program was implemented.

Question 2.8 classifies the HWTS technology being implemented into those that have been the subject of health-based studies, i.e. randomized, controlled epidemiological studies conducted to provide evidence of their efficacy, namely: household chlorination (the "Safe Water System"), solar disinfection (SODIS), cloth filtration (for guinea worm eradiation), certain types of ceramic filtration (ceramic candles manufactured by Berkefeld or Katadyn), and combined flocculation/disinfection (PuR). The organization is asked to select from a list the option that best describes the technology they are currently implementing. The question is provided in table form and also prompts the organization for information on additional components of the program and what primary dissemination method is used for the distribution of the technology. Oftentimes, HWTS technologies are implemented as components of an overall program framework aiming to benefit communities by various means. Safe water storage, education, hygiene promotion, sanitation interventions, and water supply interventions are some of the components implemented alongside HWTS technologies. Furthermore, it is also of interest to determine how information about the technology is being spread, whether by social marketing or commercial means. This is addressed further in subsequent sections.

Questions 2.9 to 2.11 obtain additional information on the product and program. Question 2.10 is based on a table also obtained from the aforementioned document by Tom Clasen and Laurence Haller, only this time it has the objective of determining the extent of program implementation, measured in terms of people and households reached to date and projected. Question 2.11 attempts to determine if there are any other organizations that aid in the implementation of the program.

Problems Encountered and Potential Improvements:

From an efficiency standpoint, one might rearrange the section such that questions addressing products are completely separate from those addressing the overall program. This would require the following order:

• HWTS Product Questions: 2.1 to 2.6, followed by 2.8 and 2.9

• HWTS Program Questions: 2.7 followed by 2.10 and 2.11

In regards to the specific questions, 2.1, 2.2, 2.7, and 2.9 all pertain to details about the technology being implemented, which results in some redundancy. These might be condensed with the elimination of one or two of the questions. While it is true that each of the questions does look for a specific type of information on technology, leading to a thorough evaluation, if interview efficiency is the priority then these would have to be modified. Some of the tables are technical in nature and required the interviewer to explain options in detail; this took up some time in the field and it is not expected that an organization would be able to easily comprehend the options without assistance. That being said, the information is important and efforts were made to make the questions as clear as possible.

Some redundancy is also experienced in asking about baseline conditions as water sources are once again addressed in the next section. Consolidating the information between these two sections might be worth consideration.

For the most part, the questions were very well received. Organizations had no trouble answering questions specific to the technologies. That being said, questions regarding the overall implementation of the program were found to be more difficult to answer. In particular, the organizations oftentimes did not have accurate numbers on the extent of implementation in terms of how many people were impacted by the technologies. This number often had to be estimated from the number of units manufactured or distributed, which was a value more easily recorded. Additionally, the question in regards to pre-implementation water and sanitation was also answered with difficulty as it was often the case that target areas had too many variations in water sources for easy generalizations to be made.

As was the case in the previous section, the interviewer could save time by obtaining information on this section prior to the actual interview. In Kenya it was often obvious as to what technology was being implemented and the team, by knowing this information, was able to focus on questions that were only obtainable from the organization, such as where the technology was manufactured, and to what extent the technology had been implemented.

3.3 Pre-Implementation Sections

The following sections of the survey address considerations prior to the implementation of the program.

3.3.1 Target Population and Current Water Use Practices and Concerns

Questions Included in Section:

3 Target Population and Current Water Use Practices and Concerns

3.1 What are the major types of water supply/supplies in your implementation area?

(Indicate answer by checkmarks or percentages)

(maicale answer by checkmarks of percentages)	
Piped water supply inside the house (private)	
Piped water supply outside the house (public)	
Borehole well	
* private	
* public	
Dug well	
Spring	
* protected	
* unprotected	
Surface water	
* creek or river	
* lake, pool or pond	
* canal or ditch	
Hole	
Water Vendor (indicate cost if possible)	
* standpipe or watering point	
* truck-delivered water	
Rainwater harvesting	
Other	
<u> </u>	

- 3.2 Percentage of people in target population lacking "access" where access means greater than 1 km or 30 minutes travel time to obtain water:
- 3.3 Demographics of target population:
 - a. Urban / Rural:
 - b. Literacy Rate:
 - c. Size of Population:
- 3.4 Was a baseline health survey carried out prior to HWTS intervention? If yes, please describe the key results:

3.5 Incidence of diarrhea in children under 5 in target population:

If answer to 3.4 was "yes" then neglect the following question (3.6).

- 3.6 Source of data other than baseline survey?
- 3.7 How much does your organization utilize the above information prior to implementation? Do you feel the information is important to program success?

Intent of Section:

The primary intent of this section is to obtain information on the population being targeted for program implementation.

Questions 3.1 and 3.2 tackle concerns regarding water supply and availability. Question 3.1 attempts to gain information on the specific water sources utilized by a community. It is not expected that specific information on the quality of water be available at this level which is why such information is not included in the section. Water quality of the water source is an important consideration that is a key parameter of the technology selection tool described in the Chapter 5. For the purposes of the survey instrument, a general idea of water quality is determined from the types of water sources utilized.

Question 3.2 addresses the issue of access. Although access to water is not a specific concern of HWTS technology per se, such information is valuable in understanding the overall water situation of the target community. The importance of access to water should not be understated; water access is not considered more completely in the survey only because it does not fit into the considerations of HWTS technologies.

This section would also be where one would include questions on water use practices such as safe water storage and hygiene. However, it was determined early on in the process that such information was not typically known by the implementers of the technology and that these questions could only be addressed completely through interview and observation at the household level. It is with this reasoning that questions pertaining to these issues are not included in the implementation organization survey.

Question 3.3 is concerned with demographics of the population that may impact program implementation. For instance, urban/rural considerations come into play with technologies that require high levels of technical assistance or depend on commercial means of marketing. In both cases, high density urban areas might be advantageous since homes are concentrated in one area allowing more access to technical assistance and more exposure to mass media and other mass marketing approaches. These aspects are explained in more detail in the technology selection tool chapter of the thesis.

Questions 3.4 and 3.5 address whether health studies were conducted for the area prior to implementation, this issue is addressed further in subsequent sections. Question 3.6 prompts the organization for further data or research obtained prior to implementation. In questions 3.4 to 3.6, if the organization is determined to have used prior studies on the target area, the interviewer will follow-up the question by asking if any of the said data is available for review.

Question 3.7 attempts to gauge in a qualitative manner whether the topic of the section, "Target Population and Water User Practices", is considered by the organization as important to program success. This gives the interviewer an idea of what criteria are used for evaluating program efficacy.

Problems Encountered and Potential Improvements:

The questions for this section posed no problems in terms of being clear and understandable. However, information in regards to water practices and access was often not known by the organizations interviewed. The same could be said for the demographics of the target population. It was also notable, with the exception of the Anglican Church of Kenya's SODIS implementation project and the NETWAS ceramic candle filter study, that there were very little, if any, baseline health studies conducted prior to system implementation. Target population and water use practices, as well as health information, are the main topics addressed by the "Household Survey" developed. The "Household Survey" is discussed in Section 3.6.

3.3.2 Resource Availability

Questions Included in Section:

4 Resource Availability

- 4.1 Are resources and raw materials to construct, operate and maintain the HWTS locally available and accessible? Are they utilized in manufacturing the HWTS technology?
- 4.2 Is skilled labor available to locally manufacture HWTS technologies?
- 4.3 How important is the availability of local materials and labor to the success of programs?

Intent of Section:

The section is simple in that it addresses whether there are raw materials and skilled labor available for the manufacturing of HWTS technologies. Resource availability is an important parameter considered in the implementation of programs in developing countries and oftentimes is seen as one of the sole determinants of whether a technology is appropriate for a target area.

Resource availability varies from technology to technology. For instance, a technology such as the concrete BioSand filter might be more material and labor intensive than a technology such as SODIS. Furthermore, in knowing the technology being implemented, specific questions in regards to resources may be asked. Again, using the concrete BioSand filter as an example, one would ask if sand, gravel, and concrete are available as well as the skilled labor required for concrete work.

Problems Encountered and Potential Improvements:

The questions for this section pose no problems.

3.3.3 Education and Training

Questions Included in Section:

5 Education and Training

- 5.1 Are training/education programs a part of the pre-implementation activities?
- 5.2 If yes, please describe the specific training/education program given in pre-implementation:

Intent of Section:

This section addresses the questions pertaining to whether education, training, and awareness creation are utilized during the implementation of the technology. A number of the organizations surveyed in Kenya cited education as being integral to whether a technology was accepted by potential users in a community.

The questions prompt users for qualitative answers and attempt to gauge the types of education and training conducted, as well as the frequency and extent to which these are employed.

Problems Encountered and Potential Improvements:

The questions for this section pose no problems.

3.3.4 Funding

Questions Included in Section:

6 Funding

- 6.1 What is the primary source of funding for the program/product implementation?
- 6.2 To date, how much total funding have you received?
- 6.3 What is the average funding cost per family?
- 6.4 Is funding primarily for implementation alone or for maintenance and operation as well?

6.5 Were any cost-benefit analyses conducted on the target population prior to implementation? If yes, what were the primary results of these analyses?

6.6 Were efforts made to determine the target populations wealth information and "willingness to pay" prior to program implementation? If yes, what were the primary results of these efforts?

Intent of Section:

This section addresses the issue of funding from two directions, one in regards to the source of funding for the implementation of the program and the other in regards to whether the program is financially sustainable.

Questions 6.1 to 6.4 address the funding utilized by the organization and whether this funding was provided for implementation alone or for operation and maintenance as well. Funding sources and amounts are determined to evaluate if the program is utilizing resources effectively depending on the target area considered.

Questions 6.5 and 6.6 determine whether any financial analyses were conducted prior to implementation to determine if the project was sustainable from an economic viewpoint. Question 6.5 addresses the traditional cost-benefit analysis which monetizes all facets of a project, revealing whether overall costs are worth the financial benefits gained. Question 6.6 addresses a willingness-to-pay study which in turn determines the amount of money a typical resident would be willing to pay for a particular HWTS technology. Both analyses are conducted to gauge whether a technology can be operated and maintained effectively with the available financial resources of a community.

Funding is an important issue in program implementation as initial financial resources of implementing organizations as well as small and even large businesses are oftentimes not sufficient to cover start-up operations of for a new project.

Problems Encountered and Potential Improvements:

Organizations in Kenya were surprisingly open to providing financial information about their operations. Questions for the section were easily understood.

3.4 Implementation Sections (Evaluation Methodologies and Targets)

The following sections of the survey address considerations during implementation of the program. Of specific interest in these sections are the evaluation methodologies or "targets" employed by various organizations to determine if programs are being implemented successfully.

At least five different types of health-based targets have been identified by either the WHO 3rd Edition Guidelines for Drinking Water Quality (WHO GDWQ 3rd Edition, 2004) and/or the Implementation Working Group of the WHO Network. They are:

- 1. Health Outcome
- 2. Water Quality
- 3. System Performance
- 4. Specified Technology
- 5. Behavior/use (Social Acceptability)

Health outcome, water quality, and system performance are defined and explained in the World Health Organization 3rd Edition GDWQ. Specified technology is a target that was not utilized in this survey instrument due to the fact that it is highly specific to a particular technology and does not fit well into the overall framework of this survey, which addresses the entire universe of HWTS systems, or in other words, a wide variety of technologies. Behavior/use is a target that has been added to take into account other concerns critical to successful, sustainable implementation. Additionally, another potential target, "Costs", which pertains to financial and economic considerations, has also been included in this survey.

3.4.1 Operational Monitoring

Questions Included in Section:

7 Operational Monitoring

The following section has the purpose of obtaining basic information on the operational monitoring procedures employed by an organization. The standards by which the programs are measured and indicators by which program success is evaluated are addressed in subsequent sections.

- 7.1 Is operational monitoring conducted? (IF NO, MOVE TO QUESTION 7.9)
- 7.2 If yes, please describe briefly:
- 7.3 What is the frequency of operational monitoring?
- 7.4 What is the extent of operational monitoring? (average number of households/total number in given implementation area)
- 7.5 Who conducts operational monitoring?
- 7.6 Who funds operational monitoring?
- 7.7 What is the reporting hierarchy of the operational monitoring?
- 7.8 Are other organizations involved in operational monitoring?
- 7.9 Briefly, what standards are used as a basis for adequate **water quality**? (e.g. WHO guidelines, National Standards, NSF standards, etc.)

7.10 Briefly, what parameters are used to assess **system performance?** (e.g. pH, turbidity, chlorine residual, flow, presence/absence bacterial testing, etc)

Intent of Section:

The section addresses issues regarding the O&M (O&M monitoring) of HWTS technologies currently implemented by an organization. Of interest is the method, frequency, and extent of O&M monitoring. Also of concern is how O&M monitoring is funded and who conducts the said monitoring of these implemented technologies. It is important to ascertain information on O&M practices to determine if a technology is being monitored effectively. Successful and wide-scale implementation of a technology can be negated if O&M is neglected or carried out poorly, or if use of the technology is discontinued after a short period of time.

In order to utilize evaluation methodologies effectively one needs to determine if there is adequate data available to be analyzed. This is addressed by determining the type and amount of data collected and recorded during operation, maintenance, and monitoring of the programs in question.

Questions 7.1 to 7.8 address the details of O&M while questions 7.9 and 7.10 take a preliminary look at what standards and assessment parameters are employed. In much the same manner that questions were asked in earlier sections to gain understanding of topics addressed fully in later sections, questions 7.9 and 7.10 obtain preliminary data on what, if any, water quality and system performance standards are used to evaluate program success.

Problems Encountered and Potential Improvements:

This section poses no problems as questions were easily answered by organizations when the survey was tested in the field. This section also serves as a good indication to the interviewer as to how to go about following sections of the survey.

Most of the organizations conducted some form of operational monitoring of their implemented systems.

3.4.2 Target: Health Outcomes

According to the World Health Organization: In some circumstances, especially where there is a measurable burden of water-related disease, it is possible to establish a health-based target in terms of a quantifiable reduction in the overall level of disease. This is most applicable where adverse effects soon follow exposure and are readily and reliably monitored and where changes in exposure can also be readily and reliably monitored. This type of health outcome target is therefore primarily applicable to microbial hazards in both developing and developed countries and to chemical hazards with clearly defined health effects largely attributable to water (e.g., fluoride). In other circumstances, health-based targets may be based on the results of quantitative risk assessment. In these cases, health outcomes are estimated based on information concerning exposure and dose–response relationships. The results may be employed directly as a basis to determine water quality targets or may provide the basis for development of performance targets. There are limitations in the available data and models for quantitative microbial risk assessment. Short-term fluctuations in water quality may have a major impact on overall health risks – including those associated with background rates of disease and outbreaks – and are a particular focus of concern in expanding application of quantitative microbial risk assessment. Further developments in these fields will significantly enhance the applicability and usefulness of this approach. (WHO GDWO 3rd Edition, 2004)

This topic is discussed further in the following sections.

Questions Included in Section:

8 Target: Health Outcomes

Do you think that health outcomes are an important indicator of program/product success?

Was a cohort study conducted to evaluate the impact of the program/product? If yes, go on to the rest of section 9.

Cohort Study Questions

(from Jim Wright and Stephen Gundry – IWA – Marrakech Special Session on HWTS - Questionnaire)

- 8.1 Age cohort studied (e.g. children 24-59 months; all participants, or children 5-14 years) (General diarrhea / cholera / other (please specify: _____)
- 8.2 Health outcome studied:
- 8.3 Definition of health outcome (e.g. how was diarrhea defined in study?):
- 8.4 Method of assessing health outcome (e.g. weekly interviews, through diary, etc.):
- 8.5 Number of individuals within age cohort in intervention group:
- 8.6 Number of individuals within age cohort in control group:
- 8.7 Number of individuals suffering health outcome in intervention group:

- 8.8 Number of individuals suffering health outcome in control group:
- 8.9 Number of person-days of health outcome monitoring in intervention group:
- 8.10 Number of person-days of health outcome monitoring in control group:
- 8.11 Number of person-days of ill health in intervention group:
- 8.12 Number of person-days of ill health in control group:

Characteristics of Study Setting

- 8.13 Type of study area (rural / urban / peri-urban):
- 8.14 Percent of participants (in both groups) with access to sanitation:
- 8.15 Percent of participants (in both intervention & control groups) using improved water supplies (i.e. protected wells, boreholes, protected springs or standpipes):
- 8.16 Percent of participants treating water (e.g. by boiling) before the start of the intervention:
- 8.17 Percent of participants using covered water vessels before onset of study:

Intent of Section:

Most of the questions included for this section of the survey were derived from Jim Wright and Stephen Gundry's "Summary of Intervention Study Characteristics" questionnaire which was presented at the International Water Association Congress Workshop on Household Water Treatment in Developing Countries held in Marrakech (Wright and Gundry, 2004).

The following explanation on pages 64 to 66 on the health outcome target has been provided by Jill Baumgartner of the Harvard School of Public Health who was our team's public health expert.

The risk of microbial disease associated with drinking water is presently a priority of concern among many developing nations. Water-borne disease transmission occurs through the consumption of contaminated water, and can cause those illnesses transmitted by the fecal-oral route, including diarrhea. In the 1996 Global Burden of Disease (GBD), Murray and Lopez calculated that 5.3 percent of all deaths and nearly 7 percent of all Disability Adjusted Life Years (DALYs²) lost were attributable to diarrheal and selected parasitic infections, a consequence of inadequate access to clean water and sanitation (Murray and Lopez, 1996). Annually, two million people, most of them children under five, die from water-borne diseases like diarrhea and millions more become seriously debilitated (WHO, 2005).

² The Disability Adjusted Life Year, or DALY, represents one year of life lost to poor health.

The GBD study illustrates that water, sanitation, and hygiene are major causes of death and morbidity, particularly among children under five. Indeed, the burden created by this risk factor exceeds the burden of many major diseases such as malaria and tuberculosis. The results of the GBD study show the high potential for interrupting the transmission of fecal-oral and other parasitic disease though simple household interventions such as safe drinking water storage and disinfection in the home (Quick et. al, 1999).

The health outcomes portion of the HWTS implementation organization survey introduces an epidemiologic method for measuring health outcomes associated with the implementation of a given HWTS intervention. Outcome measures from epidemiology studies are used to estimate risk. In epidemiology, risk has the connotation of the probability of illness. In other words, it describes how common a disease is in a particular community. The two measures used to describe the commonness of a disease are "incidence" and "prevalence." The incidence of a disease is the number of new cases occurring within a certain population during a specified time period (e.g. diarrhea cases per 1,000 persons per year). Prevalence is the number of cases of a disease within a specified population at a specific point in time (e.g. diarrhea cases per 1,000 persons). For the purpose of evaluating a HWTS intervention using a health outcome target, we might use prevalence to decide where to focus an intervention and we would be most concerned with measuring incidence of disease with and without the intervention.

In the survey portion above, Question 8 poses the question of whether or not health outcomes are considered by the implementing organization to be an important factor in determining the HWTS program or product success. The section then goes on to ascertain if the organization has conducted an analytical epidemiologic study, specifically a cohort or case-control study, to assess health outcomes in the population of interest. The remaining questions in the section apply only to organizations that have completed such a study.

If the organization has completed a health outcomes study, Question 8.1 determines the population cohort(s) in which the study took place. Typically, children under the age of five are enrolled in health outcomes studies, as they tend to have a higher incidence of water-borne disease compared to other age cohorts. Question 8.2 goes on to report the specific health outcome studied. The outcomes and impacts of waterborne diseases can be acute, chronic or delayed. The effects of acute diseases such as cholera occur over a short period of time, whereas the effects of chronic diseases such as skeletal fluorosis accumulate over much longer periods of time. For the purpose of assessing an intervention, implementing organizations are most concerned with the intervention's effect on acute diseases due to time and financial constraints in measuring a particular health outcome. Potential waterborne health outcomes of interest may include diarrheal disease, cholera, typhoid and other acute diseases. Given the high incidence of diarrheal disease in children and ease of diagnosis, it is the most frequently chosen waterborne disease health outcome of interest.

Questions 8.3 and 8.4 refer to the methodology used in study design, specifically how the outcome of interest is defined (i.e. should investigators define diarrhea as watery and frequent stools or just as watery stools, and for what time period?). An equally important consideration is how this will be monitored. Will mothers record diarrheal disease incidence for their children in a diary themselves or will the case information be collected at the local clinic? It is up to the investigator to decide which method will yield the most valid and accurate measurements in a particular population and setting.

Questions 8.5 to 8.12 refer to measurements recorded for a particular health outcomes study. There are several options for using an epidemiologic study to measure health outcomes with an intervention. Two of the most-common study types used in the HWTS intervention assessment literature will be discussed here: cohort and case-control studies. In a cohort study, the population under investigation consists of individuals who are at risk of developing a specific disease or health outcome. These individuals will then be observed for a period of time in order to measure the frequency of occurrence of the disease among those exposed to the suspected causal agent as compared to those not exposed. Exposure can refer to individuals' contact with an intervention as well as a risk factor for disease or illness. In this instance, we would consider the "exposed" group to be those individuals who used the HWTS intervention and compare their incidence of disease to the individuals not exposed to the HWTS intervention. Incidence among the unexposed group would represent baseline prevalence of disease and serve as a benchmark for comparison of individuals with the intervention.

The second type of study, the case-control study, examines the association between exposure and a health outcome by comparing individuals already ill with the disease of interest (i.e. cases) to a control group that is a sample of the same population from which the cases were identified. The advantages of case-control studies are that they require smaller sample sizes, fewer resources, less time and less money, and are sometimes the only way to study rare diseases such as typhoid. The difficulties are in appropriate study design to minimize bias, including the selection of appropriate controls and the control of confounding variables and minimizing recall bias. Recall that bias is particularly problematic in studies on diarrheal incidence in that family members have the difficult task of trying to recall the number of times a child had diarrhea in the past six months or year.

The remaining questions in the survey, 8-13 to 8-17 collect information on the study setting. This information is helpful in assessing any potential confounding factors in the study population as well as conducting descriptive epidemiology. Descriptive epidemiology is a quick and easy way to assess the possible determinants of disease in the population of interest, and can often lead to suggestions of important risk or protective factors.

Problems Encountered and Potential Improvements:

Only a few of the HWTS implementing organizations in Kenya had conducted a health outcomes study. The commonly stated reasons for not conducting a health outcomes study included cost of study design and implementation, personnel limitations, and time constraints. Organizations concerned with chronic diseases resulting from long-term exposure (i.e. skeletal fluorosis) will need to wait many years before being able to assess the health outcomes of their particular interventions.

3.4.3 Target: Water Quality

According to the World Health Organization: Water quality targets are established for individual drinking-water constituents that represent a health risk from long-term exposure and where fluctuations in concentration are small or occur over long periods. They are typically expressed as guideline values (concentrations) of the substances or chemicals of concern. (WHO GDWQ 3rd Edition, 2004)

This topic is discussed further in the following sections.

Questions Included in Section:

9 Target: Water Quality

How important are water quality targets in evaluating program success?

Was water quality tested to evaluate the impact of the program/product? If yes, go on to the rest of section 9.

- 9.1 What standards are used to measure water quality?
- 9.2 Indicator bacterial removal: Initial and final concentration (CFU E.Coli or thermotolerant coliform bacteria/100 ml) and % removal.
- 9.3 Analytic Method (Standard Methods, ISO, etc), Lab or Field Instrument(s) and Detection Limit:
- 9.4 Indicator for viral removal (e.g. F-RNA coliphage):
- 9.5 Analytic Method (Standard Methods, ISO, etc.), Lab or Field Instrument(s) and Detection Limit:
- 9.6 Protozoa removal (e.g. cryptosporidium, giardia):
- 9.7 Analytic Method (Standard Methods, ISO, etc), Lab or Field Instrument(s) and Detection Limit:
- 9.8 Helminth removal (e.g. ascaris):
- 9.9 Analytic Method (Standard Methods, ISO, etc), Lab or Field Instrument(s) and Det.Limit:
- 9.10 Laboratory Site: # HWTS units tested

HWTS unit Volume (L) or Flow rate (L/day):

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Duration:
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9.11 Pilot Test Field Site(s):
# HWTS units tested:
HWTS unit Volume (L) or Flow rate (L/day):
Duration:

9.13 Full-Scale Application Site(s):
# Units installed:
Unit Volume (L) or Flow rate (L/day):
Duration:

9.14 Procedures used for Lab Test of this Technology:
9.15 Procedures used for Field Test of this Technology:
9.16 Sludge or other Disposal Issues:
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9.17 Contact Person (Principal Investigator or other person(s) responsible for validation studies):

Intent of Section:

Water quality has a significant impact on health in both developing and developed nations. The World Health Organization (WHO), in an attempt to address this concern, has developed an evaluation methodology to deal with issues pertaining to water quality. This methodology takes the form of normative "guidelines" that provide an authoritative assessment of the health risks associated with exposure to health hazards through water and of the effectiveness of approaches to their control (WHO, 2001).

There are actually three guidelines put forth by the WHO in regards to water quality issues, these are listed as follows:

- Guidelines for drinking-water quality.
- Guidelines for the safe use of wastewater and excreta in agriculture and aquaculture.
- Guidelines for safe recreational water environments.

Of particular interest to this thesis is the first set of guidelines, those pertaining to drinking water quality.

It must be made clear that the World Health Organization considers water quality as a "health-based" target. This implies that water quality is not a target in and of itself but is instead considered a measure that may be used to evaluate overall impacts on health. It follows that the guidelines in question do not consist solely of fixed limits for specific contaminants of concern, but instead address an overall health risk assessment methodology comprised of several components. In other words, the limits discussed in this section for water quality do not represent the entire health risk assessment approach established by the WHO, but only present one of the components on which the risk assessment is based. This risk assessment methodology is not discussed in this chapter but is introduced briefly in Appendix C (WHO GDWQ: Supplemental Information) to provide a background and context for the water quality target considered in the survey.

That said, the WHO approach to water quality is not necessarily that utilized by other implementing agencies around the world. Organizations such as government agencies, or NGOs operating within countries subject to those government agencies, may not view water quality standards in the context of health but may utilize water quality as a target in itself. Although these agencies and organizations often realize that the ultimate impact of meeting fixed water quality targets is the improvement of health, the organization may not necessarily go through the effort of establishing a formal connection between the two through their own health outcome evaluations, for example, and may consider water quality standards as the end-all evaluation target for whether a technology is operating effectively and whether users are receiving "safe" water. Such is the case in industrialized nations; for example, in the United States, the Environmental Protection Agency (EPA) has strict drinking water quality standards for over 100 contaminants and their Maximum Contaminant Levels (MCLs). Such is also the case in Kenya where water quality is tested against defined standards without any additional analysis in terms of risks to health.

The water standards addressed in this section may be used in both ways: as a target under health or as a target in and of itself. This section of the survey pertains to the collection of information on the specific water quality parameters tested for as well as the testing methods utilized by implementation organizations.

For the purposes of this document, the following sections addressing the target of water quality are limited to a discussion of microbiological contamination of drinking water sources and does not go into the details of standards pertaining to contamination by other chemical constituents.

3.4.3.1 Guidelines for Drinking Water Quality (GDWQ)

The main purpose of the guidelines for drinking water quality (GDWQ) is to protect human health through the provision of a set of water quality guidelines that may serve as a basis for the development of national quality standards. The guidelines aim to ensure the safety of drinking water through the elimination or reduction of constituents of water that are known to be hazardous to health. (WHO GDWQ 3rd Edition, 2004)

The guidelines serve as an international point of reference for water quality issues. Although the guidelines present numerical values for water quality measures, the real intent of the guidelines is to propose "good practice" or "adequate safeguards" in minimizing risk to deleterious health effects attributable to water-borne pathogens. It must be noted that the 3rd Edition GDWQ are not meant to be adopted directly in every scenario across the globe. In fact, the organization recognizes that social and environmental conditions may require standards that vary significantly from those recommended by the guidelines. That being said, the 3rd Edition GDWQ does suggest that a risk-benefit approach be adopted to address water quality-related issues.

The first and second editions of the GDWQ gave precedence to microbial safety and provided fixed guideline values for a large number of chemical hazards as well as for some microbial indicators and contaminants such as *E. coli* and thermotolerant coliform bacteria. These guidelines served as the basis for regulation and standard setting to ensure the safety of drinking water. In the third edition of the GDWQ, less focus was given to the provision of fixed water quality limits for microbial contamination although limits for chemical constituents were retained. Microbial contamination is still addressed, only now through guidelines pertaining to the development of comprehensive system-specific "water safety plans".

In the most recent version of the guidelines it is recommended that median raw water turbidity "be below 0.1 NTU for effective disinfection" to occur (WHO GDWQ 3rd Edition, 2004) and that drinking water should contain no indicator organisms, such as total coliform, *E. coli*, or F-RNA coliphages (WHO GDWQ 3rd Edition, 2004). Microbial risks are concerned with a variety of different pathogenic micro-organisms. However, specific information on these various micro-organisms is not utilized in the derivation of fixed water quality limits. Instead, a generalized approach based on tried and tested principles such as fecal pollution prevention and sound engineering practice are used. As such, the results are end-product fixed water quality limits which can be evaluated by microbial analysis of finished water at the point of consumption.

Testing of microbial quality may be the responsibility of the supplier, user, an independent surveillance agency, or a combination of the three. In Kenya, the Water Resources Authority was the authority in charge of water quality testing. Testing of source water, water immediately after treatment, water in distribution systems or stored household water should all be targeted for testing.

The reader is referred specifically to the World Health Organization's "Guidelines for Drinking Water Quality (3rd Edition, 2004)" for specific standards relating to microbial contamination and operational guidelines. Supplemental information to the guidelines that has not been included in this section has been provided in Appendix C.

3.4.3.2 Application to the HWTS Implementation Organization Survey

The survey has the intent of evaluating two main items in its consideration of water quality targets: (1) what, if any, water standards are utilized by the implementing organization and (2) what types of testing methods are utilized by the organization in determining if drinking water quality meets the set standards. In doing so, the survey determines if water quality targets are being considered to evaluate the success of a program, and whether the methods of using these targets are effective.

Problems Encountered and Potential Improvements:

This section was applied with varying success in the field. Some organizations had difficulty providing the technical information requested in the section. Although most organizations recognized the importance of water quality, more often than not the interviewee was not technically knowledgeable of the laboratory analysis performed on the treated water. In most cases the organization relied on the Kenya Water Resources Authority to conduct water quality testing.

Some organizations, such as KWAHO, CDN, and ACK had in-house laboratories for testing water quality. Subsequently, these organizations were also those that were able to address this section more completely.

This section is technical in nature and it must be ascertained by the interviewer if the interviewee has an adequate knowledge of water quality parameters and laboratory testing methods. If the interviewee cannot provide answers to these questions then it might be worthwhile to the interviewer to find another member of the organization more proficient in answering these questions.

3.4.4 Target: HWTS System Performance

According to the World Health Organization: performance targets are employed for constituents where short-term exposure represents a public health risk or where large fluctuations in numbers or concentration can occur over short periods with significant health implications. They are typically expressed in terms of required reductions of the substance of concern or effectiveness in preventing contamination. (WHO GDWQ 3rd Edition, 2004).

This topic is discussed further in the following sections.

Questions Included in Section:

10 Target: HWTS System Performance

Performance is defined as a target specific to the technology being employed in that it "performs" as intended according to its specifications. Performance targets should not to be confused with water quality targets which are concerned specifically with the quality of water produced by the system.

Is "system performance" used as a target/indicator to ascertain if a HWTS program/technology is being utilized effectively?

If yes, please answer the following specific questions:

10.1 What standards are used to measure system performance?

10.2 Is a performance data sheet with the following information available to potential buyers for each system?

Source: National Sanitation Foundation's "Drinking Water Treatment Unit-Heath Effects" ANSI/NSF 53-1999, Section 7.4 Performance Data Sheet:

- 1. Complete name, address, and telephone number of manufacturer
- 2. Model number and trade designation
- 3. Reduction capabilities of specific contaminants in Table 3 (pH, temperature, total dissolved solids, total organic carbon, turbidity) and Table 4 (alkalinity, hardness, pH, polyphosphate as P, total dissolved solids, temperature, turbidity)
 - * name of contaminant
 - * average influent and effluent concentration(s) during test period and percent reductions (NOTE: Average concentrations shall be the arithmetic mean of all reported influent or effluent concentrations the detection limit value shall be used for any nondetectable concentrations. The percent reduction shall be calculated from the arithmetic mean of the influent and effluent concentrations)
 - * US EPA maximum contaminant level
 - * VOC claims
 - * testing parameters
 - *rated service flow rate in L/min or L/day (gpm or gpd)
 - * maximum working pressure in kPa (psig)
 - * general installation conditions
 - * general operation, maintenance requirements including, but not limited to:
 - frequency of component change or service to system
 - user responsibility
 - parts and service availability
 - * manufacturers limited warranty
 - * statement that the system conforms to the ANSI/NSF 53 for the specific performance claims as verified and substantiated by test data."
- 10.3 Are the requirements of the said data sheet met for most households?
- 10.4 How important are performance targets in evaluating program success?

Intent of Section:

3.4.4.1 American National Standard / National Sanitation Foundation (NSF)
International Standards

The National Sanitation Foundation International (NSF) is an independent non-profit organization dedicated to public health and safety and the protection of the environment. The organization acts by certifying products and writing standards for food, water, air, and assorted consumer goods. The NSF is also involved in providing education and third-party conformity assessment while representing the interests of all stakeholders (NSF Website, 2005).

The NSF has established a set of standards in coordination with the American National Standards Institute (ANSI) for drinking water treatment units (NSF, 1999). It is in this regard that the organization is of specific interest to the discussion of the system performance target presented in this section. The standards presented by the organization act in much the same way as the EPA drinking water standards in the previous section. The similarity stems from the fact that both sets are not mandatory for HWTS technologies, but instead provide a framework and guidance for setting proper water quality and system performance targets. Such standards may be adopted directly by an organization or government policy or adapted and modified to suit area specific needs. However, the NSF standards differ from the WHO guidelines in that they address issues pertaining specifically to the treatment technologies being utilized and do not directly focus on the water these units are providing. In other words, the NSF standards are focused on how a technology performs in treating water and not specifically on the quality of the water itself.

Although not mandatory, the standards do set an acceptable level of performance for drinking water treatment units and in doing so transmit a level of confidence and credibility to a technology being employed. The standards are based on professional judgment and give preference to the use of performance criteria that are measurable or easily tested by simple methods.

3.4.4.1.1 NSF Standards for Drinking Water Treatment Units

NSF Standards for Drinking Water Treatment Units, or NSF Standard 53, have the objectives of establishing minimum requirements for materials, design and construction, and performance of drinking water treatment systems that are designed to reduce specific health-related contaminants in public or private water supplies (NSF Standard 53, 1999). These contaminants may be microbiological, chemical, or particulate (including filterable cysts). The standards address a number of treatment units including those at the household level, and even go as far as to consider systems used in the production of bottled water. The following discuss briefly the sections included in the NSF standards.

Materials. The standards set forth in this section pertain to the materials of which the treatment unit is composed. Standards are set on the potential contaminants that these materials may impart upon contact with the treated water. Specifically, the standards utilize "Maximum Drinking Water Level" (MDWL) and "Good Manufacturing Practices" (GMP) concentrations that serve as the allowable limits for these potential contaminants. The standards reference those set forth by the United States Environmental Protection Agency (EPA). The standards also address temperature resistance and the evaluation or testing methods to be employed.

Design and Construction. This section addresses issues particular to the performance of the system from a design and construction standpoint. Subsections include: Working Pressure, Performance Indication, Elements, Flow Control, Waste Connections, Product Water Dispensing Outlets, and Hazards. "Performance indication" pertains to effective means that warn users if the system is not working properly, while "hazards" refer to the potential of the units having sharp edges that may physically harm users.

Chemical, Mechanical, and Structural Performance. This section is lengthy and includes detailed standards addressing multiple facets of the drinking water treatment units. Of particular interest in this section is its consideration of "claims" pertaining to aesthetic effects, chemical reduction, organic chemical reduction, and mechanical filtration reduction. The standards set forth primary criteria that need to be satisfied prior to a technology being able to claim that it addresses the aforementioned water quality issues. Remaining subsections address structural integrity, filter media, rated pressure drop, minimum service flow, chemical reduction test methods, and mechanical filtration test methods. This section presents comprehensive supporting information for the standards established and tests suggested.

Instruction and Information. This section addresses issues concerning the required instructions and specifications to be included with the technologies provided. Such instructions would include those for installation, operation, and maintenance as well as the provision of a data plate physically attached to the unit. In addition to this, sufficient provision of replacement components is also required throughout the design life of the system. Lastly, a performance data sheet is required that actually serves as the basis for the information included in the HWTS implementation organization survey.

Some additional NSF standards also of interest are: Standard 42 (Drinking Water Treatment Units – *Aesthetic Effects*), Standard 60 (Drinking Water Treatment Chemicals – *Health Effects*), and Standard 61 (Drinking Water Treatment Units – *Health Effects*).

3.4.4.1.2 Application to the HWTS Implementation Organization Survey

Standard 53 of the document specifies minimum product literature requirements that manufacturers must provide to authorized representatives and owners (NSF Standard 53, 1999). In other words, the standards put forth the required instructions deemed essential to the correct operation and subsequent performance of the technology in question. These have been included in the survey due to the fact that these standards are presented in an efficient and easily understandable format that fits well with the overall structure of the survey. In ascertaining if these requirements have been satisfied, the interviewer can assess whether a set of system performance criteria are recognized and utilized by the organization implementing the technology.

It must be mentioned once again that such standards, although specific to system performance, are once again considered by the WHO as health-based targets. Although this is not formally addressed in the NSF standards, the standards do recognize that the ultimate purpose or goal of the standards set is the improvement of health.

3.4.4.2 United States Environmental Protection Agency

Prior to the existence of the NSF standards discussed in the previous section, the United States Environmental Protection Agency (EPA) provided similar system performance standards in a document entitled "Guide Standard and Protocol for Testing Microbial Water Purifiers" (US EPA, 1986). While this document is out of date and while EPA is no longer the responsible entity with regards to household systems (this responsibility has devolved to NSF) it is nonetheless instructive to review EPA's approach. It must be noted that the standards address microbiological contaminants alone and do not consider other aspects of water contamination such as those by chemical constituents.

While the standards set by NSF International present a comprehensive set of standards pertaining to every facet of a technology's performance during operation and use, the EPA standards take a narrower approach to system performance by specifically addressing a protocol for testing microbiological water purifiers. In other words, the EPA standards determine a technology to be performing adequately if the said technology satisfies the requirements set forth by a predetermined test methodology. The standards set forth to satisfy the following goals (US EPA, 1986):

- Provide a basic framework and starting point for the testing and evaluation of water purifiers for EPA registration
- Provide a guide to the acceptance of water treatment units for requirements of the Safe Drinking Water Act
- As a testing guide to manufacturers wishing to have their units considered as microbiological water purifiers
- As a guide to consumers regarding what they may expect from microbiological water purifiers tested using the protocol set forth by the standards

The above goals are somewhat similar to those established for the NSF standards in that they provide a means for microbial water purifiers to gain credibility based on an established set of guidelines. Once again, the units are not required to submit to these standards but stand to gain acceptance by users because the standards are based on EPA targets set for safe drinking water quality.

The standards state that a unit may only be called a microbiological water purifier if it has the ability to remove, kill, or inactivate all types of disease-causing micro-organisms from water, including bacteria, viruses, and protozoan cysts (US EPA, 1986). The standards serve as a general guide to the minimum features and framework for testing the efficacy of these technologies.

The standards are decidedly "performance-based" and utilize realistic worse case challenges and test conditions for source water quality (US EPA, 1986). Among the treatment units considered by the standards are ceramic candle filters (filtration and adsorption), halogenated resins (chemical disinfection), and ultraviolet disinfection. Although the standards only focus on these types of units, it was intended that the protocol developed be applicable to other treatment technologies of concern. Although not in the same detail as the NSF standards, the EPA "Guide Standards and Protocol" does touch upon issues such as chemical constituents emanating from the units themselves, and also puts forth requirements on instructional information to be included with the product upon distribution. However, the main thrust of the document is the establishment of standards and required tests pertaining to the microbiological reduction required in order for a unit to be considered as a water purifier.

Problems Encountered and Potential Improvements:

This section of the survey experienced some difficulty during application in the field. The main constraint of the section was explaining to organizations the distinction between and system performance and water quality targets. Oftentimes, the technologies were not of the type where the performance data was readily available. For example, the concrete BioSand filter project in Machakos was very much a local undertaking and did not have the resources to disseminate literature on the filters installed. In addition to this, it was recognized by a number of organizations that the target population using these technologies often did not possess the capacity or need for this type of instructional information. Organizations recognized that instruction through personal contact with users was the most effective method of gauging system performance.

A number of technologies are in their early stages of development and have not been distributed on a wide enough scale to have a set document with established standards pertaining to system performance. This is not to say that organizations interviewed did not recognize system performance as an important variable to consider in program implementation. In fact, for organizations implementing technologies employing somewhat larger physical units, such as concrete BioSand and defluoridation filters, it was observed that the structural performance of these units was one of the more closely observed parameters during operation and maintenance. Even SODIS technology addressed system performance through the detailed selection of appropriate plastic bottle types to be used for implementation. In other words, this section of the survey led us to conclude that the organizations evaluated do utilize system performance as a target for evaluation. However, it is proposed that this section of the survey be improved so as to be better able to collect information regarding this particular target.

3.4.5 Target: Behavior/Use (Social Acceptability)

Behavior/use (social acceptability) is different from previous targets discussed as it pertains to considerations that are more qualitative in nature. While some considerations within the target are quantifiable, such as rate of adoption and sustained use, most are only qualitative. This target might be considered as a "real world" measure of program success in so far as it evaluates programs based on factors that have not been tackled by the previous targets but are nonetheless recognized as having a major potential impact on the implementation of programs.

This target is composed of the following subsections: rate of adoption and sustained use, environmental sustainability, user input, education (training, and awareness), and social acceptance. The target looks at how the system is used, how it changes the "behavior" of users, and subsequently evaluates the parameters that may or may not lead to the sustainability of the system. The first questions asked by this section are presented below.

Preliminary Questions Included in Section:

11 Target: Behavior/Use (Social Acceptability)

The following section has the purpose of obtaining information on how the system changes the behavior of users, if the system is used properly by users, how it is accepted, and if it is sustainable.

11.1 To what extent does available support for operation and maintenance determine program/product success?

11.2 Do you use frequency of break-downs and requirements of technical support as a basis for evaluating if a program/product is effective and successful?

Intent of Section:

This section asks two simple questions to gauge how operation and maintenance and breakdowns of the technology are used to evaluate program success. These questions are included to supplement previous sections.

The subsections of this target are discussed in the next sections of the thesis.

3.4.5.1 Rate of Adoption and Sustained Use

Questions Included in Section:

Rate of Adoption and Sustained Use

We define "rate of adoption (ROA)" as the percentage of uptake of a HWTS practice or product after an initial period of training/education and/or marketing:

ROA (%) = # of people using the HWTS after 1 month of ownership # of people originally receiving or buying the HWTS

We define "rate of sustained use (ROSU)" as the percentage of continued use of a HWTS practice or product after a 1 year of ownership.

ROSU (%) = # of people using the HWTS after 1 year of ownership # of people originally receiving or buying the HWTS

- 11.3 Do you keep records of the people who initially obtain, use and/or continue to use the HWTS intervention?
- 11.4 Do you keep records of the people who are maintaining use of the system after one month of ownership? After one year?
- 11.5 Do you maintain those records in a database?

Intent of Section:

Rate of adoption and sustained use might be considered a target in itself. It pertains to whether the technology is accepted and utilized by users for a prolonged period of time. Obviously, a HWTS implementation program would not be considered a success if the rate of uptake of a technology was very low. Plainly stated, if a technology is not being used then it is not a success.

Furthermore, the target is easily quantifiable as long as records are kept and monitoring is performed on a regular basis. This makes the variables ROA and ROSU above attractive in terms of their efficacy in measuring program success.

The questions presented first differentiate "adoption" from "sustained" use and provide definitions/equations for each. The definitions are straightforward and were easily comprehended by the organizations interviewed. Specific questions then stem from these definitions, one of which asks how the data is recorded.

Problems Encountered and Potential Improvements:

There were no problems encountered in applying these questions in the field. Although most organizations did not apply this target in the manner it was defined, several organizations did have some means of evaluating if the technology was being used properly and used continuously in the community.

3.4.5.2 Environmental Sustainability

Questions Included in Section:

Environmental Sustainability

- 11.7 What are the wastes created during the entire life cycle of the product? Can these wastes be quantified in terms of cost? (cost/kg waste generated).
- 11.8 Are the raw materials used for this technology accounted for in terms of potential environmental impacts? Are these resources renewable?

11.9 Are there any other environmental impacts of the HWTS system?

11.10 How important are environmental considerations in evaluating if a program/product is effective and successful?

Intent of Section:

Environmental sustainability is a vital issue throughout the world. Buildings are now being built with "green" considerations in mind; impacts to the environment are considered throughout their life cycle, in every aspect of design, from construction to use to eventual disposal. Waste processes in manufacturing are being designed to minimize short and long-term impacts to the biosphere. The issue of renewable resources is being considered in national policies of countries across the globe. The issue is even integral to the MDGs, in fact, the water and sanitation target actually falls under the specific goal provided for environmental sustainability.

It therefore becomes pertinent that new technologies take environmental sustainability into consideration as well. Oftentimes developing nations have more pressing policy issues pertaining to hunger and poverty to address, meaning environmental concerns often fall by the wayside. This requires that steps be taken to ensure the environmental sustainability of systems, including HWTS systems, prior to their introduction into developing nations.

This section presents questions that address the environmental sustainability of the HWTS technologies implemented. Are resources renewable? Are wastes of the technologies during production and use accounted for? Are these wastes accounted for in terms of potential costs? How do these considerations affect an organization's evaluation of program success? It is important to put forth these considerations since HWTS technologies are solutions that were applied somewhat "on the fly" as temporary and immediate means to address issues of safe drinking water and therefore may not have been designed with long-term impacts in mind. Furthermore, the HWTS technologies are poised to be implemented on a very wide-scale, meaning that if numerous units of a technology are installed, then there could one day be a large impact and potentially unintended consequences in terms of the disposal of these units.

Problems Encountered and Potential Improvements:

There were no problems encountered in applying these questions in the field. Most organizations did express some concern about the renewability of resources used for construction and maintenance of these units but did not consider the impacts of technologies as waste products.

3.4.5.3 *User Input*

Questions Included in Section:

User Input

- 11.11 How frequently is user input obtained after a program/product has been employed?
- 11.12 Do users comment on the ease of operation and maintenance of the program/product? If so, what is their common perception?
- 11.13 Do users comment on how much their water has improved due to the program/product? If so, what is their common perception?
- 11.14 How important is user input in evaluating whether a program/product is effective and successful?

Intent of Section:

User input is feedback from current users of the system. There may not be a better source of data on the efficacy of a technology than the people that utilize the technology on a daily basis. Questions in this section pertain to whether users find the technology easy to use and whether operation and maintenance requirements are excessive.

User input on the perceived quality of water is also ascertained. Although microbial contamination is not observable, a qualified statement on whether water has improved visually or in terms of taste or odor after treatment does indicate success for other parameters such as turbidity and color.

The frequency that user input is obtained by the organizations is also one of the questions included in the section.

Problems Encountered and Potential Improvements:

There were no problems encountered in applying these questions in the field. It was noticeable that organizations providing commercially available technologies were in many ways much more concerned with user input than those producing locally in the community. This might be due to the overall approach in supply and demand marketing, which has a specific focus on the needs of consumers.

3.4.5.4 Education, Training, and Awareness

Questions Included in Section:

Education, Training, and Awareness

11.15 Are education and training available to users AFTER program implementation? To what extent? Who implements education and training? Who funds it?

- 11.16 In your opinion, how aware are community members of the current threats to health posed by untreated water sources? How aware are they of the technologies available to treat water on a household level?
- 11.17 How important are these factors in determining program/product effectiveness and success?
- 11.18 Are ongoing training programs provided for staff members?

Intent of Section:

Education, training, and awareness were discussed in a previous section pertaining to preimplementation of the technology. The same concept is provided here, only now in the context of whether these are continued throughout the use of the technology. A question is also presented regarding whether or not the community in question is "aware" of the problems to health posed by poor water quality and the technologies available to address this. Furthermore, the training of organization staff members involved in the implementation of these technologies is also ascertained.

Problems Encountered and Potential Improvements:

There were no problems encountered in applying these questions in the field. Most organizations continue to spread awareness and education about the technologies even after implementation. These efforts are often combined with education about sanitation and hygiene. Organizations also continue to train staff members to varying extents.

3.4.5.5 Social Acceptance

Questions Included in Section:

Social Acceptance

- 11.19 How do users receive the program/product? Are they eager or wary of the new technology?
- 11.20 In your opinion, does the program fit well in the culture of the target population?
- 11.21 Do political considerations ever come into play during implementation? Does local government and community support typically aid in the implementation of these programs/products?
- 11.22 How important are these factors in determining program/product effectiveness and success?

Intent of Section:

Social acceptance pertains to how the technology is received in a social context, or by the community as a whole. Typically, there are noticeable trends of acceptance that are common throughout an entire community. Cultural and political considerations might come into play as well.

Question 11.19 addresses acceptance by asking the specific question of how the technology is received, and whether community members are generally eager or wary of the new technology. One answer received in the field from KWAHO in regards to their implementation of SODIS was that users were very much in doubt about the efficacy of the technology, specifically doubting whether "water could be cleaned by the sun".

Question 11.20 addresses the general question of cultural acceptance. Cultural values in regards to water use can potentially be a hindrance to the implementation of new technologies, especially in traditional communities. Sometimes religion comes into effect as some regions do not believe in adding chemicals to water; other times it may merely be a case of changing common practices and habits in regards to water practices at the home.

Question 11.21 attempts to determine if political considerations come into play in the implementation of technologies. Political considerations pertain to the local government and whether the programs are supported by these entities. Sometimes a community can be controlled in such a thorough manner by its government that any programs implemented must first be approved by the said administration.

Problems Encountered and Potential Improvements:

There were no problems encountered in applying these questions in the field. The section poses very general questions which led to lengthy explanations in some instances. Some thought might be given to making these questions more specific. Organizations in Kenya typically cite the Ministry of Water³ and The Ministry of Health as being integral to "political considerations" in the implementation of technologies in the field.

3.4.6 Target: Costs

Costs in this section refer to financial and economic considerations from both a community and organizational standpoint. The questions are thus separated accordingly. Also, a section on marketing and distribution is included in the questions for this section.

The section collects cost data on implementation. The data in turn may be used to evaluate if a program is operating in a financially sound manner relative to benefits produced. Knowing the costs for various facets of program implementation also serves to give a general idea of the funding required for HWTS technology program implementation.

3.4.6.1 Individual (Household) Costs

Questions Included in Section:

Please see table on next page.

³ Kenya Ministry of Water Resources Management and Development

12 Costs

Individual (Household) Costs

Report any and all costs of the intervention incurred by the target population. Include annual quantities for the population covered by the program, description and unit costs. Expand this spreadsheet as necessary by adding rows under each cost category.

	Quantity	Description			Unit Cost	Annual Cost
12.1Capital costs ³		Item	Useful Life	Residual Value		
1 Equipment						
2 Other						
2 Oiner						
12.2 Recurrent						
costs						
1 Supplies						
2.1						
2 Labour						
3 Utilities						

Intent of Section:

The question is given in the form of a table adapted from a "Cost Assessment for Selected Household Water Treatment Interventions" by Tom Clasen and Laurence Haller (Clasen and Haller, 2004). The questions collect comprehensive data on all costs incurred by a household for the installation of a HWTS technology. These costs encompass those used to purchase the technology and progress into costs incurred during use of the technology on an annual basis. The data collected here is assumed to be sufficient for a cost-benefit analysis to be performed in the future.

Problems Encountered and Potential Improvements:

This section was somewhat difficult to apply in the field, first and foremost because organizations were typically not aware of costs incurred by households during the actual operation of the system. This information was cited as being too comprehensive and exhaustive in nature, sometimes being beyond the knowledge of interviewees. In this regard it was noted that the section might be better suited for interviews on a household level. Furthermore, unless organizations were at the location where records were kept, it was very hard to come up with the specific numbers being asked for. Hence, this section of the survey was the most tedious to apply. However, it must be noted that this section of the survey was obtained from the "Cost Assessment for Selected Household Water Treatment Interventions" (Clasen and Haller, 2004), which is intended to be provided to a respondent to be answered at their own leisure. In other words, it was not intended that the information be obtained during an interview.

3.4.6.2 Program Costs

Questions Included in Section:

Please see table on next page.

Program Costs

Report all costs of the intervention incurred other than by the target population. These costs should be accumulated and allocated to the national (N), regional (R), community(C) and household (H) level. Include annual quantities for the population covered by the program, description and unit costs. Code for the party responsible for payment as follows: National or local government (G), Donor or other funding agency (D), program implementer (P), business (B). Do not include householder expenditures that were separately reported. Expand these spreadsheets as necessary by adding rows under each cost category.

Start Up Program Costs:

	Quantity	Description		Level Code	Payer Code	Unit Cost	Annual Cost	
12.3 Capital costs ³		Item	Useful Life	Residual Value	Use N, R, C or H for each	Use G, D or P for each		
1 Building			<i>y</i> -		<i>y</i>	,		
2 Transport								
3 Equipment								
4 Other								
12.4 Recurrent costs				I.				
1 Personnel								
2 Materials/Supplies								
3 Media & IEC								
4 Transportation								
5 Equipment								
6 Maintenance								
7 Utilities								
8 Rented Space								
9 Other Recurrent								

Post Start Up Costs:

1 ost start op cos	Quantity	Description		Level Code	Payer Code	Unit Cost	Annual Cost	
12.5 Capital costs ³		Item	Useful Life	Residual Value	Use N, R, C or H for each	Use G, D or P for each		
1 Building								
2 Transport								
3 Equipment								
4 Other								
12.6 Recurrent costs				1				
1 Personnel								
2 Materials/Supplies								
3 Media & IEC								
4 Transportation								
5 Equipment								
6 Maintenance								
7 Utilities								
8 Rented Space								
9 Other Recurrent								

- 12.7 Who is typically responsible for costs incurred during the operation and maintenance of programs and products? What percent of costs are shouldered by each?
- 12.8 Are the costs incurred for the operation and maintenance typically affordable by responsible entities?
- 12.9 Is a cost-benefit analysis conducted for the program/product? Or alternatively, if a cost-benefit (or cost effectiveness) analysis was conducted prior to program/product implementation were the results of the said analysis ever verified with up-to-date field data?
- 12.10 Was a willingness to pay study ever conducted for the target population? If so, what were the methods employed and the results obtained?
- 12.11 How important are economic considerations in evaluating program/product effectiveness and success?

Intent of Section:

The question is given in the form of a table also adapted from a "Cost Assessment for Selected Household Water Treatment Interventions" by Tom Clasen and Laurence Haller (Clasen and Haller, 2004).

The information collected here is different from that in the previous section as it addresses overall program costs in start-up and post start-up scenarios. The costs are those included in the program that may be distributed among various organizations involved, specifically national or local government, donor or other funding agencies, program implementers, or businesses. The questions are quite comprehensive and provide clear instructions on what information is to be obtained. As was the case in the previous section, the data collected here is assumed to be sufficient for any cost-benefit analysis, or other standard financial type of cost analysis to be performed in the future.

The section then proceeds into questions specifically addressing operation and maintenance costs of the system and whether these costs are sustainable by the target population and/or the funding agencies. Then, earlier questions in regards to cost-benefit analysis and willingness-to-pay studies are revisited, only this time in a "post-implementation" context.

Problems Encountered and Potential Improvements:

The main problem with this section was length. The questions asked are very detailed and require numbers that may or may not be readily available to an organization at the time of the interview visit. A better approach might be to ask for financial data in the form of documents from the organization, and, upon review of the data, follow-up with the organization if there are any additional questions.

3.4.6.3 Marketing and Distribution

Questions Included in Section:

Marketing and Distribution

12.12 Are marketing activities a part of the implementation activities of your business or program?

12.13 If yes, please describe the specific marketing activities:

12.14 In your opinion. Which method of information dissemination is most effective?

12.14.1 Public – Government

12.14.2 Public - NGO

12.14.3 Quasi-Commercial – Social Marketing

12.14.4 Commercial – Private

Why do you find this method to be most effective?

12.15 What role do other organizations play in the implementation of the program/product? In your opinion, how important is the relationship to other organizations to program success?

12.16 Are local distributors and business playing a role in the implementation of the program/product? Do you feel that these distributors are important to program success?

Intent of Section:

Marketing and distribution is an important facet of program implementation. Awareness of the availability of a particular HWTS technology was cited by several organizations as being the first hurdle to overcome in implementing technologies successfully. This is especially true for commercially available technologies that rely heavily on marketing methods to promote the product(s). The questions in this section address this topic by asking the organization to describe marketing methods typically employed, ranging from wide-scale commercial approaches (television, radio, print ads, billboards, etc.) to social marketing methods conducted at the community level (skits, games, kiosks, etc.). Different entities involved in marketing are also identified. The organization is asked what method they deem most effective in promoting their particular HWTS technology.

Additionally, the methods by which products are distributed also impact the implementation of a program. For instance, the availability and accessibility of local retailers is a fundamental requirement for the implementation of products such as Waterguard and PuR®. Distributors also provide a source of technical assistance for products that contribute to program success.

Problems Encountered and Potential Improvements:

There were no problems encountered in applying these questions in the field.

3.5 Other Sections

3.5.1 Other Types of Approaches and Questions

Questions Included in Section:

13 Other Types of Approaches and Questions

HWTS implementation activities run as for-profit business enterprises will have an extensive set of additional or alternative targets, related to sales, marketing, supply chain, labor, quality control/quality assurance, product safety, etc. that have NOT been covered here. We will need to address for-profit implementation models in later iterations.

Intent of Section:

The intent of this section was to address organizations classified specifically as enterprises or businesses that promote and distribute HWTS technologies on a for-profit basis. These organizations stand to have a different set of methodologies for evaluating program success and may require additional questions to be included in the survey.

These organizations were not surveyed in Kenya.

Problems Encountered and Potential Improvements:

This section was not applied in the field.

3.5.2 Final Thoughts

Questions Included in Section:

14 Final Thoughts

14.1 Achievements to date of this program/product implementation?

14.2 Failures or limitations to date of this program/production implementation. What improvements might be suggested? Research to be conducted?

14.3 Please Rate the Following on a Scale of 1 to 4 (1=low, 4=high) in terms of:

Importance in Pre-Implementation of the Program/Product:

- 1. Current Scenario or Region Designated for Implementation:
- 2. Household Practices of Region Designated for Implementation:
- 3. Availability of Resources:
- 4. Training and Education Programs:
- 5. Available Marketing/Distribution Methods:
- 6. Funding:

Importance in Implementation / Monitoring / Evaluation of the Program/Product:

- 7. Health Outcome:
- 8. Water Quality:
- 9. Performance:
- 10. Frequency of Required Maintenance:
- 11. Available Support for Operation and Maintenance:
- 12. Rate of Adoption and Sustained Use:
- 13. Environmental Sustainability:
- 14. User Acceptance:
- 15. User Education and Awareness:
- 16. Involvement/Partnership with Other Organizations:
- 17. Political Climate:
- 18. Financial
- 19. User Willingness to Pay:

14.4 Any additional comments:

Intent of Section:

The intent of this section is simply to allow for the organization to add any information they feel is important in their implementation of HWTS programs. This section also serves as a quick summary of topics discussed, prompting the organization for a brief description of program achievements and difficulties encountered. Additionally, this section also asks the organization to "rank" parameters they feel are important for consideration in program implementation. In effect, the previous sections of the survey are reviewed and organizations give scores on a scale of one to four based on how these topics impact the success of implementation.

Problems Encountered and Potential Improvements:

The scaling questions can be excluded if time is a constraint. This section in its entirety is merely meant to provide an opportunity to tie up loose ends and allow for a more informal exchange on the part of the interviewer and the organization being interviewed.

3.5.3 Publications

Questions Included in Section:

15 Publications

Please List All References to Published Studies (s) describing program/product implementation (please provide electronic or hard copy if possible). Include the following information:

15.1	Principal author	
15.2	Principal author email address	
15.3	Name of study as it appears in source	
15.4	Complete citation of publication or other	
	source from which information is extracted	

15.5	Publication status	Published in journalPublished in conference proceedingPublished on Internet onlyPublished elsewhere (designate)Not published
15.6	Country/countries of study	
15.7	Type of home treatment and safe storage intervention	
15.8	Period of intervention	
15.9	Details of any contact with author(s) to obtain supplemental information on study.	
15.10	Relevant Websites	

Intent of Section:

The intent of this section is to collect any additional published information on the organization. Such information would include previous studies conducted or relevant sources used by the organization in the implementation of the HWTS technology.

Problems Encountered and Potential Improvements:

There were no problems encountered in applying these questions in the field.

3.6 Household Survey

As previously mentioned, the survey was modified for use on a household level. Throughout the previous section, several areas were identified as being more applicable for use on a household level. In other words, organizations typically did not have information for certain sections that were household or target population-specific. This necessitated the collection of this information from other sources, such as the households themselves.

Interviewing households was not in the original methodology suggested for the project, but in anticipating the opportunity to interview households the team developed a survey for application at this level. Given the time constraints and expediency in which the survey was developed, it was a relief that the survey held up well upon application to several households throughout Machakos and Mathuru. This household-based survey may be found in Appendix B.

Survey sections are discussed as follows:

- **General Information**: The survey starts by determining general information on the household and the time and date on which the survey was conducted. Also of interest is specific information such as age, sex, and position in the household of the person being interviewed.
- Water Use Practices: It was noted in the organizational survey that such information pertaining to water use practices was not easily determined due to the fact that various sources were utilized throughout a community. In addressing this topic on a household level a more accurate idea of water sources used may be ascertained. Questions asked in this section aside from water source include who collects the water, how water is transported, where the water is stored, and how water is removed from storage containers prior to use. An effort is also made to determine the perception of raw water quality by the household.
- **HWTS Program/Product Description**: This section tackles issues specific to the HWTS technology being implemented. The questions in this section are similar to those included in the organizational survey.
- **HWTS Program/Product Use**: Also on the topic of HWTS technologies, this section addresses how these products are being used. Questions in this section are in regards to whether the household feels that water is improved after water treatment. The section also goes into the details of who in the household is responsible for treating the water and what the treated water is used for.
- Perceptions and Acceptability: This section addresses issues of perception and acceptability of the technology, asking questions on how easy the technology is to use and whether the technology is considered beneficial to the household. Also considered here is whether the household would recommend the technology to their neighbors.
- Operation and Maintenance: Operation and maintenance is addressed in much the same manner as in the organizational survey, only this time focusing on the operation and maintenance required by the household. This section also details how often spare parts and technical assistance are needed.
- Willingness-to-Pay: The survey then attempts to conduct a tertiary willingness-to-pay study which also includes questions in regards to how much the household thinks a particular technology costs.
- Household Composition and Wealth Information: The survey also attempts to gauge household wealth information through questions pertaining to how large households are compared to income.
- **Knowledge of Diarrhea**: Finally, a section is provided in regards to a household's knowledge of diarrhea. This last section is the health-focused portion of the survey and not only measures the knowledge of a household about disease, but also attempts to record the number of times a particular household has contracted these diseases in the past.

3.7 HWTS Implementation Organization Survey Short Form / Web-Based Information Collection Tool

Activity 1b of the WHO Implementation Working Group seeks to "Create Web-based database of implementation experience of the Members". This activity was carried out using the HWTS implementation organization survey as a basis for the creation of a web-based collection tool. The Web-based collection tool is to be utilized in the collection of the information to be included in the Web-based database. The "long form" of the survey was utilized to first create a "short form" of the survey in which only the most important sections pertaining to HWTS implementation were considered. This "short form" was subsequently revised and iterated, eventually resulting in the Web-based collection tool.

The final version of the web-based collection tool is in MS Excel format and is available on the WHO website at: http://www.who.int/household_water/implementation/en/. The tool is also included in Appendix B.

The web-based tool has the primary function of obtaining a better understanding of where household water treatment and safe storage is occurring; what types of technologies or systems are being implemented; and what organizations are active. To date, there have already been several responses to the tool by HWTS implementing organizations around the world. The answers received from the organizations are being synthesized into a database that will serve as a resource for HWTS program implementation and evaluation.

The web-based database is expected to be on-line by summer 2005 also at the address: http://www.who.int/household_water/implementation/en/.

The following sections are included in the web-based tool:

- 1. Respondent Information
- 2. Institutional Information
 - Type of Organization
 - Focus of HWTS Activities
- 3. Implementation
 - HWTS Technologies Implemented
 - Additional Components of Program
 - Means of Implementation
- 4. Settings
 - Project/Product
 - Characterization of Source Water
 - Date of Commencement and Termination
- 5. Extent of Current Implementation
- 6. Baseline Health Survey
- 7. Organizational Targets

CHAPTER 4 – SUMMARY OF ORGANIZATIONS VISITED IN KENYA

4.1 Background

Eleven organizations implementing HWTS technologies were visited during the field visit to Kenya in January 2005 in order to collect information on HWTS program implementation practices in the country. The implementation organization survey was the main instrument used to collect information. Additionally, it was through face-to-face dialogue with respondents that improvements to the survey were made.

The eleven organizations visited in Kenya are listed in Table 4.1 along with the technologies they implement and the places in which these organizations are located:

Organization	Technology	Location	
Population Services International (PSI)			
Nairobi	Waterguard	Nairobi (Headquarters)	
Mombasa	Waterguard	Mombasa, Coast Prov.	
Network for Water and Sanitation (NETWAS)	Ceramic Candle Filter	Nairobi (Headquarters)	
Kenya Water for Health Organization (KWAHO)			
Nairobi	SODIS	Kibera District, Nairobi	
Maseno, Western Province	EcoSan Toilets	Maseno, Western Prov.	
Kenya Ministry of Water Resources	Boiling / Chlorination	Nairobi (Headquarters)	
Kenya Ministry of Health	Boiling	Nairobi (Headquarters)	
MEDAIR / BushProof	BioSand Filters	Machakos, Eastern Prov.	
World Vision International (WVI)	Safe Water System	Nairobi (Headquarters)	
Anglican Church of Kenya (ACK)	SODIS	Eldoret (Headquarters)	
Catholic Diocese of Nakuru (CDN)	Defluoridation Filters	Nakuru, Rift Valley Prov.	
Society for Women and Aids in Kenya (SWAK)	Waterguard / PuR /	Kisumu (Headquarters) /	
	Modified Clay Pots	Western Prov.	
CARE	Safe Water System /	Kisumu (Headquarters) /	
	Modified Clay Pots	Western Prov.	

Table 4.1 – Organizations Visited in Kenya

Some of the organizations had different projects in various locations across the country. For instance, PSI was implementing Waterguard in Nairobi, Mombasa, and Kisumu. Regional offices existed in each of these three provincial capitals, but for the most part operated independently of one other. A map of the organizations visited is included as Figure 4.1.

In this chapter, the information collected on these organizations during the site visit to Kenya is summarized. As the HWTS implementation organization survey was the instrument used to collect data, the information presented in this chapter follows the same format as the survey. First, background information and pre-implementation considerations, such as resource availability and funding, are presented, followed by implementation considerations which identify the evaluation targets utilized by each organization. It must be mentioned that not every section included in the survey is discussed, instead, only the most salient information collected has been included in the chapter.

Furthermore, in this chapter, only the organizations formally interviewed using the survey instrument are discussed. This is due to the fact that the amount of time available to survey all organizations and visit their respective project sites(s) varied from group to group. In some instances there was sufficient time for both detailed data collection using the survey and for observation of actual implementation of technologies in the field. For other organizations there was time for only brief interviews. Only the organizations for which detailed information was collected are discussed in this chapter. The following organizations will be discussed: Population Services International (PSI; Section 4.2), Network for Water and Sanitation (NETWAS; Section 4.3), Kenya Water for Health Organization (KWAHO, Section 4.4), Kenya Ministry of Water Resources Management and Development (Section 4.5), Kenya Ministry of Health (Section 4.6), MEDAIR/BushProof (Section 4.7), Anglican Church of Kenya (ACK, Section 4.8), Society for Women and Aids in Kenya (SWAK, Section 4.9), and Catholic Diocese of Nakuru (CDN, Section 4.10).

Completed samples of the long form of the HWTS organization implementation survey and the household version of the survey are included in Appendix B. Data collected on the organizations served as the basis for developing the HWTS technology selection tool discussed in Chapter 5. For demonstrative purposes, the technology selection tool was applied to some of the implementing organizations visited. The results of this application are included in Chapter 6.

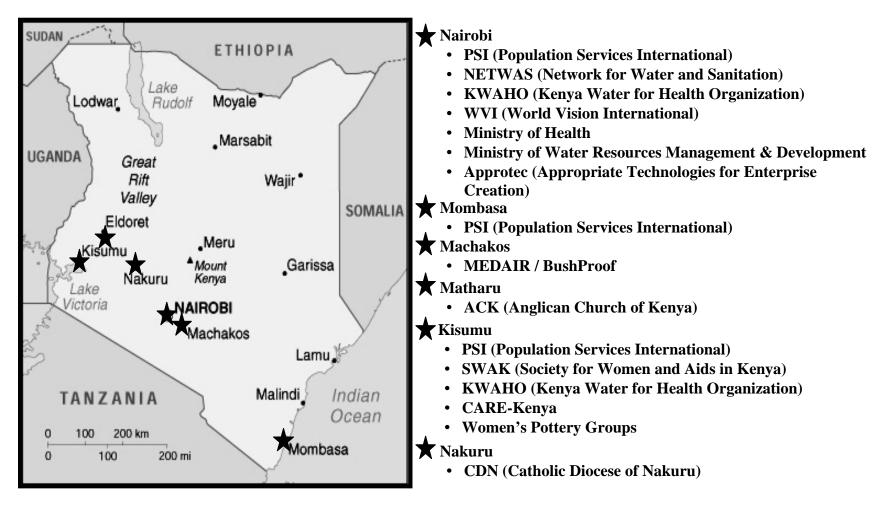


Figure 4.1 – Map of Organizations Visited in Kenya

4.2 Population Services International (PSI)

Population Services International (PSI) is a nonprofit organization based in Washington D.C. that harnesses the private commercial sector to address health problems through programs in safe water, malaria, micronutrients, family planning, and HIV/AIDS. PSI is unusual in that it is a non-profit organization that still charges for all of its products and services. PSI is an amalgam of the worlds of commerce and charity, borrowing the best strategies from each and using them to improve the health of the poor and vulnerable in a way that is tangible and measurable. And it has turned its tool of social marketing, originally applied only to family planning, to other areas of health where social marketing could also make a difference. Founded in 1972, PSI now works in more than 60 countries worldwide. (PSI, 2005)

PSI's Mission Statement is given as follows: "PSI deploys commercial marketing strategies to promote health products, services and other types of healthy behavior that enable low-income and other vulnerable people to lead healthier lives". The organization has a president and vice president located in Washington D.C. who appoint regional and country directors in countries where PSI programs are currently being implemented. It is a requirement that country directors be native citizens of the countries in which they are appointed.

PSI Kenya was established to give better lives to the people and to increase production by increasing man-hours of the local workforce. PSI Kenya began operations in 1993 with the distribution of Trust Condoms, eventually expanding distribution in the year 2000 to the other health-oriented products discussed in the following section. All strategic decisions undertaken by PSI Kenya are done in consultation with PSI Washington. PSI Washington monitors and audits all activities of PSI Kenya

4.2.1 Pre-Implementation

4.2.1.1 Background

PSI Kenya launched its household chlorination product, "Waterguard®", in May 2003. The project was launched on a national level and was meant to "piggy-back" on the organization's other more established products, which already had large-scale distribution systems in place. These other PSI products, along with their initial dates of implementation in Kenya, are listed as follows:

- Trust Condoms (1993)
- Supanet Insecticide-treated Mosquito Nets (2000)
- Femiplan Oral and Injectable Contraceptives (2000)
- Power Tab Insecticide Treatment for Mosquito Nets (2001)

The household chlorination product was initially launched under the name "Klorin" as part of a safe water system project being implemented by the NGO CARE-Kenya in the Nyanza Province in collaboration with the CDC. It was reported that CARE could no longer sustain funding for distribution of the product and so allowed PSI to take over distribution. Upon doing so, PSI decided that the product should reflect the change in ownership and so, combined with regulatory considerations, proceeded to change the product's name to the current "Waterguard®" trademark. It has been reported that the new name has had a positive impact on product sales as consumers more readily accept and associate water protection with the name "Waterguard" than they do with the name "Klorin". The product is implemented under the same name in all African countries and on a nationwide level; this is an additional reason cited for the product's warm acceptance in target communities. Jet Chemicals, the original manufacturer of Klorin, is also in charge of manufacturing the same product only under the new name Waterguard®.

Although interview sessions were held with key PSI personnel in Nairobi during the site visit conducted in January, only one specific geographic area of Waterguard implementation was investigated in detail. This was Kenya's Coast Province, specifically the Mombasa and Kwale Districts. Throughout the following sections the nationwide PSI program will be the focus of the discussion, although separate subsections will be provided containing the information collected during the site visit specific to PSI Mombasa.





Photo 4.1 – Waterguard Distribution in Mombasa (2005)

4.2.1.2 Target Population and Current Water Use Practices and Concerns

According to the PSI Kenya website, the official target populations of the organization are sexually active youth ages 15 to 24 for AIDS prevention, married women of reproductive age for family planning, and women of reproductive age and children under five for malaria prevention. It is assumed that since Waterguard® is distributed in conjunction with these products that the target population of Waterguard® is encompassed by the target populations specified for each of the three products above. That being said, PSI has indicated that the product is specifically targeted at mothers having children under the age of five. This is due to the fact that the organization recognizes that children of this age are the most susceptible to diarrhea. Approximately 95 percent of Waterguard® marketing is currently targeted at urban and peri-urban centers. However, the product is distributed to vendors in rural areas as well.

The organization cites budgetary constraints as the reason why the entire available market in Kenya is not targeted. The rural centers or markets are vast areas where poor roads and communication networks are prevalent. These conditions cause difficulty in distribution.

Due to the large-scale distribution of the product it is assumed that the entire spectrum of water sources utilized in Kenya could potentially be treated by this technology. In two of the distribution areas visited, Nairobi and Mombasa, piped systems were a common source of water. According to PSI, in the urban areas being targeted by the intervention, boiling is the primary method of treating water in households; however, most residents living in rural areas cannot afford the wood fuel that is the preferred energy source for boiling, and oftentimes drink untreated water. Furthermore, kerosene is becoming the only available fuel in urban slums. Kerosene is considered expensive and is oftentimes outside the available budget for families in these areas.

PSI Mombasa:

The population in Kenya's Coast Province is estimated at seven million, with approximately 300,000 people in Mombasa alone. The region is separated into seven distinct autonomous districts. The province encompasses a predominantly rural area of 86,800 square kilometers having an arid coastal climate with a yearly average rainfall of 16-24 inches.

Water in the region is supplied from an integrated water system. There are an estimated seven groundwater aquifers in the region with three being located in the Kwale District alone. Some piped systems also serve the area, such as the Mailindi and the Tiwi systems which are piped from groundwater sources and natural springs. Water is also vended in the region by truck and local water kiosks alike; typical price ranges for a 20-liter jerry can of water are 10-40 KShs⁴ (US\$ 0.13-0.53). Water supply is not an issue in the region as the multiple sources of water are more than adequate to serve the needs of the residents. However, due to the fact that tourism is a large industry in the region, water quality has been identified as a high priority concern.

Many people have boreholes in their communities. Unfortunately these are built in close proximity to pit latrines, which typically cause problems of contamination. The Water Ministry in the region identified these boreholes as specific sources of concern, citing potential contamination of these sources as the cause of reported disease outbreaks in the region. The Ministry wants to address this problem through specifying the siting of these boreholes. Technically the Ministry already has authority over all boreholes in the region and possesses the responsibility to test these sources for water quality and to inform the public of potential water quality problems.

Chlorination of municipal supplies by the appropriate government authorities happens throughout the region, although the Ministry of Water has reported a need for the public to be more informed about keeping water clean between source and point of use. Current perception in the area is that clear water is clean water. Chlorination is only implemented through advising the people, as is safe storage. The Ministry is only now starting to work with NGO's such as PSI because it has determined that these NGO's have access to communities at the grassroots level. PSI bridges the gap and fills in the areas where the Ministry of Water has less access.

A specific region visited in the Coast Province was the Kwale District, which is rural and has a population of 500,000. Reportedly, 60 percent of the population has access to clean drinking water, and some areas are served by expensive piped systems due to the inaccessibility of groundwater and surface water sources in the region. From 1995 to 1997, the Ministry of Water in the region conducted the "Kwale Water and Sanitation Program" which received \$320 million in funding from external sources to serve the Kwale population with water and sewer service. The program was able to service up to 40 percent of the population through the construction of pit latrines, dams, and boreholes. Unfortunately some areas in the District were not easily provided with water and sewer service. The Kintango Hinterlands for example were only serviced with seven boreholes out of the 574 installed for the entire district. This was in part due to the excessive depth of the groundwater aquifer in the region, which was oftentimes reported as being more than 120 meters deep.

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⁴ KShs – Kenyan Shillings = US\$ 75

4.2.1.3 Implementation Program

PSI launched Waterguard in 2003 as a chlorine-based water treatment product that when added to water is capable of purifying the water of bacteria responsible for cholera, diarrhea, and other fatal diseases rampant throughout Kenya. A single bottle of Waterguard is able to purify water for a family of six at the cost of only 45 KShs (US \$0.60) per month.

The product reportedly had low initial sales of 7,000 units/month. However, after a mass media campaign that included television advertising in urban areas, sales in September, 2003, were reported at 12,000 units/month. Current sales in November, 2004, were reported at 40,000 units/month for the entire country. Assuming that six people use one bottle in one month, it is estimated that approximately 240,000 people are benefiting directly from this intervention.

Waterguard has currently increased its price from 35 to 45 KShs (US\$ 0.46 to 0.6). The impact of the price change will not be determined until old stocks of 35 KShs product have been completely sold and a full month of sales data is recorded. The increase in price is a direct result of the increasing prices of oil, which in turn affect the cost of manufacturing the plastic bottles. Additionally, the new India-owned manufacturers of the product have been reported as being less "giving" compared to the old owners who would oftentimes donate the Waterguard bottles to PSI at reduced cost. Waterguard is currently subjected to a 16 percent value-added-tax (VAT) which affects the pricing of the product. As several of PSI's products are VAT-exempted, the organization has submitted a petition to exempt the Waterguard product as well. If granted, the exemption could potentially reduce the price of the product, further resulting in greater sales, especially in rural areas where costs of the product are prohibitive⁵.

PSI plans to introduce smaller bottles in 2005 to address both a) the difficulty of purchasing a 45 KShs (US\$ 0.6) product and b) the rural purchasing patterns that encourage packaging in the smallest quantities available. The new bottles will initially cost 25 KShs (US\$ 0.33 including VAT), but will include a more concentrated chlorine solution that will last almost as long as the existing, larger bottle. The reduction in price, particularly if combined with VAT tax exemption, which would lower the total price to KShs 21(US\$ 0.28), would help rural sales considerably. Not only would the end-user purchase become more affordable, but individual groups would have lower capital requirements to buy and expand stock. (Chasse et al, 2005)

More detailed information on marketing and distribution of the product is included in later sections.

⁵ The Kenya Ministry of Water Resources is supportive of the VAT exemption of PSI 's Waterguard product.

PSI Mombasa:

Implementation of the technology in the region is both urban and rural. The urban focus of the program is specific to the City of Mombasa. It is reported that Waterguard sales in this sector have been steadily increasing, although it is expected that sales will be somewhat constrained by the fact that the city is supplied with a relatively clean piped water source.

The rural sector is achieving less success, as there has been some difficulty in promoting the technology throughout the sparsely populated communities in the region. The key rural setting observed during the site visit was the Kwale District, in which current sales of Waterguard were reported at 360 bottles/month. The Kwale region is also reported as having a relatively consistent and high-quality piped water system, which is a potential explanation for low sales in the area. Waterguard sales also fall during the rainy season, when rainwater harvesting is utilized.

At the time of the site visit, the main problem facing the region was the failure of crops due to a drought and a lack of irrigation. Evidently there had been very little rain in the region over the past three months which had left most of the crops withered and dying. This left little to no hope that the residents of the community would be able to get income or even just food from the crops they had grown. This imminent threat of starvation shifted residents' focus away from clean water onto more pressing concerns.

During the first leg of the visit, a health clinic was visited. Two women with their infants were among the patients waiting for treatment. Upon speaking to the health technician and helper in charge of the facility it was discovered that the clinic did not specifically utilize, much less promote, Waterguard. They did, however, practice chlorination and safe water storage at the clinic using a chlorination product other than Waterguard. They also taught patients about safe water and the effect it has on preventing disease.

Two kiosks in the Kwale District were visited and both were experiencing low sales of Waterguard. The first kiosk (Photo 4.2) was an actual kiosk provided by PSI that had the "Supanet" logo printed on it; the second was a privately owned store selling a wider range of products than the first. The following sales were recorded for each:

- Kiosk #1 = Dec. 2004 purchased 6 bottles; sold 1 by Jan 7, 2005
- Kiosk #2 = Nov. 2004 purchased 24 bottles; sold 6 by Jan 7, 2005

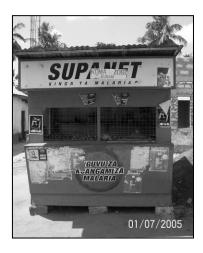


Photo 4.2 – PSI Kiosk in the Kwale District

These feeble sales figures underscore the lack of success the Waterguard product is having in an area obtaining relatively clean water from (oftentimes) piped water supplies and experiencing a crop and life-threatening drought.

Additionally, a pharmacy in the area was also visited. The pharmacy was located along the main thoroughfare leading into Mombasa and was serving a more densely populated area than the two rural kiosks. Current sales at the pharmacy were at 120 bottles/month. The pharmacy owner explained that residents were very much aware of the product, so much so that it had become a "household name". He explained that television and other wide-scale marketing efforts had reached the people in his area. Although he said that his customers were typically from the immediate semi-urban area, he also said that some of his customers came in from the more rural areas outside town. From a user's perspective, he also said that the system was very user-friendly and efficient.

4.2.1.4 Resource Availability

Waterguard is locally produced and bottled in Kenya through a private company called Jet Chemicals. The product is then distributed to all regions of Kenya through PSI's distributors.

4.2.1.5 Funding

The PSI-Kenya Waterguard program is currently subsidized by PSI Headquarters in Washington D.C. PSI Washington and the United States Centers for Disease Control and Prevention (CDC) jointly make decisions on funding as well as product selection for PSI Kenya. This means that CDC selects the specific parameters for the technical aspects of the product such as the percent composition of chlorine in the solution as well as bottle size, while PSI Washington determines the amount of funding to be released for the program on an annual basis. At the time of the site visit in January 2005, PSI Kenya was currently waiting to determine if funding for the program was to be continued into the coming year.

Up to 70 percent of the funding allotted to the program is utilized for marketing purposes. PSI has a structured approach at selecting products to promote and distribute, identifying the need to have all implementation programs fully funded and running smoothly prior to the release of any new products. The organization has been approached to distribute Proctor and Gamble's PuR® water product, however, despite the fact that funding is already available for PuR®, the organization is declining the offer until additional funding has been secured for the Waterguard program. In other words, PSI Kenya does not want to promote a competing water treatment product until it has established its current water treatment product.

Additional contributors to PSI programs identified on the website are listed as follows: British Department for International Development (DFID), Family Health International, Pathfinder, U.S. Agency for International Development (USAID), and the U.S. Centers for Disease Control and Prevention (CDC).

4.2.2 Implementation

Despite being an NGO, PSI is different from other aid-type organizations in that it takes a large-scale product-based approach to implementation. Due to the nature of this social marketing-based approach, the organization focuses most of its resources on marketing the technology and has little involvement in monitoring and evaluation. PSI does, however, have an in-house research department that conducts pre-implementation data collection regarding the suitability of the technology to the target population (essentially a market survey). This department also attempts to determine the demand for the technology in terms of health concerns in specific regions throughout the country.

As PSI implements the technology on a nation-wide scale, all research and analysis is conducted on this large-scale level as well. Specific information about the performance of the technology on a household level is therefore considered outside the scope of PSI Kenya⁶.

4.2.2.1 Target: Health Outcomes

Health outcome is the primary concern of PSI in distributing its products. Although not conducting health impact surveys themselves, the organization does work closely with the CDC and relies heavily on studies conducted by this organization. CDC was even cited by PSI as the primary mechanism for monitoring and evaluation of health-based targets.

⁶ It was precisely to address this information gap the MIT team member Pragnya Alekal undertook her thesis "Appropriate Water Treatment in Nyanza: A Case Study of SWAK Communities in Nyanza" (Alekal, 2005).

According to data obtained from the PSI Kenya website, the distribution of PSI products throughout Kenya has had the following impacts to date:

Primary HIV infections averted: 23,500
Unwanted pregnancies averted: 162,000
Episodes of malaria averted: 9,800,000
Diarrheal episodes averted: 430,000

According to PSI personnel, the above information was obtained from a health survey conducted through the efforts of the CDC. The primary area of interest was the Nyanza Province, which was researched through the evaluation of 3,500 households (Kiraguri, 2005). In this instance, health-based research was used in the prioritization of the regions in which the Waterguard technology was to be implemented. Subsequently, marketing and sales in the Nyanza region are reportedly the highest in the country.

4.2.2.2 Target: Water Quality

Water quality was not cited as a specific evaluation target for the organization. However, information received from the organization about the aforementioned CDC study indicated that 70-80 percent of households surveyed felt that their water was unsafe and needed improvement (Kiraguri, 2005). This was also considered, along with health information, in the determination of the areas appropriate for the distribution of the technology.

PSI sometimes utilizes other agencies in order to obtain water quality data. For example, PSI Mombasa works closely with the Ministry of Water in the region and relies on water quality testing by the Ministry for indications of raw water quality. The Ministry of Water attempts to test as many water sources as possible, and also provides services at cost to residents that want to test their private water sources. The Ministry typically tests for turbidity, color, and microbial contamination.

4.2.2.3 Target: HWTS System Performance

Like water quality, system performance was not cited by the organization as being a specific target for evaluation. Jet Chemicals, the manufacturer of the product, is not monitored for quality control. This is because funds and logistics do not allow for this to be possible.

4.2.2.4 Target: Behavior/Use (Social Acceptability)

PSI is concerned with consumer input; they want to determine who is using the product, why they are using the product, and if they are using the product correctly. They also expressed that data regarding prior water use practices would be helpful, as well as information on consumers that discontinued use of the product. Although interest is high in regards to receiving user input, the organization has made it clear that funds are not sufficient to conduct any research into this facet of program implementation.

Other barriers to the technology in terms of social acceptance were identified by PSI personnel as follows:

- Local beliefs that chilling the water will treat it.
- Local beliefs that rainwater has been blessed and is therefore safe to drink without treating.
- Religious sects that do not permit their members to add chemicals to their water.
- Some consumers have commented on its similar smell to *Jik*, a popular cleaning agent in Kenya, and don't want to drink the same type of chemicals they use to clean their floors.
- Problems in scales of consumption i.e. large families may use a large quantity of water whereas smaller families may find treating one entire jerry can of water excessive.

4.2.2.5 Target: Costs

The target of "Costs" (finances and economics) includes not only the cost required to implement and maintain the technology, but also the willingness to pay of the consumer. As PSI is a product-oriented organization, the success of a product is measured largely by profitability. Profitability in the context of the PSI philosophy is not necessarily a matter of earning revenue, but is instead measured by the financial sustainability of a particular product. If a product can be sold at a price that completely sustains costs incurred during manufacturing and distribution, then PSI considers a product successful. In this regard, sales of a product are a direct indicator of the demand and the willingness to pay of the consumer, which in turn translates into the presumption that the product has been implemented successfully.

It was indicated by PSI personnel that the organization had conducted a preliminary cost/benefit analysis of the product in terms of a sales increase before and after the advertising campaign. The analysis is ongoing and is being conducted to determine if advertising has resulted in increased sales.

The increase in the product's price poses a potential financial setback for PSI. It is expected that in some areas, consumers will find the price of the product higher than the cost of purchasing coal for boiling water, resulting in lower sales for the product. As previously discussed, the organization is looking at ways to reduce the product cost and volume through petitioning for a VAT exemption and decreasing manufacturing costs through the utilization of a smaller bottle.

4.2.2.6 Marketing and Distribution

A nationwide mass media campaign for Waterguard, which includes television, radio, wall branding, and point-of-sale advertising, is carried out by the PSI Nairobi "Office for the Creatives". Due to prevailing health conditions in the Kisumu and Lake Victoria region, this has been the predominant area of focus for program marketing.

The Waterguard product is targeted at middle-income consumers and approximately 95 percent of the marketing is directed at urban and peri-urban centers. PSI does not necessarily select regions for distribution based on pre-existing demand. Rather, region selection is typically dictated by the economy in a particular region, as well as by the water quality situation, as exemplified by higher sales in the Nyanza region versus those in other regions of the country.

For consumers in the rural sector, PSI has established a "Rural Sales Force" to manage distribution efforts. Sales in rural areas are geared more towards profit than those in urban areas. The primary focus of marketing in rural areas is on insecticide treated bednets – this includes drama, education, and training in those areas. Knowledge about these products is identified as key to their success. Bednets, unlike Waterguard, are subsidized. Marketing in the rural areas is conducted through trucks with megaphones, as well as by teams performing skits.

Distribution of Waterguard is facilitated through both the urban market (supermarkets, pharmacies and *barazas*⁷) and retail outlets in rural areas (*dukas*⁸ and kiosks). PSI utilizes designated "uplifters" that act as a type of intermediate distributor between local warehouses and vendors in kiosks and supermarkets. These uplifters are aggressive sales groups that move the product more efficiently and effectively through direct contact and interface with supply sources and vendors. Uplifters are considered integral to the distribution process and are treated as part-time employees of the organization. PSI also looks at the potential of local empowerment by providing local business people with kiosks.

The product is stored in a central warehouse located in Nairobi and trucked to various local warehouses through the Tibet and Britten transport company. Uplifters then take these products from local warehouses for distribution to local vendors. A problem identified with the product is that it is "too bulky" and is difficult to transport in large volumes, as opposed to condoms which are easily transportable in bulk.

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⁷ Baraza – A marketplace where an assortment of products is sold.

⁸ Dukas – A stall at a marketplace.

PSI Kenya works closely with the National AIDS Control Program, other Ministry of Health departments, the Social Marketing Initiative of Kenya (SMIK), and other local NGOs and cooperating agencies funded through USAID. PSI has identified local community groups and NGOs as being vital in the promotion of technologies in rural areas. NGOs such as the Society for Women and AIDS in Kenya (SWAK), which will be discussed in more detail in Section 4.9, have the advantage of being able to disseminate information and instruction to small communities that are unreachable by mass media campaigns. These organizations work through personal interaction within these communities, establishing trust and a consistent source of information for rural residents. Another additional resource for the promotion of the technology is the "influencer" or local community leader that has the ability to mobilize and educate people in the community. In implementing the program in rural settings, these leaders are key to effectively demonstrating a technology and raising awareness about water quality issues.

4.3 The Network for Water and Sanitation, International (NETWAS)

4.3.1 Pre-Implementation

4.3.1.1 Background

The Network for Water and Sanitation, International (NETWAS) was founded in 1986 as an independent non-profit organization through the United Nations Development Program-World Bank Water and Sanitation Program. NETWAS is a capacity building and information network for Africa focusing on water, sanitation and environment sectors. It is comprised of resource centers in Eastern Africa that implement capacity building activities on training of professionals, applied research, networking and information sharing, advocacy, advisory and consultancy services (NETWAS, 2003). The centers consist of a regional center, NETWAS International, and two national centers, NETWAS Uganda and NETWAS Tanzania. NETWAS International, which is situated in Nairobi, Kenya plays the dual role of NETWAS Kenya and the regional office (NETWAS, 2005).

NETWAS is recognized as one of several global centers comprising the International Training Network for Water and Waste Management (ITN). The global centers of the ITN are extensively involved in capacity building in the water and sanitation sector of developing nations (NETWAS, 2005). NETWAS has 22 full time staff members (16 professional, 6 support staff) comprising a multidisciplinary team of engineers, scientists, sociologists, and information technology personnel (Kirimi, 2005).

NETWAS is currently considering the implementation of the ceramic candle filter and has in fact already conducted a baseline study in the Kirinyanga District of Kenya to acquire information on the potential target population. This study is discussed in the following section.

4.3.1.2 Target Population and Current Water Use Practices and Concerns

NETWAS conducted a baseline study to determine the current water quality situation in the Kirinyanga District, a region 200 kilometers from Nairobi in the foothills of Mount Kenya. Similar surveys were conducted in South Africa and Zimbabwe under the AQUAPOL project, which was coordinated by the University of Bristol, United Kingdom (AQUAPOL, 2005).

NETWAS implemented this study in Kenya from October 2000 to September of 2004 with funding received from the European Union. A total of 120 sample families were studied. Water sources in the area are predominantly natural springs and select boreholes.

The primary objectives of the study were as follows:

- 1. To establish whether rural water policy adequately takes into account the deterioration in quality between source and point-of-use.
- 2. To evaluate policy alternatives by assessing the relative cost effectiveness of different types of water-related interventions.

The study is targeted at the rural poor, the primary beneficiaries of improvements in water policy. A secondary objective of the study was to collect data on a potential target population for the ceramic candle filter technology. Water samples were taken at various points and tested using a Colilert System field laboratory. Palm handhelds were used as well to facilitate data entry using barcode technology. These results were entered into a database and analyzed.

Implementation in Kenya of the ceramic candle intervention has not yet occurred although demonstrations of the filter have been performed at the district level in select communities. NETWAS is looking for policy support as well as a means to evaluate programs and coordinate intervention implementation efforts. This ceramic candle filter technology has been implemented by AQUAPOL project partners--Institute for Water and Sanitation Development in Zimbabwe and the Council on Scientific and Industrial Research in South Africa (Kirimi, 2005). It is expected that the implementation method for this program in these countries will serve as a model for the future implementation of the technology in Kenya. Although not an implementing organization per se, NETWAS does conduct operational monitoring and evaluation of other programs they are involved with. In fact, the organization even conducts on-site training specifically in regards to proper monitoring and evaluation methods. In addition to this, as evidenced by the baseline study conducted, the organization utilizes innovative technologies in data collection which may be applicable to the process of monitoring and evaluation.



Photo 4.3 – Ceramic Candle Filter used by NETWAS for demonstration (2005)

4.3.1.3 Resource Availability

The organization is giving due consideration to resource availability in that they are attempting to determine the most accessible and least expensive ceramic candle filter available locally in Kenya. Ceramic candle filters were observed by the MIT team to be available at many local stores in Nairobi; these filters are typically imported from manufacturers in India and Brazil. At the time the site visit was conducted, there was one local manufacturer of the ceramic candle filter identified in Kenya.

NETWAS is interested in the results of the research being conducted on ceramic candle filters available in the shops in Nairobi by Amber Franz, a fellow MIT Master of Engineering student and Kenya team member. During the time spent in Kenya, Ms. Franz conducted tests on various locally available ceramic candle filters. Her study included tests for flow rate, turbidity removal efficiency, and total coliform, Escherichia coli, and viral removal efficiency. The research is intended to determine the most effective ceramic candle filter in terms of performance and cost (Franz, 2005). Such information would be valuable to NETWAS in their selection of an appropriate ceramic candle filter to utilize in future implementation programs.

4.3.2 Implementation

As previously mentioned, NETWAS Kenya is not actually implementing the ceramic candle filter technology in the country and subsequently has not had the opportunity to monitor and evaluate any household water treatment and storage products to date.

However, NETWAS collaborators have carried out ceramic candle implementation programs in South Africa and Zimbabwe. The ceramic candle filters used were the British Berkefeld or "Doulton" water filters manufactured in the United Kingdom, which are among the set of filters evaluated by Amber Franz (Franz, 2005). The programs are ongoing and serve as a model for potential programs in Kenya.

NETWAS is concerned with training of community groups in water, sanitation, and hygiene. The organization considers the wide-scale distribution of the actual interventions a very costly undertaking. The organization feels that the best way to implement a technology is through raising awareness (education and training) about current water problems and the appropriate solutions available.

4.3.2.1 Target: Health Outcomes

Although health outcomes have not been used by NETWAS as an evaluation tool, the organization has conducted baseline health surveys as a part of the above described European Union-funded project. Health measurements of the target population were conducted through the use of a "Smiley" template which documents instances of diarrhea. A copy of the "Smiley" template is available in Appendix D.

4.3.2.2 Target: Water Quality

Like health, water quality has not been used as a target per se but has been utilized in preimplementation research for the ceramic candle filter intervention.

4.4 Kenya Water for Health Organization (KWAHO)

4.4.1 Pre-Implementation

4.4.1.1 Background

The Kenya Water for Health Organization (KWAHO) is a non-government organization that has its headquarters in Nairobi. Its efforts are geared towards providing sustainable water and sanitation for the disadvantaged communities in Kenya. Its existence dates back to 1976 when it was launched as a UNICEF/NGO Water for Health Project by the National Council of Women of Kenya. In 1983, KWAHO was registered as an indigenous non-governmental organization under the Kenya Societies Act. In 1992, it was registered under the Kenya NGO's Coordination Act. (KWAHO, 2005)

The following are the organization's main objectives:

- To support and promote the government's efforts of realizing water for all through mobilizing local NGO's and communities for self-reliance
- To provide safe water within reasonable distance and promote health through improved sanitation
- To improve capacities of communities through training to manage their own local water and sanitation initiatives
- To promote collaboration and partnership with all other agencies in the water sanitation sectors

The following are the organization's main projects in Kenya:

- Water and Sanitation projects in Lower Tana (Coast province) and Maseno division (Nyanza province) funded by the Austrian Development Agency
- Water, Sanitation and Hygiene projects in Gem (Siaya district) and Kibera (Nairobi) funded by WaterCan Eauve Canada
- SODIS (Solar Water Disinfectant) project in Kibera funded by SANDEC, EAWAG Foundation
- Butere-Mumias Water and Sanitation project funded by SIDA through Water Trust Fund by Ministry of Water

KWAHO works closely with the Kenya's Ministry of Water on both water and sanitation projects. The formal mission statement of the organization is as follows: "To supply water, sanitation, and hygiene at a grassroots level." Apart from national and local governments, the organization also works closely with other international and local aid organizations in implementing community-oriented projects in both rural and urban settings. KWAHO implements programs primarily through working with local community groups (KWAHO, 2004).

Currently, KWAHO is implementing a Solar Disinfection (SODIS) project in the Kibera District of Nairobi as well as some surrounding rural areas. Kibera, with an estimated population between 500,000 and 700,000, is considered to be one of the largest slums in the world. Kibera is situated seven kilometers southwest of the center of Nairobi City (UN-HABITAT, 2004). The SODIS project in Kibera is considered by KWAHO to be an effective and inexpensive method of enhancing community's access to safe drinking quality water at the household level. KWAHO has 50 people employed by the project, 30 of whom are working in rural areas and 20 of whom are working in Kibera. These 20 staff members are composed of five full-time promoters and 15 part-time promoters.



Photo 4.4 – SODIS bottles on a rooftop in Kibera (2005)

4.4.1.2 Target Population and Current Water Use Practices and Concerns

Kibera is a multi- ethnic community consisting of migrants to the city from rural areas as well as refugees from neighboring countries. The migrants come to Kibera in search of income and cheaper residence (KWAHO, 2004). The community is more volatile because of the general poverty level. This leads to conflict over access to the few resources available, including water and sanitation.

The available water sources in Kibera are identified as follows:

- Nairobi City Council The Council reportedly supplies water once a week. The
 water is stored in tanks typically owned by community groups and water vendors.
 Shortages are caused by rationing and burst pipes, which sometimes result in
 elevated water costs.
- Public Borehole There is one borehole in the community where the water is available for free. The demand for this borehole water is extremely high, resulting in congested conditions at the facility.
- Kibera-based Water Vendors Water is also sold by vendors at "kiosks" which utilize piped water from the Nairobi City Council as a source.
- External Water Vendors Similar to Kibera-based water vendors discussed above only these obtain water from sources outside the community.
- Nairobi River The Nairobi River is accessible to some areas of the community, although this source is identified as being highly polluted.

The water supply in Kibera is unreliable, with frequent water shortages. During the dry season, water rationing by the Nairobi City Council takes place such that on a given day only one half of the community has access to water. The most utilized of the Kibera water sources listed above is water piped to the community and sold by certain Kibera-based vendors operating water kiosks. These vendors are reported to be licensed and are the major source of water for the area, typically charging consumers between 3 to 10 KShs (US\$ 0.04 to US\$ 0.10) per 20-liter jerry can of water. These charges fluctuate depending on the availability of water. Although kiosks are accessible, the length of the lines at these kiosks can be excessive. Residents transport the collected water to their homes by hand and typically fill the SODIS bottles using modified rudimentary plastic funnels.

4.4.1.3 Implementation Program

The current phase of the Kibera SODIS project is targeting 20,000 households. With an assumed average household size of five people, the project stands to benefit 100,000 people. As previously stated, it is estimated that the Kibera District of Nairobi has a total population of 500,000 to 700,000 living on 235 hectares of land; this statistic is only a rough approximation due to both the transient nature of the population and difficulties encountered in conducting an accurate population census.

KWAHO conducted a "community needs assessment" in the Kibera District and determined that water quality was a concern, and that treatment at a household level was required to help the people in the area. Key findings of the assessment included:

- As a priority, the community needs access to quality drinking water;
- Incidences of water-borne diseases and unsafe water handling a common;
- Contamination of water through burst poly-vinyl chloride (PVC) pipes occurs during flow of water to Kibera from the main city water supply;
- Community leaders recognize that drinking water safety is a major problem;
- There is a willingness by the community to participate in the project implementation.

Upon completion of the assessment, KWAHO then searched the Internet and, combined with a suggestion from their Executive Director, selected SODIS as the technology to implement. In implementing the technology it was determined by KWAHO that the most important people to convince were the community leaders. These leaders were not necessarily those formally elected, but instead those that had garnered community respect and were sought out by residents for common day-to-day problems. These are the key people identified that have the ability to mobilize and influence the rest of the community.

Apart from the above community needs assessment, KWAHO also employs a method they identify as "salvation" (also known as "participatory appraisal" or community mapping"), which is basically defined as the act of walking across an entire community and just observing general practices. The organization recognizes the value of preliminary data collection and believes that any successful program requires a community needs assessment survey to know exactly what the needs of a community are. The organization attributed previous failures of government-funded water infrastructure to inadequate pre-implementation research. They feel that by knowing a community and training them as much as possible, one can almost guarantee that the technology will be maintained and sustainable.

The implementation strategy used by KWAHO is participatory and involves the use of trained promoters who are focused and aggressive in their outreach to user families. In addition to this, they use social marketing strategies that highlight issues of self pride, shame, privacy, and convenience in sanitation. They give out research-based information that potential users need to know about SODIS.

Objectives, activities, and subsequent measurable targets identified for the program are provided in the table on the next page:

Table 4.2 – KWAHO Kibera SODIS Program Objectives and Indicators

Objective 1: To promote and disseminate SODIS to user communities as an alternative water treatment method	MEASURABLE INDICATORS (Qualitative and Quantitative)
Activity 1: Community mobilization Selection of no. of trainers/promoters Selection of site Selection of peer promoters Community awareness meetings	 4 promoters selected. 4 promotion zones sited. 20 peer promoters selected. 12 community meetings carried out. 100 people attended meetings. 4 SODIS groups formed.
Formation of SODIS groups Activity 2 Educational materials/training/promotional materials (Charts, leaflets and posters) Activity 3 Training of SODIS promoters	 40,000 people reached. 40,000 leaflets circulated to the people. Leaflets and diarrhea charts are in use for education. 4 promoters were trained. 16 sessions held.
Activity 4 Training of Peer promoters Activity 5	 Record of training available. 20 peer promoters trained in 16 sessions. Record of training available. 9,000 household trained.
Training of 20,000 families Activity 6 Training of three schools, 71 teachers and 3250 children	 40,000 PET bottles in use. 24 teachers trained. 1000 pupils trained. 8 training sessions held. Record of training available.
Activity 7 Follow ups visits	 9,000 household visited. 60 day follow ups recorded (2 days per week).
Activity 8 Setting up PET bottle supply scheme	 10 percent of users obtaining used bottles themselves. Discussed the collection of used bottle from some restaurant around the city and they agreed to bottles for collection. The discussion is going on the supply scheme with the Coca cola and Rotary International.
Activity 9 Networking for SODIS users	2 networking sessions held.80 users in attendance.
Objective 2. Assess health benefits of SODIS through reduced diarrhea particularly to children less than five years of age	MEASURABLE INDICATORS (Qualitative and Quantitative)

Activity 1 Do occasional and consistent water tests of raw water (Community water sources) and random testing of SODIS treated water of user families.	 Results of random samples tested available. 20 tests done. 					
Activity 3 Survey1 (Pre-project) of sample 400 household for baseline data on diarrhea incidence	 400 families surveyed. 4 clinics visited. Record of data collected available. 					
Activity 4 Survey 11 (Post –project) of sample 400 households for baseline data on diarrhea incidences	■ To be completed.					
Activity 5 Report writing	 Has been done monthly. Copies of report kept. Use of report format done. 					

Source: KWAHO, 2004

An updated version of the above table has been included in Appendix D.

The level of acceptance of SODIS technology in the community is reported to be high. Perceived benefits to families include fuel savings from no longer boiling water, reduced expenses on medication, and reduced incidence of water-borne diseases.

At the time of the site visit, it was estimated that the project had been successful in implementing the technology in 8,000 households and two schools, reaching an estimated 40,000 people. The project is covering three villages within the Kibera District: Kambi Muru, Kisumu Ndogo, and Makina.

According to KWAHO, the projected extent of implementation is as follows:

- As of September 2004: 8,000 households total
- As of January 2005: 10,000 households total
- Total Users to Date (as of January, 2005, assuming 5 people/household): 50,000 people served

KWAHO also works with other organizations through instruction and technology education in hopes that these other organization can implement the technology on their own. KWAHO also receives support from the government in terms of the provision of office space and logistical support and security when required. Technical and financial support for the program are provided through SANDEC, and laboratory testing is provided through the Ministry of Water in Nairobi.

4.4.1.4 Resource Availability

KWAHO buys empty Polyethylene Terephthalate (PET) bottles from manufacturers in the area. They are also starting to ask restaurants to donate the bottles they typically throw away, and are starting to get the people to obtain their own bottles so that the systems will be self-sustaining. In fact, KWAHO is currently employing a "Local Bottles Supply Scheme", which is basically a strategy for the sustainable supply and monitoring of PET bottles. During the mobilization and training of communities, emphasis is put on educating the community about how to sustain the project by utilizing different types of bottles from different sources. The organization educates residents on the types of bottles that have been determined to be effective in disinfecting water and also directs residents to places where these bottles are available.

4.4.1.5 Education and Training

Education and training is very much the focus of KWAHO; they deal specifically at the community level and spread knowledge through SODIS promoters that visit households, through monthly workshops, and through social marketing at schools and community events. They focus not only on water quality, but also on hygiene and sanitation.

The following are two of the specific education and training methods used by the organization:

- Awareness-raising, education and information dissemination Accomplished by SODIS promoters through door-to-door sensitization and awareness creation. Workshops and seminars with the communities are also held. Additionally, promoters share ideas with Community Based Organizations (CBOs) working within the area. Full community participation is sought in the implementation of the project.
- **Training and demonstration** The training and demonstration of SODIS water technology at the community level is being performed by the promoters. This is done during the community workshops and during door-to-door promotions. The promoters use drama, information leaflets, and diarrhea charts to reach the community.

4.4.1.6 Funding

The initial funding for the SODIS program was provided by the Austrian Embassy, which is actually one of the organization's principal donors. They provided immediate funding for a pilot project that took place in 2001 for a duration of six months. The Solaqua Foundation through SANDEC provided funding for the year 2004 program. Three quarters of the funding, about US \$15,000, have been released to date. The contract terminates in February 2005 at which point additional funding was sought to reach the remaining areas of Kibera as well as other villages.

A detailed willingness-to-pay study or cost benefit analysis was not conducted for the target population.

4.4.2 Implementation

Monitoring, in the form of inspections and follow-up visits, is provided twice a week. Promoters visit the homes at random to make sure the system is being used properly and to answer any questions that users might have. Promoters fill out forms and keep them on file for the project manager to review when necessary. The project manager then reports to the head of KWAHO at certain periods during the year. The current extent of program implementation is monitored in part by the number of SODIS bottles distributed to the community. The following tabulated data was provided by KWAHO regarding program implementation:

Table 4.3 – Monitoring or SODIS Bottle Supply/Distribution

Name of Communities and	Nu	Number of Bottles Used over the 6 months period (actual field implementation period)						Total Bottles used	Bottles per Household			
Number of Households	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		6 to 4
Makina Village (2 zones) 4000 Households		2,250	3,500	4,000	2,750	3,500	4,000				20,000	6 to 4
Kambi Muru Village 2700 Households		1,500	2,500	2,250	2,250	2,350	2,500				13,500	6 to 4
Kisumu Ndogo Village 2500 Households		1,250	2,000	1,500	1,500	1,650	2,500				11,500	6 to 4

Source: KWAHO, 2004

KWAHO has evaluated the system and has reported a rapid acceptance of SODIS technology in the community, the success of which has been attributed to the implementation strategy employed. Continuous contact with users has enabled KWAHO to ensure that SODIS is practiced correctly and consistently. The following observations were acquired by the organization through an internal evaluation of the program:

- Water quality and health improvement of the users has improved through SODIS
 combined with proper hygiene practices; user families have improved their
 drinking water quality. The users have reported health improvements and
 financial benefits through savings on medication. Some savings are spent on
 purchasing fruits and vegetables for improved health of the residents.
- Awareness building through intensive mobilization and sensitization on hygiene and sanitation, many households have changed their hygiene practices: They drink SODIS water, wash their hands with soap at critical moments (i.e. after visiting the toilet) and keep their private environment clean.
- Technical Expertise Promoters must have the necessary social skills (personality leadership, marketing and communication skills) to communicate knowledge about the technology effectively. The back-up technical information provided by SANDEC on SODIS has been useful and necessary for the implementation of the project. Promoters have been able to use the instructional information provided to give leaflets and bacteriological tests on water samples to the communities.
- Political Support Partnerships with government agencies, donors and CBOs are crucial for the success of the project. Prior to the last five years, the government was wary of acknowledging or supporting tangible development activities in urban slums as they were viewed as illegal settlements. This change of heart has taken place as a result of pressure from local lobby groups (civil society) interested in serving the poor. Therefore, the government Ministry of Housing has started an urban slum-upgrading program in partnership with the UN-Habitat program. Thus SODIS implementation is within the current government focus to support development for the poor. The new government policy and legislation on water and sanitation is aiding this process.
- Organizational Structure It is essential to have KWAHO as the guiding agent responsible for the overall planning of the program, while SODIS promoters continue to be the vital link to the community. Promoters must be committed and driven by the spirit to change the situation of the community for the better.

Challenges to the Program were identified as follows:

- Frequent movement of people from one village to another in search of better livelihoods or evictions by landlords means that there are always new persons coming into the project who need to be recruited into SODIS.
- Competing water treatment options confuse the residents.
- Available resources are not enough to meet the great demand for SODIS water.

4.4.2.1 Target: Health Outcomes

KWAHO does recognize the importance of health outcomes as a target to program success. In fact, the organization cites "health improvement" as the overall goal of the program. However, the organization considers the studies too expensive and cumbersome to accomplish. They do, nonetheless, plan to do a survey of the system to determine qualitatively if diarrhea has been reduced in the community. This survey will be performed as a follow-up to the "community needs assessment" conducted prior to program implementation, in which cases of diarrhea were recorded on a somewhat informal basis in order to gauge the level of water-borne disease occurrence in the community. The survey was done from January to March of 2005 through a sampling of random households throughout the community. KWAHO currently attempts to track cases of diarrhea for children under five.

4.4.2.2 Target: Water Quality

Water quality is the main target used to evaluate if the intervention is working effectively. Water quality is used to prove to users that the bottles can in fact, treat the water through UV. Regulations set down by the Kenya Bureau of Standards are used as the basis of the testing, which is conducted in the Ministry of Water facility.

The areas selected for the implementation of the technology were partially prioritized according to the quality of water sources available. Water samples were collected within the predefined "project zones" at different sites for water tests. Fecal coliform was the main parameter used to assess water quality. Raw water was collected from the following sources: water tanks, water vendors, standpipes, boreholes, and the river. The raw water was tested before and after SODIS treatment. Results for a typical set of samples are included in the following table:

Table 4.4 – Water Treatment Data for Kibera SODIS Project

Sample	Source of Water Raw Water		SODIS water		
no.		Fecal Coliform CFU/100 mls	Fecal Coliform CFU/100 mls		
629	Borehole	15	Nil		
630	Tank water vendor	Nil	Nil		
633	Water tank – Makongeni	1100	Nil		
634	NCC Water tank Makina	Nil	Nil		
635	NCC Tap Kichinjio	15	Nil		
636	Motoini river	460	15		

Source: KWAHO, 2004

4.4.2.3 Target: Behavior/Use (Social Acceptability)

The following are several "behavior/use" parameters used by KWAHO to evaluate program success:

- Technical Support This is considered especially important during the
 introduction of the program into a community. It is at this time that the SODIS
 promoters follow-up regularly. KWAHO plans to be available to SODIS users
 well into program implementation. The KWAHO offices in Kibera are fullystaffed with personnel versed in SODIS operation.
- Environmental Sustainability KWAHO has given consideration to the potential impact that a large-scale SODIS system might have on the already polluted public areas in Kibera, namely in the generation of mountains of plastic PET bottles as solid waste refuse. The project has not yet gotten to a point where the impacts of bottle disposal can be adequately assessed. The program does make it a point to inform users of proper bottle disposal. Proper bottle disposal entails throwing the bottles into proper public receptacles and not merely discarding these bottles into the surrounding area.
- User Input User input is obtained through meetings with the community and through follow-up visits with the users, which are conducted twice a week. The users typically comment that the system is very easy to use once it has been accepted and understood. KWAHO relies on user comments to make improvements to the system
- Education, Training, and Awareness KWAHO continues with education and training through follow-ups at the households after the technology has been implemented.

4.4.2.4 Target: Rate of Adoption and Sustained Use

In the implementation organization survey developed in this thesis, rate of adoption and sustained use have been considered a sub-category under "behavior/use (social acceptability)." However, KWAHO refers to this as "acceptance analysis" and uses this parameter in a manner so integral to their monitoring and evaluation of the system that it is worth considering as entirely separate from other targets utilized. KWAHO only considers a system successful if it is used continuously by the user. They have standard forms for these records which track the rate of uptake for SODIS users in the community. The following table consists of the acceptance analysis data received from KWAHO:

Table 4.5 – SODIS Acceptance

Community, Target Number of Households, and Actual Number of Households	Regular Users (Daily)		Irregular User (Certain times only)		Non User (Stopped using)	
	Hholds Reasons		Hholds	Reasons	Hholds	Reasons
Makina (Target: 12,000) Trained: 4,000	3500	 They know the value of SODIS water To prevent waterborne diseases. 	100	Most of them are single people	400	Moved to unknown areas.
Kambi Muru (Target: 4,000) Trained: 2700	2500	To prevent water- borne diseases	20	They are using water guard	180	They are using Waterguard
Kisumu Ndogo (Target: 4,000) Trained: 2300	2000	To prevent water- borne diseases	100	They only use SODIS water during week end when they have free time.	200	Moved to unknown area

Source: KWAHO, 2004

The above data was collected through direct household observation by promoters of the system. A summary of the results is as follows:

Table 4.6 – SODIS Acceptance Analysis Results Summary

Item	Value	Percent
Total target households	20,000	
Number of household reached/trained (out of total target households)	9,000/20,000	45 percent
Regular users (out of household reached/trained); i.e. regularly using	8,000/9,000	88 percent
SODIS water to prevent water-borne disease.		
Irregular users (out of household reached/trained); some use Waterguard;	220/9,000	3 percent
others only use SODIS on weekends when they are around.		
Non-Users (out of household reached/trained); some moved to unknown	780/9,000	9 percent
areas, and some are using Waterguard.		
Overall acceptance level (out of total target households)	8,000/20,000	40 percent
Acceptance level (out of number of households reached/trained)	8,000/9,000	89 percent

Source: KWAHO, 2004

4.4.2.5 Marketing and Distribution

Social marketing is the primary method of disseminating knowledge about the technology. SODIS promoters act at a community level and work with community leaders through home visits and workshops. They feel that social marketing is essential to the program and that it is necessary to change attitudes about water. SODIS is a new technology to which people react with initial skepticism. Some users expressed doubt about whether sunlight and bottles could effectively clean water.

Commercial marketing is considered somewhat effective but in Kibera most people do not have media access such as that obtained through television; therefore alternative means are necessary to market the product. KWAHO finds that the best way to reach the people is to use meetings and house visits to talk to the people personally and to gain their trust. Additional schemes discussed by promoters of the system are t-shirts, school competitions, and incentive prizes to families that "use SODIS the best".

4.5 Kenya Ministry of Water Resources Management and Development

The Kenya Ministry of Water Resources Management and Development acts as the agency in charge of all water and sanitation in the country. The agency has its headquarters in Nairobi and various regional offices throughout the country's seven provinces and one area. The Ministry has started to become more involved in the promotion of HWTS technologies, until this point in time however, the Ministry of Water has mainly been concerned with the promotion of boiling as the appropriate method of water treatment. The agency also promotes proper sanitation and hygiene practices to communities throughout the country.

During the site visit conducted by the MIT Master of Engineering team in January, we were fortunate to be assisted in our travels by Mr. Isaac M. Kilonzo, the Deputy Director of the Water Quality-Pollution Control Program of the Kenya Ministry of Water. Mr. Kilonzo, acting with support from the Permanent Secretary of the Ministry of Water, was vital in helping provide transportation and access for the team to many of the sites visited throughout the country. As a product of this interaction between the MIT team and the Ministry of Water, an official document was co-authored by Mr. Kilonzo and Susan Murcott, the MIT project team leader, summarizing the HWTS technologies and implementing organizations visited during the project. The document is intended for official use by the Ministry in producing new policies in water quality and control for the country (Murcott and Kilonzo, 2005).

Mr. Kilonzo represented the Ministry in many of the site visits and even facilitated a symposium at the end of the project to promote the use and awareness of HWTS technologies throughout Kenya. The symposium was attended by many representatives from each of the organizations visited and served as a forum for the propagation of knowledge about the numerous HWTS technologies already being implemented throughout the country. It was the overall goal of the symposium that these technologies be promoted and supported to a wider extent by both non-government and government agencies alike.

4.5.1 Pre-Implementation

4.5.1.1 Boiling

Currently, the Ministry of Water has been primarily involved in the promotion of boiling as an appropriate water treatment technique. Boiling is promoted through the efforts of Ministry of Water personnel located in regions throughout the country. The Ministry attempts to identify, in coordination with the Ministry of Health, hotspots for water contamination and subsequently informs residents in these areas of the necessity of boiling water. It was observed that there was a high level of awareness of this water treatment technique in all of the sites visited during the project. The organization does however realize that this technique is not affordable for all communities and is seeking other more cost-effective means of water treatment.

The Ministry of Water is also involved in providing water infrastructure for the country. During the site visit the team witnessed several water treatment plants, pipelines, boreholes, and protected wells among the numerous water services provided by the Ministry.

4.5.1.2 Implementation Program

Throughout the process of visiting various HWTS technology-implementing organizations, Mr. Kilonzo saw to it that appropriate Ministry of Water personnel working in these specific areas were available to assist the project team. In locations such as Nairobi (KWAHO SODIS), Mombasa (PSI Waterguard), and Nakuru (CDN defluoridation filter), the Ministry was observed to be very much involved in the implementation of the said technologies. The extent of Ministry involvement was mainly through water quality control and testing, although in some areas, such as Nairobi, the Ministry went as far as to provide laboratory facilities and offices for one of these organizations (KWAHO).

The involvement of Ministry personnel during site visits was twofold: (1) to assist the MIT team in collecting information on water quality and water use practices in these specific regions and (2) to in turn gain an awareness and understanding of the HWTS technologies being implemented so that a more conducive and efficient relationship be could be developed between the Ministry of Water and the organizations implementing these technologies. Evidence of this relationship was observed in the interaction between PSI Mombasa and the head chemist of the Ministry of Water in the Coast Province, Mr. Haji S. Massa; as personnel of the two organizations had an obvious familiarity with one another. The Ministry of Water was the primary source of water quality testing for PSI Mombasa, and the Ministry in turn was relying on the efforts of PSI to promote chlorination as an appropriate means of addressing water quality concerns in the region – a win-win partnership.

According to Mr. Kilonzo, the Ministry is making a concerted effort to become more involved in the promotion and support of HWTS technologies, as it has determined that the resources available to the Ministry are not sufficient to provide safe water at a household level. The Ministry has cited these organizations as having the access and marketing techniques that are effective in implementing programs at the grass-roots level.

The Ministry currently has plans to revise the current water code used by the country and intends that policy support for HWTS technologies be provided through the revision of this document. The site visits to the various implementing organizations was as much a learning experience for the Ministry as it was for the MIT team; Mr. Kilonzo were oftentimes impressed with the innovativeness and effectiveness of the technologies being implemented.

The organizations implementing these technologies also stand to benefit in a number of ways from potential policy-support provided by the Ministry of Water. For example, PSI and also CARE-Kenya are hoping for support from the Ministry in its current petition for VAT exemption of Waterguard. Through obtaining VAT exemption, PSI can sell the product at a lower price allowing for a more wide-scale distribution of the technology to rural areas. Also hoping for Ministry support is the Catholic Diocese of Nakuru (CDN), which stands to benefit greatly if defluoridation is mandated at contaminated groundwater sources serving the public. Currently, there is no policy that requires public water supplies contaminated with fluoride to be treated in any manner prior to use. In general, HWTS organizations also stand to benefit from the simple sharing of water quality data that the Ministry has amassed over its many years of operation. Water quality records have been taken at various periods and regions throughout the country and could stand to benefit any pre-implementation efforts by organizations involved in HWTS technology programs.

4.5.2 Implementation

Monitoring and evaluation are considered essential by the Ministry. Although the Ministry does not conduct monitoring specifically in regards to HWTS technologies, the organization does conduct monitoring that is valuable to organizations implementing these technologies, i.e. water quality data collected for the sources of water being utilized by communities. The collection of this data serves as a basis for determining the need for HWTS interventions. In this regard, water quality is considered a target for the organization. The Ministry has several offices and laboratories throughout the country to collect water quality data from a variety of water sources.

A secondary target would be the impact of water quality on health, i.e. health outcomes. Although more of a target for the Ministry of Health, health impacts are also a consideration and an indication of areas that need to be addressed by the Ministry of Water. A third target that might also be considered is Behavior/Use (Social Acceptability) in that the organization relies heavily on the applicability of treatment methods such as boiling to a specific area. The organization attempts to obtain a general understanding of common water practices and attempts to introduce interventions through raising awareness and disseminating knowledge about proper water use, sanitation, and hygiene practices.

4.6 Kenya Ministry of Health

During the site visit in January, the MIT team had the fortune of meeting with Mr. Alfred Lang'at, the Chief Public Health Officer of the Ministry of Health, and Mr. Amos Odhacha, a public health officer with the Ministry of Health. According to Mr. Lang'at, a large number of administrative units and clinics operated by the Ministry of Health are located in communities all around Kenya, having a total staff of 4,200 officers and technicians. The Ministry of Health conducted an "Environmental Health Project" from 1987 to 1997 in order to address the following issues:

- 1. Provision of fecal disposal, protection of water sources, and collection of rain water:
- 2. Homestead hygiene issues;
- 3. Food safety and storage;
- 4. Nutrition emphasis on foodstuffs that can be grown locally and inside compounds;
- 5. Improvement of housing structures (i.e. floors);
- 6. Minimization of air pollution inside of the household (i.e. proper ventilation).

Although the team requested from the Ministry more information on this project, such information was not received at the time of writing.

The Kenya Ministry of Health is considered here because of their indirect efforts to address water quality concerns. The primary thrust of the agency is to address problems relating to health, which includes the proliferation of disease in the country. The agency acknowledges water-borne diseases, such as typhoid and cholera, as being an alarming problem in many communities throughout the country, and seeks to address it by promoting safe water practices in addition to hygiene and sanitation. In doing so, the Ministry of Health works closely with the Ministry of Water to increase knowledge about proper water treatment techniques such as boiling and chlorination.

The primary means of disseminating information by the Ministry of Health is through various Ministry-operated and funded health clinics throughout the country. The Ministry makes a concerted effort to educate patients, especially those suffering from water-borne disease, on proper methods of treating water. This was confirmed by visits to several of these facilities during the January 2005 visit. A large number of the HWTS implementing organizations visited indicated that health clinics were key resources in promoting the technologies. However, upon closer observation of these facilities, it was discovered that the HWTS technologies, such as the BioSand filters and Waterguard, were not being promoted in clinics where these technologies were available. Although the clinics were typically chlorinating their water, one was doing so using an industrial type of chlorine product, while another was using Waterguard improperly.

In addition to this, the Ministry of Health also lends support to the Ministry of Water in installing water infrastructure, such as protected wells and springs, as indicated in the goals of the above mentioned "Environmental Health Project".

4.7 BushProof, MedAir, and Samaritan's Purse

4.7.1 Pre-Implementation

4.7.1.1 Background

There are a number of organizations that have been instrumental in the start-up and implementation of the concrete BioSand filter in the Machakos District of Kenya's Eastern Province. These organizations are listed as follows:

- MedAir A non-governmental international humanitarian aid organization founded in 1988 with headquarters based in Switzerland (MedAir, 2005) provided initial funding for the project. This organization was involved in the Machakos District concrete BioSand filter project through the efforts of Adriaan Mol, who had been involved with the implementation of the BioSand filter in Somalia and Sudan. Mr. Mol had initially worked with MedAir on community-wide water filtration systems, eventually concluding that similar filter systems could be implemented more effectively at the household level. During the start-up of the project, Mr. Mol and another MedAir associate, Mrs. Cleo Weisent-Brandsma, were responsible for training the two technicians currently implementing the concrete BioSand filters in the area.
- NakoDev A religion-based NGO that was formed by the local church organization in the Machakos District area. An officially recognized NGO by the Nation of Kenya, NakoDev is intensively involved in numerous programs promoting the health and well-being of community members. The organization has received funding from the World Bank in order to implement the "Machakos Rural Development Programme" which has been responsible for the introduction of community-based programs in the following areas: food production, horticulture, community rehabilitation, livestock, water harvesting, leadership and management, agro-forestry, education, and safe water. Concrete BioSand filter promotion is integrated into trainings happening throughout the community. The organization also supports the concrete BioSand filter technology by allotting a portion of church grounds (free of charge) to the filter technicians for use as a workshop. The church Lead Minster, Reverend Cosmas Mwanzia, reports that the filters have reduced death and disease in the community, even saying that there have been no deaths of children under five in the past three years on account of the concrete BioSand filters. Reverend Mwanzia was kind enough to meet with the team twice during our site visit. David M. Kilonzo, one of the two filter technicians in the area, is also a reverend with the church.
- Samaritan's Purse A nondenominational evangelical Christian organization providing spiritual and physical aid to needy people around the world. Since 1970, Samaritan's Purse has helped meet needs of people who are victims of war, poverty, natural disasters, disease, and famine. Samaritan's Purse has an active presence in Kenya and was another of the organizations involved in providing funding and technical support for the project in Machakos.

BushProof – BushProof is a newly formed organization headed by Adriaan Mol and Eric Fewster. Ms. Cleo Weisent-Brandsma, MIT team's main in-country contact for the project, acts as a consultant for the organization in Kenya. BushProof is a humanitarian business which was started by several emergency aid and development professionals. The company is registered in the UK and has completed contracts in several countries, including Sudan, Madagascar and Kenya (BushProof, 2005). BushProof participates in several professional networks, and is a member of the WHO Network for Household Water Treatment and Safe Storage. Nowadays, BushProof is the primary organization providing technical support for the concrete BioSand filter project in the Machakos District. The involvement of the organization is currently limited to implementing training workshops for NGOs, selling improved round filter moulds, and the development of a mass-producible plastic filter unit, which is intended solve many issues related to the concrete version. It is hoped that the improved plastic filter unit, which is not yet available in Kenya, will allow for better implementation of the technology on a more massive scale.

As mentioned above, initial funding for the project was received predominantly from MedAir. Cost of the filters was subsidized by MedAir and Samaritan's Purse, while filter users paid the cost of materials. Marketing and production costs were covered by outside funding as well. Currently, implementation of the technology in the Machakos District is being undertaken solely by two local technicians, Simon Mwangangi Nutiku and David M. Kilonzo, as an endeavor independent of external financial aid.

4.7.1.2 Target Population and Current Water Use Practices and Concerns

Machakos has a few small towns but is mainly a rural area. Residents of the area obtain water primarily from surface water sources such as dams and rivers. Seasonal springs, rainwater harvesting, and groundwater wells are also utilized in certain areas. Visual inspection of the sources determined clarity in the rainwater sources to be high, while surface sources were typically quite turbid. One such source was actually a communitybuilt facility consisting of a man-made dam and a groundwater lift pump. The facility was fenced with an attendant and users of the facility paid a monthly fee for access to the water. Surface water from the dam was used primarily for irrigation and drinking water for livestock in specially built troughs. The protected pump below the dam supplied water that was used for household uses such as drinking and cooking. Water is typically transported by hand or through the use of donkeys and ox-carts. Water treatment was reported to be typically done through boiling, although several dispensaries and households in the area reputedly use the household chlorination product Waterguard®. Water is a scarce and precious commodity, as the area is semi-arid. At the time of the visit, the area had not seen rain in quite some time, so irrigation was practiced infrequently resulting in failing crops.

4.7.1.3 Implementation Program

Concrete construction is the chief skill employed in the production of the concrete BioSand filter in Machakos. The program started in 1998 with 12 technicians being trained in the proper construction of the BioSand filters by MedAir personnel Adriaan Mol and Cleo Weisent-Brandsma. The technicians were separated into groups of two located at different building sites. Different combinations of technicians, in terms of gender and age, were evaluated in order to determine which partnering would be most effective. Eventually it was decided that the two-man combination was the best combination due to the physical nature of the construction process, specifically when dealing with the concrete.

The technicians were initially paid through outside funding, but payment was gradually decreased until the filter project was no longer subsidized and the technicians were responsible for their own income. The technicians were trained to operate the program as a micro-enterprise endeavor designed to generate an income. Unfortunately, only two technicians, Simon Mwangangi Nutiku and David M. Kilonzo, remained from the original twelve. The technicians claim that they cannot fully make a living from the filters, and that they consider filter installation only as a source of supplemental income and a voluntary endeavor to help the area's current water quality problems. The primary goal of the project, as cited by the technicians, is the continued promotion and distribution of filters that are effective in addressing problems of water quality. The technicians also hope to continue to educate other people, in other regions of Kenya, in the construction of the filters. Pictures of concrete BioSand filters observed in the area are included in Photo 4.5.

Technical support for the technology was originally received from Samaritans Purse or MedAir. Samaritans Purse previously provided technical assistance in the form of a volunteer that conducted follow-ups with households for three months.

The goal of the technicians implementing the technology is to install a concrete BioSand filter in every household, regardless of water source. The estimated population in Machakos is 54,000 people. The total population in the entire region that could potentially benefit from the program, including surrounding communities, is estimated by the technicians at about 300,000 people. To date, the technicians estimate that 2,400 filters have been installed throughout the Machakos District. It is estimated by the technicians that half of the population in Machakos is utilizing a concrete BioSand filter for water treatment. As observed in the field, each filter may serve more than one primary family unit as people in this region live in compounds with extended family groups, each compound utilizing a single filter. It is estimated then, assuming an average household size of ten people, that the total population currently benefiting from the project in the Machakos area is about 24,000. This does not account for the fact that the technicians have conducted numerous training sessions in the construction of the filter throughout Kenya.



Photo 4.5 – Concrete BioSand Filters installed in Machakos (2005)

4.7.1.4 Resource Availability

Sand and gravel are readily available in numerous stream beds in the area. Cement for the concrete is also easily accessible at a hardware supply store located at Katanggi, the main town off the major east-west highway. The only resources that are not locally produced are the steel moulds, which have been manufactured in Nairobi. Resource availability was a determining factor in selecting the concrete BioSand filter technology for implementation in the area.

4.7.1.5 Education and Training

The original twelve technicians were trained for several weeks in the construction of the filters at the beginning of the project in 1998. The remaining two were supported by MedAir and Samaritan's Purse in obtaining 1.5 additional years of training in accounting, marketing, and construction.

General education about the concrete BioSand filters is provided at town gatherings. This also provides a forum for the technicians to promote the technology. As previously mentioned, the technicians also conduct 10 to 15-day trainings in filter construction in other districts of Kenya. In the local area, the technicians have identified male farmers with high school educations as primary candidates for training in the construction and distribution of these filters.

The technicians also attempt to train residents regarding safe water practices and sanitation. Prior to implementation, people had a moderate knowledge of water treatment methods and hygiene. However, it was found that knowledge of problems did not necessarily translate into action in following safe water practices.

4.7.1.6 *Funding*

Samaritan's Purse, the German Development Service, MedAir Uganda, MedAir Madagascar, and the Rotary Club all provided funding at various stages of the project. Since 2001, the project has been self-sustaining. Although it was initially heavily subsidized by donors, payments from filter buyers now account for 100 percent of the project income. Most buyers pay for the filters in installments.

Prior to implementation, people were informally interviewed on how much they could afford. Average income in the area was also determined, and it was decided that until demand grew, users would only be charged for materials. Materials are considered the largest cost determinant in the entire price of the filter, typical costs required for the construction of the filters, as reported by the technicians, has been included in Table 4.7. It is reported that people generally felt that the value of the filter is worth more than they paid for; this was the case even when paying full price.

Item	Quantity	Cost
Labor to construct filter	1 laborer	KShs 50/hour
Labor and materials to obtain gravel, sand, and concrete		KShs 125
1 bag concrete		KShs 580 makes 3 round concrete filters or 1 ½ square filters
Labor to obtain and sieve and wash sand		KShs 200
Steel mould	1 round /square	KShs 35,000. Volume of round is ½ volume of square, but they cost the same, either way.
Water for washing sand	4 20-liter jerry cans	KShs 10/ one jerry can in rainy season. KShs 15/one jerry can dry season.

Table 4.7 – Cost of Materials and Labor for Concrete BioSand Filter Construction

4.7.2 Implementation

The two technicians who currently construct the filters also conduct operational monitoring for this program. They follow up with each household 21 days after installation (the recommended time it takes the filter to ripen). In the initial months of the project, samples of the filtered water from various households were analyzed in the government lab at the Ministry of Water's Pollution Control Division-Nairobi to test for fecal coliform and turbidity. According to the technicians, the results of these tests indicated a 95-98.6 percent reduction in *E. coli* count and turbidity less than 5 NTU in all samples.

4.7.2.1 Target: Health Outcomes

A health outcomes assessment was not completed for the project. However, there is a perceived reduction in child mortality and diarrheal disease incidence in the community. Previously, it was estimated from community input that diarrhea occurrence was at 2-3 times/month/child.

Mrs. Weisent-Brandsma intended to do a health impact study to see if there was a difference in the health of children in the households with filters. Unfortunately, there had not been a baseline study completed and it was difficult for her to find the information needed to complete such a study in diarrheal disease incidence. Hospital records were disorganized and misreporting was common when soliciting information about the topic from families.

4.7.2.2 Target: HWTS System Performance

Regarding structural performance of the concrete BioSand filters in the Machakos District, out of the 2,400 filters produced, only four of them cracked, either during transport or from handling of the filter before full curing was complete; all of these were subsequently repaired by the technicians.

In regard to microbial water quality, the following information was taken from the biosandfilter.org website pertaining to the concrete BioSand filter project in Machakos:

MedAir carried out two sets of bacteriological tests in 1999 and 2000 on filters installed in Machakos District, Kenya (MedAir, 2000). Random testing of 160 installed filters showed an average *E. coli* removal rate between 91 to 93 percent. It has to be mentioned that this average was brought down by six samples with a count of less than 80 percent, caused by owners misusing the filter. Excluding these samples an average removal rate of 96 percent was established, while in all but 11 cases turbidity was reduced to less than 5 NTU. Except for 17 cases drinking water was produced with less than 10 *E. coli* per 100 ml - an acceptable standard for most of rural Africa. (biosandfilter.org, 2005)

These values are comparable to previous research conducted for the filters which indicate a removal efficiency anywhere from 95 percent (Snider, 1998) to 99.5 percent (Lee, 2001).

Although the technicians attempt to teach proper monthly maintenance methodology to residents upon installation of the filters, it was discovered during the site visit that this suggested methodology was not being followed and that instead people were only cleaning their filters once per year or less – only when the filter became unbearably clogged. Clogging was defined by an unacceptable decrease in flow rate and was remedied by a complete removal and subsequent cleaning of sand, a procedure that would not be necessary if monthly maintenance was performed.

4.7.2.3 Rate of Adoption and Sustained Use

In the Machakos BioSand filtration program, there was a remarkable 100 percent rate of sustained use of the filtration system which seemed to be confirmed during the MIT team's visits to randomly selected households. Technicians reported that most people in the community continued to use their filters and temporary discontinuation only happens when filters are clogged. Mrs. Weisent-Brandsma highly credits the two technicians in the program's success in adoption and sustained use.

4.7.2.4 Environmental Sustainability

Production of the filters is dependent upon access to and availability of both coarse and fine sand. By-products of production are negligible; they include water for washing the sand and leftover pieces of PVC pipe used to create the filter's outlet. Water was also cited as a sustainability problem in terms of access, as some of the workshops are located long distances from water sources and require a considerable amount of time to get to.

4.7.2.5 Education, Training, and Awareness

Training in filter use and safe water storage happens prior to, during, and post-installation. Filter users first attend a group training on water quality and system use, and then receive individual trainings both during installation and during follow-up visits. Users also receive hygiene education and safe storage training in their households.

4.7.2.6 Social Acceptance

Turbid water sources in Machakos aid in social acceptance of the filtration system in that users observe their turbid water become very clear as a result of treatment (treated water turbidity <5 NTU according to local data). This facilitates the perception among the community that the concrete BioSand filter "cleans" the water. Barriers to acceptability include cost and, prior to seeing filtration, incredulity that sand can treat water.

4.7.2.7 Marketing and Distribution

Technicians employed a local artist to paint wooden sign boards for advertisements as well as to decoratively paint the filters themselves (see bright blue and yellow filters in Photo 4.5). They also created an information leaflet (Appendix D) and distributed it locally. Filter buyers are responsible for the transport of their own filters from the workshop site to their homes; this is typically accomplished through ox-cart or truck. Technicians claim that the best marketing for the product is through the local Ministry of Health clinic.

4.8 Anglican Church of Kenya (ACK)

Since 2001, the Anglican Church of Kenya (ACK), Christian Community Services (CCS) in Eldoret has been extensively involved in the implementation of SODIS technology within many communities, including Emkwen, Timbaroa, and Matharu. The organization works with community-formed self-help groups in the area and is heavily involved in the promotion of safe water, sanitation, and hygiene. ACK acts as both a promoter and trainer for the technology and also assists with technical support, should this be required by community groups.

ACK is implementing a "Water Supply and Sanitation Project" which has the overall intent of improving access to clean, safe, domestic water for community groups in the area. Operating in the North Rift area of Kenya, the groups are building household rainwater catchments systems, protecting shallow hand dug wells, and using rope and washer pumps (CCS, 2003).

4.8.1 Pre-Implementation



Photo 4.6 – SODIS bottles in a farm in Matharu (2005)

4.8.1.1 Target Population and Current Water Use Practices and Concerns

The Matharu project area (Matharu village and Subukia village) is predominantly occupied by the Kikuyu tribe. Matharu has been part of the ACK CCS water and sanitation programme for quite sometime. This prolonged contact has resulted in proper hygiene due to participatory hygiene and sanitation transformation training. The majority now have pit latrines through assistance from the program.

The target population in the area observed (Matharu) is rural. Matharu is a region interspersed with farms and homesteads, resulting in a relatively low population density. The region is high in elevation and experiences a relatively temperate climate. The observed subset of the population in the area was accounted for through membership with self-help groups involved with numerous community-oriented activities. It was estimated that each group has 400 members. We were informed during that visit that there were over ten of these groups in the area, accounting for an estimated total of 5,000 people benefiting from the program.

Sources of water in the area were shallow wells and, to a lesser extent, rainwater harvesting. The pre-existing shallow wells were discovered to be of inadequate water quality at times and were reported to have been the cause of isolated instances of water-borne disease. In the past, high incidences of diarrhea, and even typhoid, have been reported, suggesting that a contamination problem may exist. Initially, community members treated their water by settling and/or storage. Disinfection by boiling was practiced, but due to time pressure and the effort involved in collecting firewood and boiling water, the practice was often neglected.

In the past few years, one prominent activity that these community groups became involved in was the protection of numerous wells. Whereas formerly people had been accessing their water supply from shallow hand dug wells, these same wells were now made deeper, protected, dug, and outfitted with manually operated rope pumps. The newly improved water sources were wells approximately 60 feet deep, protected for the first ten feet, and equipped with a rope pump. All of these improved wells have a fence built around them in order to protect the source from potential animal and human contamination. The total combined cost of these rope pumps and improved wells is approximately 37,000 KShs (US\$ 493), KShs 26,000 (US\$ 347) of which is typically contributed by the homeowner while the rest is received from ACK contributions. The ACK serves as a technical guide and funding source in this instance and it is the community groups that do the actual promotion of the technology.

The new or improved sources of water in the area are considered to be of good water quality. SODIS is predominantly used for additional protective treatment. Water from these sources, prior to treatment with SODIS, was tested and found to be "clean" with 0-10 milligrams/liter total coliform levels in 90 percent of the improved wells (CCS, 2003). SODIS was, for the most part, reported as being used properly by residents. Most bottles were left on galvanized iron sheets in direct sunlight for at least six hours prior to use. Shaking of the bottles was practiced by half of the households visited and not practiced in the other half. A number of households felt that the technology was being used merely as a safety measure, as the newly improved wells were felt to be of adequate water quality for household purposes.

Users of the newly improved well water supplies have taken advantage of the availability and quality of the water. One homestead visited in the area had even gone as far as to erect an irrigation system for crops as well as a piped system to bring water closer to the home. The sources were reported to have had a positive effect on the agricultural enterprises in the area and subsequently increased economic activity in the region.

4.8.1.2 Implementation Program

In Mathuru, it is estimated that 60 households possess the previously discussed new protected water sources. As these households are all members of self-help groups, it is assumed that all of these households also use the SODIS technology in conjunction with these new sources. Because many households typically share the water source with neighbors, it is unclear as to what extent of the area's population is affected by the intervention.

ACK distributes SODIS bottles at varying costs to self-help groups and directly to users upon request. The bottles being distributed are of uniform construction; clear plastic PET. Previously one side of the bottle was painted black, but now clear bottles are used as well since black paint was not found to make a difference in water treatment. All bottles have the SODIS logo attached to signify authenticity in terms of being composed of the right material to adequately disinfect water. Bottles are sold at cost to those users who are determined not to have the capacity to pay; otherwise the bottles are typically marked up at a small percentage above manufacturing costs. For instance, a two-liter bottle might cost 10 to 15 KShs (US\$ 0.16 to 0.20) to purchase from the market new or secondhand and would be sold by ACK to community groups at 20 KShs (US\$ 0.27). Community groups then typically provide these bottles to users at the given 20 KShs cost at no profit.

4.8.1.3 Resource Availability

Resources for the improved wells are locally available with some select parts obtained from nearby hardware suppliers. SODIS bottles are received or purchased from the ACK which in turn obtains the bottles from a local manufacturer in the area.

4.8.1.4 Education and Training

The self-help groups not only aid in the construction of improved wells but are also involved in the training of community members in construction, operation, and maintenance of the sources and pumps themselves. The self help groups also educate members on proper water use practices, sanitation, and hygiene. All of the homes using the newly improved sources were also taught to use the SODIS technology.

4.8.2 Implementation

ACK uses both health and water quality targets for evaluation of program success.

4.8.2.1 Target: Health Outcomes

For health outcomes, ACK monitored disease incidence for one year after hygiene training and SODIS implementation. Common illnesses in the area are typhoid and diarrhea – both of which decreased after the pumps were added. Detailed information on health outcome was obtained through community health workers in the area.

From October 2002 to September 2003, the Christian Community Service Water and Sanitation Programme conducted a health study of the Eldoret Region regarding the impact of SODIS. The intent of this study was to test the application of SODIS in the community.

The objectives of study were:

- To determine the water-borne diseases distribution in three distinct areas
- To compare the water-borne diseases incidences among users and non-users of SODIS
- To determine the proper practice of SODIS in the community

A total of 90 users of SODIS and 90 non-users were selected in three project areas and the water-borne diseases incidences were monitored on a monthly basis in both groups for a period of one year. It was found that there was three times less incidence of water-borne diseases among SODIS users than among non-users (CCS, 2003). It was reported that 100 percent of users supported and recommended the use of SODIS in the community because, by their testimony, SODIS is cheap, easy to use, and effective in reducing diseases.

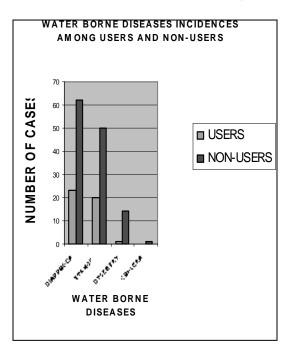
Some results of the study are presented as follows:

Table 4.8 – Waterborne Disease Incidences among SODIS Users and Non-Users

		PERCENTAGE			
	MATHARU	INCIDENCE			
USERS	5	17	22	44	26
NON-USERS	6	69	52	127	74
TOTALS	11	86	74	171	

Source: CCS, 2003

Figure 4.2 – Individual Water-borne Disease Incidence (Source: CCS, 2003)



The study concluded that water-borne diseases are endemic among the populations considered. Prevalence was considered a result of contamination of drinking water and/or food directly by human excreta, poor sanitation, inadequate water sources, and poor water handling at the home.

According to the study, the distribution of water-borne diseases among users and non-users indicates that SODIS is an effective intervention in the control of water-borne diseases (Figure 4.2).

It was also noticed that seasonal variations affect the effectiveness of SODIS in the control of diseases. Apart from less sunlight during the rainy season, SODIS is also less effective due to the fact that people tend to stop using the technology as "clean" rainwater sources are more readily available.

Recommendations of the study are presented as follows:

- Intensive and extensive health education in the community, targeting the behavior change among the target group, should be undertaken alongside SODIS practice;
- Dissemination and promotion of SODIS to all in both rural and peri-urban areas;
- An adequate bottle supply should be established.

Copies of the monitoring and evaluation forms used for the study have been included in Appendix D.

4.8.2.2 Target: Water Quality

For water quality ACK does intermittent testing of water samples in the area. In addition to these targets, the organization also utilizes a method of risk assessment that calculates exposure scenarios to diseases based on water use and sanitation practices in the household.

4.8.2.3 Target: Behavior/Use (Social Acceptability)

The organization has also researched rate of adoption through studies in relatively largescale areas of implementation. Data was collected through observation and interviews at specific households.

Included in part of the aforementioned health study discussed in Section 4.8.2.1 was a consideration of the appropriateness of SODIS to the target populations considered. The study utilized detailed interviews and concluded that SODIS was an appropriate technology in small-scale water disinfection. Of the users interviewed, 100 percent commented that it was easy, cheap, safe, saves time, and doesn't have an effect on the taste or smell of drinking water. The users further recommended that SODIS should involve the entire community, that an improved supply of bottles be located, and that an emphasis be given to intense hygiene education (CCS, 2003). This may be considered a rate of adoption and sustained use type of target being utilized by the organization.

In addition to this, a risk assessment relating exposure to disease and the correct use of SODIS was also conducted. This issue of "correct use" might be considered an operation and maintenance type of target. The risk assessment was based on the adherence of users to the guidelines illustrating the proper use of SODIS (CCS, 2003). The assessment operates on the finding that SODIS was directly responsible for reducing the threat of disease, and logically related the correct use of SODIS to this risk. The results are presented in the Figure 4.3 and Table 4.9.

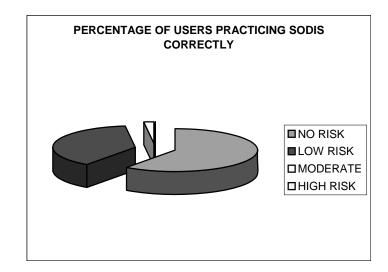


Figure 4.3 – Assessment of the Correct Use of SODIS (Source: CCS, 2003)

Table 4.9 – Risk Assessment in SODIS

Score	Percent of users in the risk category	Meaning
0	60	Very good practice, no risk at all
1-4	38	Low risk
5-7	2	Medium risk
8-11	0	High risk-bad practice

Source: CCS, 2003

As observed in Table 4.9, 98 percent of the community is using the technology correctly and subsequently experiences a very low risk of contracting water-borne disease.

4.9 Society for Women and AIDS in Kenya (SWAK)

The Society for Women and AIDS in Kenya (SWAK) is an all-inclusive and non-discriminatory national women's movement affiliated with Society for Women and AIDS in Africa (SWAA). The national secretariat of the organization is based in Nairobi and there are regional secretariats designated for each of the seven provinces in the country. The primary mission of the organization is to mobilize and empower women and girls in Kenya to reduce their risks and vulnerability to HIV/AIDS, as well as to enhance their capacity to provide care and support to the infected and affected.

4.9.1 Pre-Implementation

4.9.1.1 Background

SWAK was officially registered as an NGO in Kenya in 1996. The organization is affiliated with the Society for Women and Aids in Africa, which was started in Senegal but now has a presence in forty countries throughout Africa.

SWAK Nyanza is one of the eight regional SWAK offices in Kenya. During the site visit in January, the MIT team was able to meet with and observe the practices of this organization as well as to interview the organization's program director. The SWAK Nyanza offices are situated within the Lutheran Community Center, opposite Lions High School, in the City of Kisumu. The organization operates in the following districts within the Nyanza Province: Kisumu District, Siaya District, Bondo District, Nyando District, Rachyonyo District, Kisii District, Gucha District, Homa Bay District, Suba District, and Migori District. SWAK has not yet penetrated into the Nyamira and Kuria Districts of the province, but plans to mobilize these communities in 2005.

The organization was initially founded in 1998 in Kenya's Western Province. Alie Eleveld, our main in-country contact for the project, was one of the founding members. Mrs. Eleveld invited associates in Kisumu to attend a SWAK National Workshop in 2000; it was then that SWAK Nyanza was formed. Mrs. Eleveld continued her involvement with the organization until she was formally hired by the CDC to help with community mobilization and trainings for the "Safe Water System" (SWS) intervention. The CDC hired Mrs. Eleveld specifically for her skill and experience in implementing and promoting projects at the community level. The two organizations, SWAK Nyanza and the CDC, work together very closely to this day. The CDC promotes various health-related products while SWAK is involved with the distribution of these products to various community groups. Mrs. Eleveld is no longer formally with the CDC and is specifically focusing on SWAK Nyanza; she currently supervises all day-to-day operations of the organization, with the help of three volunteers that work in the organization's main office in Kisumu.

The total number of registered SWAK Nyanza groups is 155. There is an average of 20-30 members per group. For individuals, the organization offers a "full life" membership; currently, there are 102 full life members within the ten districts covered. Groups are comprised of people with varying professions, ethnicities, tribes, religions, and economic status. Groups are widow groups, post-test clubs, groups dealing with orphan support, youth groups, and groups performing income-generating activities. In each district, SWAK Nyanza has selected coordinators who act as leaders for all of the groups in the area (SWAK, 2004).

4.9.1.2 Implementation Program

4.9.1.2.1 SWAK's Full Range of Products

SWAK Nyanza distributes a multitude of household water treatment and storage technologies. Primarily, in treatment, the organization promotes PSI's Waterguard® and Proctor and Gamble's PuR® while, in safe storage, the organization promotes use of the modified clay pot. Prior to Waterguard, the organization was involved with the distribution of the prior product branded "Klorin" which was purchased at that time through CARE-Kenya from Jet Chemicals. The implementation of the modified clay pot is the main topic of discussion in the following sections, although both Waterguard® and PuR® will be included in the discussion as well.

SWAK's HWTS technology implementation started with the "Safe Water System" because of their involvement with CDC and CARE-Kenya. The organization subsequently started to work with PSI, promoting their health products (mosquito nets and condoms) as well as their water products. The organization quickly realized that profits obtained from sales were sufficient to pay for rent and other overhead expenses.

SWAK Nyanza has a close working relationship with all of the lead organizations distributing this set of technologies. CDC, CARE-Kenya, and PSI are some of the organizations that SWAK Nyanza works with on a regular basis. The organization is also closely involved with local community groups and in fact utilizes these groups as the primary means of knowledge dissemination and information sharing to local residents. In the implementation of the modified clay pots, the organization works with local women's pottery groups throughout the Nyanza Province. The organization strives to encourage financial sustainability, in addition to health, in that all products promoted are introduced as micro-finance ventures designed to empower local entrepreneurs and to serve as an opportunity for potential economic gain.

As reported by the organization, 25 modified clay pots and 15 crates (24 bottles per crate) of Waterguard are sold on a monthly basis throughout the Nyanza Province. A complete list of SWAK Nyanza products and corresponding retail prices in 2004 are presented in the following table (Table 4.10). Table 4.11 reports sales for the products "Klorin" and Waterguard in the years 2003 and 2004.

Table 4.10 – SWAK Nyanza Products

Product	Retail Price		
Round Mosquito net	KShs 320	US\$ 4.27	
Rectangular Mosquitonet	KShs 100	US\$ 1.33	
Powertab	KShs 30	US\$ 0.40	
Mosqbar	KShs 50	US\$ 0.67	
High Protein Flour	KShs 100	US\$ 1.33	
Immune Booster Kemri	KShs 1,000	US\$ 13.33	
Moducare Adults	KShs 1,300	US\$ 17.33	
Moducare Children	KShs 800	US\$ 10.67	
Klorin	KShs 25	US\$ 0.33	
Waterguard	KShs 35	US\$ 0.47	
Pur (treatment of turbid water)	KShs 5	US\$ 0.07	
Modified Safe Storage Water Pot 20 L	KShs 350	US\$ 4.67	
Modified Safe Storage Water Pot 40 L	KShs 500	US\$ 6.67	
Savlon Ointment	KShs 100	US\$ 1.33	
Benzyl Konium	KShs 100	US\$ 1.33	
Mouth Gargle	KShs 100	US\$ 1.33	
Red Ribbons	KShs 100	US\$ 1.33	
T-shirts (SWAK NYANZA)	KShs 350	US\$ 4.67	
T-shirts (Women's AIDS Run)	KShs 150	US\$ 2.00	
Condoms 3/pack	KShs 10	US\$ 0.13	
Women's Condoms	KShs 50	US\$ 0.67	

Source: SWAK, 2005

Around 20 registered SWAK Nyanza groups within the Kisumu, Bondo and Siaya Districts are vendors of the above products, buying them from SWAK Nyanza at wholesale price. The profit from the sales remains with the groups; becoming an income generating activity. SWAK Nyanza typically obtains products directly from distributors such as PSI and CARE-Kenya, while working with organizations such as the CDC on projects regarding training and awareness creation. The CDC and CARE-Kenya also provide most of the technical support for the HWTS technologies implemented.

SWAK Nyanza has mentioned that there has been some difficulty on the supply end of Waterguard, which is the responsibility of PSI, in that supply can hardly keep up with the demand generated by the organization. This problem is not as apparent with the distribution of Waterguard as it was with the initial distribution of "Klorin". A larger supply problem is experienced with the mosquito net product, which is reported to sell out almost immediately upon delivery. SWAK reports that sales of the nets could easily be double those currently being achieved by the organization.

Table 4.11 – SWAK Sales of Waterguard® and PuR® for 2003 and 2004

MONTH AND YEAR	KLORIN /WATERGUARD BOTTLES	PUR SACHETS
December 2002	96	
January 2003	120	
February 2003	648	
March 2003	1944	
April 2003	432	
May 2003	384	
June 2003	264	
July 2003	324	
August 2003	192	
September 2003	48	221
October 2003	600	698
November 2003	564	2049
December 2003	312	951
January 2004	420	1611
February 2004	324	524
March 2004	84	1120
April 2004	132	875
May 2004	384	1150
June 2004	480	1233
July 2004	516	1560
August 2004	408	4320
September 2004	75	1075
October 2004	48	866
November 2004	138	1640
December 2004	414	400
TOTAL	9351 bottles= 389.5 crates	20,293 sachets

Source: SWAK, 2005

4.9.1.2.2 Modified Clay Pots

Apart from the full range of products discussed previously, SWAK Nyanza is also involved in the sale of the modified clay pot.

In regards to the modified clay pots, SWAK Nyanza initially took two pottery groups to the Oriang Women's Pottery Group in Homa Bay, which is the group utilized by CARE-Kenya in the production of the modified clay pots. The organization educated these groups on the "Safe Water System" and the role of the modified clay pots, and then proceeded to help the organizations with start-up costs and materials such as taps, cement, and red oxide.

The two groups were reportedly unable to sustain their respective programs but fortunately one "master trainer" of the groups proceeded to start her own group. This group became the Kenda E Teko Pottery Group which is located in the town of Seme which borders the Asembo District of the Nyanza Province. This group was visited by the MIT team in January 2005. Reportedly started independently of the CDC and SWAK, this group has been cited as being a tremendous resource in the dissemination and production of the modified clay pots. SWAK has indicated that the pots produced by Kenda E Teko are of better quality and durability than those produced by Oriang, whose pots have a pronounced problem with leakage and breakage (See Pihulic, 2005 and Young, 2005).







Photo 4.7 – Manufacturing of Clay Pots by the Kenda E Teko Pottery Group (2005)

4.9.1.3 Target Population and Current Water Use Practices and Concerns

The target population for modified clay pots is comprised of households in urban, periurban, and rural areas. Specifically targeted were people who make decisions about household water treatment and storage purchases, as well as opinion leaders in the community.

In the Nyanza province, there is a wide range of water sources utilized, from surface to groundwater sources as well as rainwater harvesting. Commonly used water storage containers include the traditional wide-mouthed clay pot, plastic jerry cans, and both plastic and metal buckets, all of which are affordable and locally produced. It is reported that 80 percent of residents typically used traditional wide-mouthed clay pots for storage. Water stored in these containers has been determined to be more susceptible to contamination due to a lack of protection and careless water use practices.

Pre-implementation health and impact studies conducted in the region by the CDC and other organizations were relied upon by SWAK before the distribution of HWTS products. Ongoing information collection efforts by CDC and CARE-Kenya are expected to supplement current implementation by the organization.

4.9.1.4 Resource Availability

The modified clay pots are locally produced by women's pottery groups in communities such as Seme and Homa Bay. Production, expense and quality of the pots are contingent upon availability and training of skilled potters as well as upon the quality of available clay. SWAK is responsible for coordinating the transport of these pots from the pottery groups to the SWAK office where these pots are collected by consumers. Transport of the pots is a cumbersome process especially since pottery groups are oftentimes located a great distance from points of sale. SWAK sometimes utilizes transportation provided by the CDC to collect these pots (See Pihulic, 2005 and Young, 2005).

4.9.1.5 Education and Training

In regard to the modified clay pots, which were originally introduced to Kenyan pottery groups in 1999, groups were educated on the rationale behind the modification of the traditional clay pot. They were also trained to modify the structure of the clay pots to conform to the standards of modified clay vessels.

At the Kenda E Teko pottery group, a master potter with sixty years of experience provides ongoing training to the other seven novice potters in the group as well as to potters in and around Asembo and Kisumu. These additional potters are called upon when there are too many orders to be dealt with by Kenda E Teko alone.

SWAK is still working within the regions to try to increase awareness of water quality and safe storage. The organization recognizes that by involving administrative leaders in the process, the community is more likely to use the technology. SWAK also trains residents in advocacy, paralegal, community counseling, child counseling, memory projects, home-based care, mobilization workshops with leaders, safe water and nutrition trainings, malaria awareness and prevention, and microfinance to people selling products. Recently, the organization also added another training called "Ambassadors of Hope", which aims to teach people about disclosure and public speaking.

In collaboration with CARE and funds from CDC, SWAK was able to conduct the "National Workshop on Safe Water Storage" in April of 2004. This was accomplished to train SWAK provincial branch leaders and leaders from the national secretariat on the "Safe Water System" interventions. After the workshop it was noted that the Rift Valley and Western Province started selling Waterguard and PuR®.

SWAK personnel also receive training and attend seminars on HWTS interventions. One such event was the World Health Organization International Symposium on Safe Water held in Nairobi in June, 2004. Alie Eleveld attended the symposium as a technical support officer and also gave a presentation on the SWS interventions held in the community through SWAK/CDC groups. After the symposium, SWAK and CDC organized a site visit to Kisumu for ten of the people attending the event. The visit included the Oriang Women's Pottery Group in Homa Bay and the Kenda E Teko Pottery Group in Seme.

4.9.1.6 Funding

For the pottery groups involved in the construction of the modified clay pots, SWAK, in coordination with the CDC, typically provides initial supplies such as taps, cement, and other tools used in the production process. After the first set of modified pots were completed and sold, the pottery groups became self-sustaining from the profits of clay pot sales.

The overall funding of the organization comes from a number of sources, namely: the Germany-based Evangelischer Entwicklungsdienst (EED, Church Development Service), the CDC (funding for trainings and capacity building), SWAK National Secretariat, and funding generated from in-house activities such as registration fees (500 KShs per group and 1,000 KShs per life member) and sales from products. Donations and other fundraising activities also generate income for the organization. According to the organization the following is the breakdown of the typical funding received per month:

- 350,000 KShs/month (US\$ 4,666/month) for trainings from the CDC
- 70,000 KShs/month (US\$ 933/month) from the EED
- 30,000 KShs/month (US\$ 400/month) from the National Secretariat (SWAK International)
- 150 KShs/group (US\$ 2/group) membership dues / 500 KShs/group (US\$ 7.66/group) for registration
- Life members are 1,000 KShs/person (US\$ 13.33/ person) for registration (100 life members to date)

There was no cost-benefit or willingness-to-pay study conducted prior to implementation, although organizations such as CARE-Kenya often conduct these types of studies for their products. SWAK does rely on these studies when available.

4.9.2 Implementation

The extent to which SWAK monitors implemented technologies is restricted to quarterly meetings with the community leaders implementing these technologies. Because the organization has grown so rapidly and quarterly meetings became cost-prohibitive, meetings are now only held with district leaders. In these meetings, SWAK attempts to gain knowledge of how many units are being sold and whether residents are responding well to the use of these technologies. The organization also sends out a monitoring tool (Appendix D) for group leaders to fill-out. Some of the typical information collected on these forms is listed below:

- Target Group (PLWH/Widows/Women/Orphan Caretakers/Youth /Others)
- Major activities (Merry-Go-Round/AIDS Awareness/Orphan Support/Widow Support/Home Based Care/ Feeding Program/ Safe Water/ Pottery)
- Major achievements of the group.
- Major challenges of the group.
- Suggestions for SWAK.

The organization also does intermittent evaluations of some of the groups. Additionally, SWAK conducts monthly meetings with local members in Kisumu and has strategy planning meetings at the beginning of each year. SWAK is also a member of the "Safe Water Consortium" which brings together all partners dealing with safe water in hopes that experiences and information may be shared.

SWAK mainly relies on other organizations for more detailed monitoring and evaluation activities of HWTS systems. For instance, village health promoters are typically trained by CARE-Kenya in monitoring and evaluation of the "Safe Water System". CARE-Kenya's monitoring activities include spot checks at households to determine proper use of the modified clay pots and "adherence monitoring" through surveys conducted six months after introducing two of the three key components of the "Safe Water System", the modified clay pot and household chlorination.

4.9.2.1 Target: Health Outcomes

SWAK recognizes the importance of health outcomes as indicators of program/product success, but indicated that such studies require funds that are beyond those available to the organization. The organization has learned informally from people who have used these HWTS technologies that instances of diarrhea have decreased in their respective areas. The organization has stated that this is especially important factor for members that are HIV positive.

As evidence of the problem of diarrhea in the area, the organization also cited a CARE/CDC study indicating that approximately three-fourths of the children under five have experienced diarrhea in the two weeks prior to the study period. This baseline survey was administered in Nyanza communities to gather information that could be used as a benchmark for project evaluation. CARE-Kenya then looked at randomly selected intervention and control villages to evaluate the effectiveness of the program. It also conducted focus group discussions through qualitative and quantitative surveys to determine the perceptions of the target population regarding the "Safe Water System", including the modified clay pots. Part of the project included monitoring of diarrheal incidence at a given period through morbidity data collection. SWAK also works with the Ministry of Health in home-based care training.

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⁹ "Adherence Monitoring" is roughly equivalent to the "Rate of Use/Adoption" target discussed in the implementation organization survey (Chapter 3).

4.9.2.2 Target: Water Quality

SWAK also cites water quality as a very important target in program evaluation. SWAK relies on other entities to obtain data on water quality, as the organization does not currently have the funds or the facilities to conduct such studies independently. The organization cites that actual field data is essential in evaluating whether these technologies are being utilized properly. Oftentimes, individuals who say that they have adequate knowledge of how to use the technology are in reality not using the technology correctly.

4.9.2.3 Target: System Performance

The production of the modified clay pot is currently not standardized. The overall process of creating the pots is somewhat consistent but pot sizes and other pot characteristics vary from potter to potter. Oftentimes potters use arm lengths and personal judgment to determine pipe depths and thickness. Firing techniques also cause some inconsistencies in the pots produced, in that some pots may be more exposed to heat than others. Overall, there is too much variability in the process to adequately produce a standard for the modified clay pots created. Currently, Suzanne Young and Mike Pihulic, members of the MIT Master of Engineering team, are conducting thesis work on how to improve the efficiency and standardization of modified clay pot production in various pottery groups in the Nyanza Province.

Due to this lack of standardization, system performance is not a feasible target for the evaluation of modified clay pots, although SWAK does attempt to keep track of the number of pots that perform effectively in the field. The organization collects data on how many pots leak and even returns these pots to the pottery groups for repair should the leakage of certain pots be determined as excessive. Additionally, SWAK monitors production processes to a certain extent and makes sure that the pottery groups are practicing a certain level of quality control. The organization may visit a certain group and correct practices that they feel might improve the production process.

The organization does not use system performance as a target for Waterguard and relies on any efforts by PSI to monitor the product in this regard.

4.9.2.4 Target: Behavior/Use (Social Acceptability)

4.9.2.4.1 User Input

A baseline survey and focus group discussions conducted by CARE-Kenya and CDC in 2000 established that clay pots were preferred (99 percent) as storage water vessels (over other vessels such as jerry cans) for the following reasons: they have an evaporative cooling effect, water is highly palatable, and people are familiar with this type of water storage. Input from the survey triggered research on ways to modify the pots so that contamination would be limited. User input regarding the modified clay pots was reportedly positive. The pots are a good modification for a storage vessel already familiar to communities and therefore require very little technical assistance in use.

Waterguard is also a technology that has been received well, although there has been some difficulty experienced with users not using the proper dosage, as well as problems in retreating water due to low consumption of smaller family groups (See Alekal, 2005). The difficulties in Waterguard are detailed in the PSI section of this chapter. SWAK and CDC do attempt to work together in conducting training sessions to educate residents on the necessity and proper utilization of water treatment and safe storage technologies.

An interesting input received from users on the PuR® water product was that the directions printed on the back of the sachets made use of the product difficult because they were written in Spanish or Filipino. These sachets were those left over by a study conducted by Proctor and Gamble and distributed free to community members. Reportedly, SWAK has received some new stock of the product from Uganda in which the directions are in English. Some other interesting information received from users was that the product could be used to kill frogs and also was reported to reduced the sexual drive of men in the household.

SWAK values user input greatly, as this is the most direct and available indicator of program success. It is important to the organization to be "user-friendly", especially to women, who are the main focus of the organization's efforts.

4.9.2.4.2 Rate of Adoption and Sustained Use

SWAK cited research conducted by Matt Freeman for his paper entitled "Safe Water and Social Entrepreneurship: Income Generation and Distributional Equity. A Case Study in Western Kenya" (Freeman, 2004). The study sample focused on a women's group and three youth groups that were using the safe water intervention and reported a 50 percent adoption rate of the product. This was received by SWAK with optimism as the organization's definition of low uptake was in the 5-10 percent range. The organization sees rate of adoption and sustained use as a valid and effective target for evaluating program success.

4.9.2.4.3 Education, Training, and Awareness

Comprehensive training and educational materials such as brochures, posters and manuals were developed in English, Kiswahili and Dholuo (the local language) to facilitate training at all education levels. The organization is involved deeply with education and training efforts. See the Section 4.9.1.5 on education and training for a more detailed description of the issue.

4.9.2.4.4 Social Acceptance

Social acceptance of the product is reportedly high, especially with women that often report being overworked by the task of boiling water. The organization feels that they have the proper water treatment technologies for implementation in any scenario. PuR® is being promoted for highly turbid water while Waterguard is being promoted for water that has comparatively low turbidity.

4.9.2.5 Marketing and Distribution

SWAK classifies their marketing model as quasi-commercial, although the organization does rely heavily on their distributors to market individual products. For instance, PSI does all of the promotion for Waterguard, and this cost does not come out of the SWAK budget.

SWAK relies heavily on social marketing as well. In the case of mass media commercial marketing, the organization recognizes that poorer areas are not reached as these areas are far from advertising located on the main roads and thoroughfares. In addition to this, these areas do not have access to televisions and radios. SWAK feels that social marketing is the best method by which to reach these poorer communities, with trusted individuals these communities being the primary medium of information dissemination. This suggests an urban-rural divide in regards to the implementation of water products. Social marketing is facilitated through various activities, including banners, puppet shows, and promotional tournaments. A lot of mobilization is done through visiting chief's gatherings and other public events like International Women's Day and World Aids Day. These social marketing techniques are often coupled with health education and community mobilization to encourage individuals to adopt the modified clay pots, as well as the other two SWS components.

SWAK is also careful in selecting prime areas for marketing, as dictated by the culture in the area. For instance, Saturdays are funeral days in Nyanza Province, and at these events, which include a lot of feasting outside the home, clean and safe water is a concern. The organization makes it a point to promote the product at these events.

As part of the overall MIT Project conducted in Kenya in January of 2005, a group of four students from the Sloan School of Business conducted detailed research into the marketing, financial, and overall business practices of SWAK. Initially, the Sloan Team intended to produce the following deliverables: (1) "a business plan for water purification products, including best practices and microfinance indicators" and (2) "a marketing plan for water purification products, including training and scaling." Upon arriving at the site however, the team modified their approach to better address the needs of the organization and other relevant stakeholders. The revised set of deliverables produced by the Sloan Team is listed as follows (G-Lab, 2005):

- Current best practices among SWAK groups for the sale of Safe Water System products
- The attributes of an "ideal group"
- A business model, including marketing strategy, bookkeeping suggestions, ways to deal with capital constraints
- A five-day training curriculum for the SWAK groups on the business practices around the Safe Water System products
- Recommendations for addressing common challenges that SWAK groups faced

Although all deliverables were received warmly by the organization, the business model and training curriculum were reported as being the most beneficial and are expected to be utilized in the future. (Chasse et al, 2005)

4.10 Catholic Diocese of Nakuru (CDN)

4.10.1 Pre-Implementation

4.10.1.1 Background

The Catholic Diocese of Nakuru (CDN) developed a water program in 1985 and a subsequent water quality program in 1997. The water program has established the following goals:

- 1. Awareness creation in communities regarding water, sanitation, and hygiene issues:
- 2. Development of bone char defluoridation technology and production processes;
- 3. Implementation in communities;
- 4. Laboratory services.

The program covers the following civil districts in the Rift Valley Province: Nakuru, Baringo, Koibatek, Kericho, Bomet, and Boret. To date, the program has a staff of 60 people involved in the drilling of deep wells, and construction of water schemes including rainwater harvesting tanks. Since 1998, CDN has also developed filter systems utilizing bone char technology to address the issue of fluoride-contaminated groundwater sources. These filters are manufactured and distributed by CDN.

4.10.1.2 Target Population and Current Water Use Practices and Concerns

Nakuru, located in the Rift Valley Province, is one of the hot spots for fluoride in Kenya. According to the Ministry of Water-Rift Valley Province, surface water supplies about 55 percent while groundwater serves about 30 percent of community needs. Groundwater is said to supply 80 percent of all domestic water use in Kenya. Some springs and surface water sources have been identified as being contaminated with fluoride. Fluoride contamination typically occurs in areas with a geology of volcanic rock heavily laden with calcium and phosphate. The CDN program seeks to address fluoride contamination in groundwater aquifers.

CDN has drilled or rehabilitated 300 boreholes in the past 12 years. Of these, it has been determined that 75 percent have a higher fluoride content than the maximum limit recommended by the World Health Organization (1.5 milligram/liter). Furthermore, 40 percent of these boreholes exceed the maximum limit by three times (CDN, 2005). The CDN program does not distinguish between urban and rural populations; instead they target areas based on the presence of contaminated water sources.

4.10.1.3 Implementation Program

In 1997, CDN applied for a grant from Misereor, a German Catholic bishops' organization for development cooperation, to develop fluoride removal methods for use in rural communities. The grant was approved and the defluoridation program began in 1998. The organization selected bone char technology as the appropriate means of fluoride removal for the following reasons:

- Availability of local raw materials and spare parts;
- Minimal maintenance required;
- No addition of chemicals;
- High efficiency regardless of flow rate;
- Low cost.

Education about sanitation, hygiene, and safe storage are also a part of the implementation program for this technology. There were no specific health surveys conducted for the program. Therefore, there is no data regarding the number of people affected by fluoride-contaminated water and/or this intervention. The best approximation might be made by considering the number of filters constructed to date: about 25 of the large scale filters and 300 to 400 of the household filters, which would be equivalent to 50,000 to 100,000 people served (CDN Discussion Notes, 2005).

CDN expects to have some difficulty in implementing the technology on a larger scale. There is a lack of funding to expand from the current small size and local focus of the operation. The organization stands to benefit from a potential mandate from the Kenya Ministry of Water that would require the use of defluoridation filters for contaminated public groundwater sources. Three of the large-scale defluoridation filter systems installed by CDN were visited during the site visit in January. Prior to its experience in constructing defluoridation systems, CDN had considerable experience constructing ferro-cement storage tanks. These tanks were the initial containment vessel used to house the bone char.

The first defluoridation tank system we visited was at the Naivasha Mixed Secondary School, a private school with a population of 2,000 students. It was one of the earlier treatment tanks constructed (1999) and was considered a prototype by the organization. The tank was fed by a submerged pump drawing water from a borehole located on school grounds. The second defluoridation tank was located at the Peace Corps compound in Naivasha. The tank was newer than the first, made of the same ferro-cement material, only it was designed with a greater height and a narrower diameter. The third defluoridation tank system visited was much like the second, except that it was even larger in scale and this time fed into a water kiosk that provided clean water to the public at a certain set fee per 20-liter jerry can (10KShs/jerry can). Both sites also drew their water supplies from the groundwater aquifer of the area. A picture of a typical filter is provided below (Photo 4.8).



Photo 4.8 – Bone Char Defluoridation Filter at CDN Workshop (2005)

4.10.1.4 Resource Availability

Resources, including both raw materials and skilled labor are readily available in the Nakuru District. The main raw material of the system, bone, is a waste product in the meat industry, and so is apparently available in large quantities whenever required. The staff of CDN is well trained in the manufacturing of the technology, and other materials utilized in the construction of the system are readily available as well.

4.10.1.5 Education and Training

Education and training in operation and maintenance are a large part of the implementation of the bone char defluoridation system. CDN recognizes that the dissemination of knowledge about the effects of fluoride is essential for the technology to be accepted and implemented successfully. CDN is currently promoting awareness of the technology through social marketing as well as through coordinated efforts with the Ministry of Water and the Ministry of Health.

4.10.1.6 Funding

CDN's defluoridation program has no direct funding and instead operates in a self-sustaining manner off income generated by its products. The program operates on an annual budget of US\$ 50,000-60,000, of which \$10,000 is spent on research. Half of this income is from private customers such as those we visited, and the other half is from donor-supported programs.

4.10.2 Implementation

The extent to which monitoring and evaluation of the installed defluoridation filter systems is performed was not determined. However, from observation during the site visit it appears that CDN does take water samples for all of its currently installed filters at various times throughout the year. This, in combination with intermittent sampling performed by the Ministry of Water, serves as the main monitoring effort that the author observed for the said technology.

4.10.2.1 Target: Water Quality

Water quality is a specific target used to evaluate technology success. Samples are taken from the existing filters approximately two to four times per year and tested at the CDN laboratory. Results are recorded in a database and are also used as an indicator to determine when filters require bone char regeneration. Whereas a variety of parameters are tested for in experimental systems under evaluation in the CDN laboratories, fluoride concentration is the only parameter tested for implemented systems.

The laboratory is open to the public for fluoride testing. Fluoride tests typically cost 100 KShs (US\$ 1), while basic chemical analysis for irrigation or drinking water costs 2,000 KShs (US\$ 27). A standard chemical water analysis costs 5,000 KShs (US\$ 67). The lab also conducts testing for microbial contamination for a separate fee (CDN Pamphlet, 2005).

4.10.2.2 Target: HWTS System Performance

System performance in terms of bone char exhaustion is utilized in determining if a filter is working properly.

4.10.2.3 Marketing and Distribution

Social marketing is practiced by CDN, with personnel dedicated specifically to the task of spreading awareness about fluoride contamination. Creating awareness is essential and the organization conducts workshops and distributes brochures (Appendix D) about the technology in community areas and clinics. The organization also has a strong presence in schools and has plans for marketing the technology through coordinated efforts with governmental agencies such as the Ministry of Water.

CHAPTER 5 – HWTS TECHNOLOGY SELECTION TOOL

5.1 Introduction

The focus of this chapter is the development of a HWTS technology selection tool to be utilized in determining the most appropriate HWTS technology for a potential target implementation area. The target area in question may be a small community, or an entire provincial district or region, so long as parameters are relatively consistent throughout the area. The six HWTS technologies considered by the selection tool are ones currently available in Kenya. They are:

- 1. Household chlorination (Waterguard®)
- 2. Solar Disinfection (SODIS)
- 3. Boiling
- 4. Ceramic Candle Filtration
- 5. Concrete BioSand Filtration
- 6. Combined Flocculation/Disinfection (PuR®)

A detailed discussion of each of these technologies is provided in Chapter 2. It should be noted that these are technologies which solely address microbial contamination of drinking water. Contamination by other chemicals such as fluoride or arsenic is not considered even though HWTS technologies for removal of chemical contaminants were also observed in Kenya. Additionally, these are water treatment technologies and not technologies addressing the issues of safe storage.

5.1.1 Applications

The selection tool is intended to have a wide range of applications. Local communities may use the tool to determine the appropriate type of technology for their particular situation. Implementing organizations operating on a national (government and nongovernment) or international level may also use the tool to determine if a particular technology is suitable for implementation in a particular target area. To address these varying applications, the tool is presented in two formats: paper and electronic (Appendix E). The paper format of the selection tool is a document meant to be used in the field or in areas where computer facilities are not readily available. The paper format will take the form of an 18-page checklist or questionnaire that may be filled out by hand. The electronic format of the selection tool will be provided in the form of an MS Excel spreadsheet intended for use by organizations with access to the software. The spreadsheet will also be in the form of a questionnaire essentially identical to that utilized for the paper format of the tool. For the purposes of this thesis, both forms are presented in a simple format in order to make as transparent as possible the calculations used for determining the selection of the HWTS technologies; it is intended in the future that these formats be modified even further and supplemented with descriptive information such as pictures and typical examples regarding the parameters to be entered. Applications of the selection tool are further discussed in Sections 5.1.1.1 and Section 5.1.1.2.

The selection tool presented in this thesis is considered to be a prototype and is intended to serve as a basis for further versions, which will incorporate more detailed or more refined information into the scoring system presented. The selection tool is designed to be transparent in providing assumptions utilized and straightforward in its design so as to be easily modified for specific conditions. The selection tool is presented in Appendix E.

The technology selection tool developed in this chapter is not intended to be complete in terms of being suitable for direct application in the field. Instead, the tool is developed to present a framework that welcomes and encourages further revision and iteration. The tool in its present state may be considered as a "test model". The selection tool is presented as a proposed method of determining the applicability of certain HWTS technologies to specific target areas; the underlying rationale behind the creation of the tool originates solely from the author's own ideas and observations during the site visit to Kenya in January of 2005. The tool is not meant to critique methodologies or HWTS technologies currently being implemented. It is intended that the tool may act as a springboard for the consideration, discussion, and identification of parameters that need to be evaluated prior to the implementation of HWTS programs.

5.1.1.1 Community-Level Application

The technology selection tool would be intended for use "by the local community" and not "for the local community", meaning that it will seek to promote a community's own recognition and comprehension of both the need and the appropriate means of addressing problems related to safe water quality. The overall intent of such a tool would be to encourage local communities to take matters into their own hands, to use firm and immediate action to address problems threatening community health and well-being, and to imbue a community with enhanced pride and unity in all facets of day-to-day life.

In this context, the technology selection tool is not meant to undermine the impressive work being done "for" these communities by local agencies and international organizations, but rather to supplement it. It is a daunting task to "reduce by half by the year 2015 the proportion people in the world without access to safe water" as stipulated in the Millennium Development Goals; it seems apparent that a unified approach must be taken on a global level to address this problem. With adequate knowledge and motivation, local communities in developing nations can take initiative and determine beforehand what types of systems would be most suitable for their particular situation. With this part of the process accomplished, a community could subsequently contact the appropriate agency, organization, or enterprise and hopefully acquire their aid, or financing for the implementation of these household water treatment systems. It is assumed that the agency, organization, or enterprise in question would welcome such an approach as a large percentage of the work typically required in program or product implementation would have already been completed; in this situation the agency or enterprise does not have to inform the community of available technology or even determine if their technology is suitable for the said community. At the very least, the community would have already laid the groundwork and collected the pertinent data for program or product implementation and the agency or enterprise would now only have to verify the data and move forward to subsequent parts of the implementation process. To make things even more favorable, it would already be assumed that the community would welcome the said program, further facilitating overall program implementation. With this type of grass-roots approach, the global problem of access to safe water might be that much closer to being solved.

Ideally, the tool is designed for use by leaders or local organizations with adequate knowledge of the community in regards to demographics and current water, sanitation, and hygiene conditions. The tool is intended to take the community leader or local organization representative through a step-by-step "fill in the blanks" type of process in which pertinent data about the community would be entered. Upon inclusion of all the said data, the tool, through simple arithmetic, would then produce a score that would indicate the most feasible type of technology. This process is discussed in more detail in Section 5.1.2.

5.1.1.2 Organization-Level Application

Apart from community-level application, the selection tool could also be used by organizations involved with the implementation of HWTS technologies. For instance, a HWTS implementing organization could supplement information provided by a community using the tool with data that may be more accurate or specific to the organization's type of technology. Or alternatively, an organization could use the tool independently to determine if their technology is applicable for implementation to a community in question. In addition to this, a government agency may also use the tool in prioritizing regions that would most benefit from the implementation of a said technology for which funding is readily available. Lastly, agencies developing HWTS technologies might use the tool to determine what design changes need be made for such a technology to be effectively implemented in the field.

5.1.2 Methodology

The technology selection tool is designed to prompt users (such as communities or implementation organizations) for information pertaining to certain parameters. As parameters are filled-out in the document, relevant scores will be recorded and tallied in order to calculate a score for each of the HWTS technologies considered. In the paper version of the tool, computation of the scores will be straightforward and carried out by hand. For the electronic version of the tool, the spreadsheet will automatically calculate values to expedite the calculation process. The scoring methodologies utilized by the tool are explained further in the rest of the chapter.

The selection tool makes use of certain sections of the HWTS implementation organization survey (discussed in Chapter 3 and provided in Appendix B), however the technology selection tool is not designed to be identical to the implementation organization survey. Although some questions and sections in the survey are used in the selection tool, the tool does not include all sections of the survey and, in fact, presents additional considerations that have not been included in the survey. This is due to the fact that the two documents have different purposes; while one intends to collect information on HWTS implementing organizations (the survey), the other has the purpose of prompting a user for information on a target area in which potential HWTS implementation may be conducted (the selection tool). Due to the fact that both documents deal with the implementation of HWTS technologies, several areas of the documents are distinctly similar. That being said, the documents should be considered as independent of one another. Throughout the remaining discussion in this chapter, efforts will be made to identify sections that were derived from the HWTS implementation organization survey.

Parameters considered in the technology selection tool, such as target population and water source, are expressed in question form, prompting the organization utilizing the tool for the necessary information. Upon inputting information for a particular parameter, a score will be generated specific to each of the HWTS technologies considered. These scores will be an effective ranking of each technology in regard to the parameter in question. For example, if "turbid water source" is input into the "type of water source" parameter, SODIS and Household Chlorination or "Waterguard" (both of which require a relatively low turbidity of less than 30 NTU) might garner a lower score or ranking than the concrete BioSand filter for this particular parameter. In addition to this, each parameter will be weighted relative to other parameters utilized. For instance, water source might be a parameter given more importance than resource availability and would therefore receive a larger weight in regards to the overall score computed for a particular technology. The end product of the computation is an overall score for each technology which takes into account all individual scores computed and weighted for each parameter. These scores serve as an effective ranking of the applicability of each technology to a particular area.

The methodology employed by the tool may be considered as a type of "multi-factor analysis". This methodology is different from the evaluation methodologies or "targets" discussed for the implementation organization survey. A brief introduction to this type of methodology is presented in Section 5.2.

The parameters considered are divided into two main categories: site-specific parameters and technology-specific parameters. The basis for this categorization is discussed in Section 5.3 while the methodology and rationale for determining the scores and weights for each of the parameters considered is provided in the remaining sections of this chapter.

It should be mentioned that research collected by the MIT team during the site visit to Kenya in January served as the primary basis for the allocation of scores to each of the parameters and technologies discussed. For instance, in regard to assigning scores for household chlorination, only the specific parameters observed to affect PSI Waterguard implementation that were considered. That being said, attempts were also made to take into account data from the implementation of these technologies in other developing nations.

For trial purposes, the tool was applied to three areas in Kenya in which HWTS technologies were being implemented by organizations visited by the MIT team. Information collected from these organizations was entered into the tool and the results were compared to actual implementation of the technologies. These applications serve as a demonstration of how the tool may be applied, the results of which are discussed in Chapter 6.

5.2 Multi-Factor Analysis

A multitude of different methodologies may be utilized in situations where the evaluation or choice of a particular technology, design, project, or plan is dependent upon a number of different considerations or multiple criteria. The "item" being considered could range from the selection of a piece of equipment for a factory to a policy addressing environmental concerns. In all cases, there are a number of factors that may impact the item to varying extents. Engineers, planners, businesses, and governments, among others, have used several methodologies to address these issues. Among these, and one of the most popular, is a "cost-benefit analysis" which attempts to convert all factors, whether quantitative or qualitative, into monetary values for direct comparison of overall costs versus benefits. Another more recent method is a "life-cycle assessment" which attempts to measure an item's entire life cycle, from design to disposal, in terms of impacts on the environment. For the purposes of the technology selection tool, another known methodology, called "multi-factor analysis", is utilized. This is a standard tool used by engineers as a means of rationally setting out a set of alternatives judged against a set of criteria.

Multi-factor analysis attempts to gauge a number of alternatives ("technologies" in the case of the selection tool) in terms of a set of weighted factors ("parameters" in the case of the selection tool). Each weighted factor is assigned a numerical score over its designated weight; the sum of the scores for each factor in turn results in an overall score, which serves as the basis for comparing the alternatives considered. The underlying principle is that each factor has a quantifiable impact in comparison to all of the other factors considered for a particular alternative. By assigning a weight and subsequent score to each of these factors, one can theoretically obtain an approximate idea of the overall feasibility of the alternatives being considered. In the case of the technology selection tool, the factors being considered are the parameters presented in the following sections, and the feasibility to be determined is the applicability of the HWTS technology to the area in question.

It must be noted that this type of approach is considered to be "expert driven" insofar as outcomes may be dependent on the choices of the person employing this analysis. That said, in contrast to cost-benefit analysis, multi-factor analysis allows for evaluative criteria to be identified from multiple stakeholders' perspectives and not just an "objective" analyst's perspective. Weighting of factors is often a point of contention in multi-factor analysis as it is highly dependent on the point of view of a particular implementer. Arguments have been made that the weighting of factors oftentimes becomes the focus of the analysis and that the true value and meaning of the factors is sometimes lost in translation. In addition to this, weighting can blur how certain factors relate to one another; in other words the significance of benefit gained by one factor from the reduction or exclusion of another factor is not adequately reflected in the weighting process.

That being said, the author's argument here is that the methodology may still be beneficial in the selection of appropriate HWTS technologies. For one, the selection tool is transparent in nature and is designed to be modified according to the needs of the person or group seeking to make such a selection. It is not the intention of the to provide weights and scores that are set in stone or that are universally applicable. In fact, the tool may be easily modified to allow the weighting to be assigned by any interested person or group or, if desired, to apply no weights at all. As mentioned previously, the intent of the tool is to provide a framework that may be modified and improved upon to adequately reflect the views of the user(s) and the particular target population(s) for which the tool is intended. In addition to this, the tool is meant to give only one perspective of what technologies are potentially applicable to a particular area. It is assumed that other tools (such as rapid rural assessment, community mapping, cost-benefit analysis, contingent valuation, or others) will also be applied to determine if the technology selected is in fact appropriate.

Even if weighting is not employed, at the very least the selection tool can still provide a list of the parameters that an organization or community might want to consider prior to the implementation of a particular technology.

Another potentially problematic aspect of multi-factor analysis is the so-called "halo effect", which pertains to the situation in which an excessively high or low score for one particular factor can detract from how the overall score compares to the other alternatives considered. In other words, an alternative may score high across the board for all other factors considered, but may still lose out in the overall selection process due to the fact that it has an excessively low score in only one of its factors. This effect may be addressed by a cursory analysis of the scores presented. This is not anticipated to be a problem for this selection tool as no parameter is given an excessively large weight, nor is it likely that a score will be assigned that is significantly different from other scores given for other technologies considered.

The weights and suggested scores for the factors or parameters considered by the technology selection tool are discussed in the remaining sections of the chapter.

5.3 Parameter Categorization

In this section the rationale behind the categorization of the selection tool parameters will be briefly discussed.

5.3.1 Site-Specific Parameters

In determining the applicability or appropriateness of a HWTS technology to a certain region, it is essential that parameters specific to the area be considered. These parameters vary based on numerous characteristics of a given site, ranging from physical concerns such as water availability to economic concerns such as consumer willingness-to-pay. A unique set of parameters will characterize a given area.

It is anticipated that not all of the information particular to a site would be readily available. The selection tool accounts for this in that total scores are only composed of scores for parameters for which information is available. For instance, if there is no information for the parameter addressing the presence of health clinics in a community, the selection tool assigns a score of zero for each of the technologies and a corresponding weight of zero for that parameter being considered.

Site-specific parameters are discussed in detail in later sections. A list of these parameters along with suggested weights is presented in the following table:

Suggested Weight Suggested Weight **Parameter** (/1,000)**(%) Target Population** Size 40 4.00% Density (Urban/Rural) 40 4.00% Average Household Size 40 4.00% 40 4.00% Age Demographics Literacy Rate Water Source

Table 5.1 – Site-Specific Parameters

Parameter	Suggested Weight (/1,000)	Suggested Weight (%)
Туре	40	4.00%
Turbidity	40	4.00%
Microbial Contamination	40	4.00%
Water Use Practices, Access, and Transport	100	10.00%
Occurrence of Disease (Prior Studies Conducted)	100	10.00%
Local Government (Structure and Involvement)	60	6.00%
Presence of Implementing Organizations (NGOs)	60	6.00%
Presence Local Community Groups	60	6.00%
Presence of Schools (Education)	60	6.00%
Presence of Health Clinics	60	6.00%
Infrastructure (Access and Roads)	30	3.00%
Economic Considerations		
Family Wealth Information	50	5.00%
Consumer Willingness-to-pay	50	5.00%
Available Funding (i.e. subsidies)	50	5.00%
TOTAL SCORE	1,000	100.00%

As noted above, water source, water use practices, and health-related parameters garner the highest weights out of all the site-specific parameters considered. This is due to the fact that the applicability of various technologies is largely dependent upon the quality of the raw water utilized. Occurrence of disease in the area is also a large contributor to the overall score, as more effective technologies, in terms of the reduction of microbial contamination, are warranted in areas that are experiencing high rates of water-borne disease. Site-specific parameters are weighted over a total score of 1,000.

It must be reiterated that the weights assigned here are presented only to demonstrate how the selection tool might be utilized. Although the author's experience based on observations in Kenya went into assigning the weights above, the analysis was by no means comprehensive and it is anticipated that this preliminary work serve as a foundation for future improvements.

5.3.2 Technology-Specific Parameters

Determining the applicability or appropriateness of a HWTS technology also requires the evaluation of parameters relating specifically to the technologies. These parameters address individual technologies under consideration, as opposed to the previous category in which parameters were evaluated across all of the technologies under consideration. To further elaborate, parameters in this category are grouped under each technology; for instance, under SODIS one might consider the parameter addressing the availability of bottles; subsequently the score for this parameter contributes only to the overall score for SODIS. In the previous category, if a parameter such as water source was considered, the score for the parameter would be a ranking across all six technologies being evaluated. The scoring scheme in this instance allots 100 points to each technology. These 100 points are weighted for all the parameters considered specific to the technology. The total obtained over this 100 points is then combined with the total amount of points (out of 1,000) obtained from the parameters addressing site-specific considerations.

As described earlier, total scores are only composed of scores for parameters for which information is available.

Technology-specific parameters are discussed in detail in later sections. A list of these parameters along with suggested weights is presented in the following table:

Table 5.2 – Technology-Specific Parameters

Parameter	Suggested Weight (/100)	Suggested Weight (%)		
Ceramic Candle Filtration				
Resource Availability	20	20.00%		
Mass Media Presence	40	40.00%		
Available Local Distributors	40	40.00%		
BioSand Filtration				
Resource Availability	30	30.00%		
Skilled Labor Availability	30	30.00%		
Technical Support Availability	40	40.00%		
Solar Disinfection				
Resource Availability	40	40.00%		
Technical Support Availability	20	20.00%		
Exposure to Sunlight	40	40.00%		
Household chlorination				
Resource Availability	20	20.00%		
Mass Media Presence	40	40.00%		
Available Local Distributors	40	40.00%		
Combined Flocculation/Disinfection				
Resource Availability	20	20.00%		
Mass Media Presence	40	40.00%		
Available Local Distributors	40	40.00%		
Boiling				
Resource Availability	100	100.00%		

It must be noted that there are specific sub-categories under each of the parameters listed above which may take on different meanings depending on the technology under consideration. For example, the resource availability parameter for concrete BioSand filtration includes considerations for sand, gravel, and concrete availability while for SODIS it considers specifically the local availability of plastic bottles. Products that are typically available commercially have a large weight assigned for marketing concerns, such as the presence of mass media and local distributors in particular areas.

5.3.3 Applicability Factors

Site-specific and technology-specific parameters address information to be provided by the user of the tool, presumably the implementers of the HWTS technologies, and vary based on the potential areas of implementation. The parameters prompt for information that needs to be supplied by the user of the tool. However, it is worth mentioning that each of the technologies already has a built-in applicability value based on previous data and implementation experience in other developing nations. Considerations of cost, frequency of maintenance, and user-friendliness are all already built into the technologies being considered. In other words, the HWTS technologies under consideration already have a pre-existing set of characteristics pertaining to general applicability or effectiveness.

These pre-existing characteristics are partially considered in the scoring of site-specific and technology-specific parameters. For instance, cost considerations of these technologies are used to score the site-specific parameters under the "economic considerations" section of the tool. The cheaper a technology is considered to be, as determined from past experience and research on that particular technology, the more affordable the technology, which therefore garners the technology a higher score for economic parameters. In other words, pre-existing characteristics of the technologies are already considered in the design of the tool. That being said, a more formal consideration of these pre-existing characteristics may be warranted.

One potential method of considering these pre-existing characteristics within the context of the selection tool is the development of "applicability factors". After total scores have been calculated for the six technologies, a further adjustment may be made based on the inherent applicability of these technologies based on information regarding the success of these technologies in other areas. To illustrate, although SODIS may have a total score of 800 and household chlorination may have a total score of 700 after site and technology-specific parameters are considered, it may be determined that SODIS only has an applicability factor of 1.1, while household chlorination has an applicability factor of 1.3. If these factors are applied, adjusted scores for SODIS and household chlorination would become 880 and 910 respectively; this would indicate household chlorination as the more applicable or appropriate technology. These applicability factors would be based on previous experience and might indicate a greater success in chlorine implementation versus SODIS in previous implementation scenarios.

Applicability factors are proposed here merely for future consideration. These have not been developed in this thesis due to the inherent time and resource constraints regarding research.

5.4 Site-Specific Parameters

The following discussion focuses more on the rationale behind the scoring and weighting of each parameter and does not go into specific details about what each parameter means. More details about some of these parameters are included in the discussion of the HWTS implementation organization survey in Chapter 3.

5.4.1 Target Population

Target population deals specifically with information regarding the people standing to benefit directly from the said technology. It is comprised of the following parameters: size, density (urban/rural), average household size, age demographic, and literacy rate. These parameters are discussed fully in the following sections. The combination of all these parameters accounts for 20 percent of the total score for all site-specific parameters.

5.4.1.1 Population Size

Relevant Section(s) and Question(s) in Implementation Organization Survey:

Section 3: "Target Population and Current Water Use Practices and Concerns"
 Question 3.3.c

Suggested Weight: 40/1000 (4%)

Information requested:

- __ 0 500 People
- __ 501 5,000 People
- __ 5,001 20,000 People
- ___ > 20,000 People

Suggested scoring:

Table 5.3 – Suggested Scoring for "Population Size"

Technology	0 – 500 People	501 – 5,000 People	5,001 – 20,000 People	>20,000 People
Household Chlorination	40/40	40/40	40/40	30/40
Solar Disinfection	40/40	40/40	30/40	20/40
Boiling	40/40	40/40	40/40	40/40
Ceramic Candle Filtration	40/40	40/40	40/40	30/40
BioSand Filtration	40/40	30/40	20/40	20/40
Combined Floc/Dis	40/40	40/40	40/40	40/40

The size of the target population affects technology distribution. In general, scores were assigned based on the relative difficulty of implementing technologies on a small versus large scale. Technologies such as the concrete BioSand Filter as well as SODIS experience reductions in score as target populations increase because these technologies require a large amount of effort from implementers in terms of raising awareness and providing technical assistance. Hence, the larger a target population, the more effort required to implement the technology. This was a general observation made during the site visit to Kenya; the Bushproof concrete BioSand filter project, KWAHO SODIS project, and ACK SODIS project all required intensive assistance from implementing organizations in terms of the introduction and technical operation of the technologies. The concrete BioSand filter incurs an even greater reduction due to the fact that intensive production efforts are involved in the implementation of these filters compared to those required for other technologies.

Ceramic candle filtration, household chlorination, and combined flocculation/disinfection are considered easier to implement over a range of populations due to the fact that most of these are commercially produced and marketed. Ceramic candle filtration and household chlorination experience slight reduction in scores with large populations only because of the relative bulkiness of these technologies which might impede transport and wide-scale distribution; this is not a case with combined flocculation/disinfection in which PuR® sachets are implemented. These sachets can be transported easily in bulk. Boiling is also considered to be easily distributed across all populations due to the fact that this technology is already somewhat well known as a method of water treatment.

5.4.1.2 Population Density (Urban/Rural)

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 3: "Target Population and Current Water Use Practices and Concerns"
 - ➤ Ouestion 3.3.a

Suggested Weight: 40/1000 (4%)

Information requested:

- __ Urban (>500 people/square mile* or >1,300 people/square kilometer)
- Rural (<500 people/square mile* or <1,300 people/square kilometer)

Suggested scoring:

Table 5.4 – Suggested Scoring for "Population Density"

Technology	Urban	Rural
Household Chlorination	40/40	30/40
Boiling	30/40	40/40
Solar Disinfection	30/40	25/40
Ceramic Candle Filtration	40/40	30/40

^{*}Source: United States Census 2000

Technology	Urban	Rural
BioSand Filtration	30/40	20/40
Combined Floc/Dis	40/40	30/40

Population density affects each of the technologies to varying extents. Scoring for this parameter was assigned through comparing two things: (1) the efficiency of implementation and use of a particular individual technology in urban versus rural settings and (2) the efficiency of a particular individual technology in an urban or rural setting versus other technologies also considered for implementation.

Ceramic candle filtration, household chlorination, and combined flocculation/disinfection achieve high scores in urban settings once again due to the assumed improvement in distribution facilitated by the availability of mass media and local distributors. An urban setting might also facilitate sharing of the technology through the close proximity of households to one another. Concrete BioSand filtration receives a slightly low in urban settings due to consideration of space constraints; the concrete BioSand filter is the largest among the technologies considered. SODIS receives a lower score because it is assumed that the proximity of households might also reduce the exposure of certain households to sunlight. Lastly, boiling is given a lower score in urban settings in consideration of the dangers of household indoor pollution, fires, and burning accidents.

All technologies except boiling receive lower scores in rural versus urban settings. This is primarily due to difficulties caused by low population densities. Distribution and knowledge dissemination became increasingly difficult as geographic distances between homes increase. Concrete BioSand filtration and SODIS receive particularly low scores due to the transportation requirements of these technologies. The BioSand technology in particular typically requires the use of ox-carts and trucks which are not always readily available in communities. Boiling is considered ideal in rural settings due to the fact that areas are more open, resulting in better ventilation and also allowing for the opportunity to locate fires far from households. It is also assumed that resources such as wood might also be more available in terms of access and cost in these areas, although deforestation might also be a pertinent consideration as well.

5.4.1.3 Average Household Size

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 2: "Implementation Program / Product Description"
 - > Ouestion 2.10 (III)

Suggested Weight: 40/1000 (4%)

Information requested:

- ___ < 3 Persons/household
- 4 6 Persons/household
- __ > 6 Persons/household

Suggested scoring:

Table 5.5 – Suggested Scoring for "Average Household Size"

Technology	< 3 Persons/household	3 – 6 Persons/household	> 6 Persons/household	
Household Chlorination	35/40	40/40	35/40	
Solar Disinfection	40/40	35/40	30/40	
Boiling	40/40	35/40	30/40	
Ceramic Candle Filtration	40/40	25/40	10/40	
BioSand Filtration	40/40	30/40	20/40	
Combined Floc/Dis	40/40	35/40	30/40	

Household size affects both efficiency of use and incurred operation and maintenance costs of the technologies. The ceramic candle filter is most affected by the number of users as the filter produces water at the lowest rate out of all the technologies considered. Therefore, more users requiring the filter result in the filter being used at a much higher rate, which in turn leads to the larger demands for filter maintenance and replacement. This decreases the filter's effectiveness to a point where the filter becomes insufficient to meet the demands of large households. Although multiple filters may be used, this would result in increased cost and is assumed to have the same type of effect on the scores presented. For the same reasons, concrete BioSand filtration reduces in score with increasing household size, only not to the extent of ceramic candle filtration.

Combined flocculation/disinfection and boiling all reduce in score due to the assumption that costs increase in direct proportion to the total number of users. Household chlorination also reduces in score in this regard, only the technology is also reduced in score additionally if households are too small. This was due to information collected during the site visit in January. It was reported that household chlorination (Waterguard®) oftentimes produced too much water for consumption by small households. The water would frequently be stored for periods extending beyond that for which the product was effective. In this case, retreatment was warranted, which indicates a somewhat inefficient use of the technology. Furthermore, if retreatment is not practiced, then this might pose a health risk to households due to recontamination of the treated water.

5.4.1.4 Population Age Demographic (Ease of Use by Children)

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 3: "Target Population and Current Water Use Practices and Concerns"
 - > There is no specific question in the survey alluding to the age demographic of the target population. This is due to the fact that the question was considered too lengthy for inclusion in the survey.

Suggested Weight: 40/1000 (4%)

Information requested:

__ < 20% persons below age 12 in population
__ 21 - 40% persons below age 12 in population
__ > 40% persons below age 12 in population

Suggested scoring:

Table 5.6 – Suggested Scoring for "Population Age Demographic"

Technology	< 20% persons Below age 12	20 – 40% person below age 12	> 40% persons below age 12
Household Chlorination	40/40	25/40	10/40
Solar Disinfection	40/40	30/40	20/40
Boiling	40/40	25/40	10/40
Ceramic Candle Filtration	40/40	35/40	30/40
BioSand Filtration	40/40	35/40	30/40
Combined Floc/Dis	40/40	25/40	10/40

Scores for this parameter are directly attributed to the level of difficulty in regards to operation. It is assumed that the adults are going to be given primary responsibility in utilizing technologies, so in that regard the more adults available in a target population the higher the guarantee that a technology will be utilized effectively. Furthermore, if a technology can be operated by all members of a household, including children, the chance is greater that the technology will be utilized. If children can contribute to using the technology then this allows more time for adults in the household to pursue other worthwhile endeavors. With this in mind, the technologies are ranked in terms of how easily and effectively they can be operated by children.

Ceramic candle and concrete BioSand filtration rank high in terms of ease of use. The use of these filters simply entails collecting water and pouring it into the receptacles. Therefore, although it is ideal that adults undertake the responsibility of treating water, children can also use the technology should this be required. However, it must be noted that required maintenance for these technologies should be accomplished by adults. SODIS technology also entails little difficulty in operation although the process is slightly more difficult than that posed by the filters. Household chlorination, combined flocculation/disinfection, and boiling are all technologies that should not be performed by children. These are the technologies that garner the lowest scores as the percent of children in the population increases. This is due to the fact that each technology is either technically challenging or possesses a certain level of hazard in its operation.

5.4.1.5 Population Literacy Rate (General Ease of Use)

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 3: "Target Population and Current Water Use Practices and Concerns"
 - ➤ Question 3.3.b

Suggested Weight: 40/1000 (4%)
Information requested: < 25% literacy rate 25 - 50% literacy rate > 50% literacy rate

Suggested scoring:

Table 5.7 – Suggested Scoring for "Population Literacy Rate"

Technology	< 25% literacy rate	25 – 50% literacy rate	> 50% literacy rate
Household Chlorination	10/40	30/40	10/40
Solar Disinfection	30/40	35/40	40/40
Boiling	40/40	40/40	40/40
Ceramic Candle Filtration	20/40	30/40	40/40
BioSand Filtration	30/40	35/40	40/40
Combined Floc/Dis	10/40	30/40	10/40

Scores for this parameter are somewhat related to the parameter of age demographics in that scores are directly attributed to the level of difficulty involved with technology operation. Only in this case, the parameter is scored based on an assumed (unproven) correlation between literacy and the ability to utilize technology effectively. The amount of instruction, training, and written materials given to users in order to utilize the technology effectively is the main consideration of the parameter. With this criterion in mind, technologies such as household chlorination (Waterguard) and combined flocculation /disinfection (PuR) are given the lowest scores with decreasing literacy rates. This is due to the fact that each of these processes is quite technical in nature with both having detailed instructions required to guide users in proper use. It was observed in the field that the Waterguard technology was oftentimes being used incorrectly, with users either applying erroneous doses of chlorine or not allowing proper disinfection contact time prior to consuming the treated water.

Ceramic candle filtration, SODIS, and concrete BioSand filtration also come with instructions and training. However, these instructions are much simpler than those provided for the disinfection technologies; therefore scores assigned are not as low. Boiling is by far the technology that requires the least amount of literature and is therefore given the highest score across the entire range of literacy rates given.

5.4.2 Water Source

Water source is one of the most important site-specific parameters. It is characterized by the following specific sub-parameters: type, turbidity, and microbial contamination. These are explained in the following sections.

5.4.2.1Water Source Type

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 3: "Target Population and Current Water Use Practices and Concerns"
 - ➤ Question 3.1

Suggested Weight: 40/1000 (4%)

In the absence of more detailed data on site-specific water sources, the parameter of "water source type" serves as an approximation of the parameters of "turbidity" and "microbial contamination". Certain water sources are recognized as being more susceptible to contamination and turbidity than others, and a representative score may be assigned simply by identifying the type of water source used by a particular community. If there is no information for the other two parameters, "turbidity" and "microbial contamination", the scores of these parameters are taken as zero, and the score for water source is based solely on the score of the technologies assigned for the "water source type" parameter alone. This means that the score for the parameter is increased to a total over 120 (the total for the water source parameter) versus the original 40 allotted to the "water source type" parameter alone.

It must be noted that this selection tool does not provide any direction regarding what water source a community should utilize. The ranking does reflect the relative desirability of water sources in regards to water quality, but no specific methods are presented to ascertain if these sources are available in a particular site. Information regarding water source to be entered into the tool is wholly the responsibility of the potential users in the community. If a particular community is using a current source of water but intends to shift use to another source in the future, it is this intended source that should be used in the selection tool. Appendix F contains a decision chart for choosing a source of water (Skinner, 2003). The decision chart first provides the options that lead to choosing water sources of the highest possible quality, and progresses into the less desirable options as these higher quality choices are determined to be infeasible. It is this chart, along with the survey template presented in Chapter 3, that are used as the basis for the water sources considered and the relative scores assigned.

information requested:
Piped water supply inside the house (private)
Public Standpipe (piped source)
Protected Spring
Protected Borehole well (private)
Public Standpipe (protected groundwater source)
Unprotected Spring
Unprotected Borehole well (private)
Public Standpipe (unprotected groundwater source)
Truck-delivered Water
Dug Well
Groundwater Dam
Rainwater Harvesting
Surface Water (Dam or River)
Surface Water (Lake or Pool)
Surface Water (Canal or Ditch)

A few notes on the sources considered:

- Sources are considered independent of the method of transport to the home. Water access and transport are discussed in a later section of the chapter.
- Sources are considered independent of cost. An in-depth cost analysis is considered
 outside the scope and capability of the selection tool. Public standpipes and truckdelivered water are considered regardless of whether they are vendor-provided or
 provided free to the public.
- An inherent assumption in the ranking of these sources is that a public water source some distance from the home is less desirable than a private tap or access within the home This is solely due to the fact that the number of users of a particular system at a public access point increases the chances that such a system will become susceptible to contamination and is therefore less desirable than a system feeding directly into the home, which is more likely to be well maintained.
- An inherent assumption in the ranking of these sources is that a surface water source is less desirable than a groundwater source in terms of potential microbial contamination. This is due to the fact that surface water sources are more exposed to contamination and run-off from soil that can result in increased microbial contamination and turbidity. Groundwater sources often have higher water quality due to the fact that (1) the source is not exposed to the atmosphere and (2) the soils in which these waters are located often serve as filters for contamination and turbidity.

Suggested scoring:

Table 5.8 – Suggested Scoring for "Water Source Type"

Technology	Piped water supply (private)	Public Standpipe (piped source)	Protected Spring	Protected Borehole well (private)	Public Standpipe (protected gw)	Unprotected Spring	Unprotected Borehole well (private)	Public Standpipe (unprotected gw)	Truck-delivered Water	Dug Well	Groundwater Dam	Rainwater Harvesting	Surface Water (Dam or River)	Surface Water (Lake or Pool)	Surface Water (Canal or Ditch)
Household Chlorination	40	40	40	40	40	40	40	40	40	35	35	35	20	10	10
Solar Disinfection	40	40	40	40	40	37	34	30	30	25	25	25	20	10	10
Boiling	40	40	40	40	40	40	40	37	37	35	35	35	30	25	20
Candle Filtration	40	40	40	40	40	40	40	40	40	35	35	35	30	25	20
BioSand Filtration	40	40	40	40	40	37	34	30	30	30	30	30	25	25	20
Combined Floc/Dis	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40

^{*} All scores provided are out of a total of 40 points.

Scores for the following technologies reflect the effects of potential microbial contamination and turbidity for the water sources considered. The technologies considered perform differently in different conditions. This is illustrated through the following points:

- Household Chlorination Household chlorination is similar to SODIS in that it is effective in addressing microbial contamination but becomes ineffective in conditions of high turbidity. Turbidity is often caused by suspended material that in effect protects microbes from being destroyed by the chemicals in the solution. In this regard, household chlorination receives a low score as water sources increase in turbidity.
- SODIS The efficacy SODIS is affected by the turbidity concentration of raw water. Given proper conditions, up to 99.9 percent removal of micro-organisms is possible (EAWAG/SANDEC, 1998). However, the technology is considered ineffective for highly turbid waters as turbidity indicates the presence of particles that deflect UV radiation, effectively shielding micro-organisms. The scores for this technology are therefore lowest for sources having high levels turbidity (>30 NTU).

- Boiling Boiling, the process of heating water until it reaches a rolling boil, can be
 extremely effective in addressing microbial contamination. In boiling, the process of
 destroying these micro-organisms is not directly affected by turbidity. The issue
 instead is that the suspended particulate material causing turbidity, which may not
 necessarily be detrimental to health, is not removed in the process. Therefore scores
 for the technology reduce as water sources are recognized as being more turbid.
- Ceramic Candle Filtration Ceramic candle filters are effective in addressing high levels of microbial contamination, oftentimes displaying up to 99.9 percent efficiency (Franz, 2005) in removing disease causing micro-organisms. Unfortunately, these filters perform poorly in instances of high turbidity. Although efficiency of microbial contamination removal is relatively unaffected in instances of high turbidity, filter flow rates, which are already slow in low turbidity water, are severely reduced to the point that filters become easily clogged and ineffective. This is reflected in the scores in that the ceramic candle filter garners lower points for water sources that typically have high turbidity (open groundwater sources and surface water sources).
- BioSand Filtration BioSand filters are effective for high turbidity but experience some inefficiency in microbial removal. Results from MedAir for tests conducted on concrete BioSand filters utilized in Machakos report a microbial reduction rate of up to 96 percent (MedAir, 2000), lower than those reported for the ceramic candle filters. In that regard, the filter becomes less desirable in instances where microbial contamination is expected to be high. Scores for the technology start to decline for unprotected sources, and continue to decline even further in open groundwater and surface water sources where potential contamination is typically a concern.
- Combined Flocculation/Disinfection The combined processes of flocculation and disinfection address concerns of microbial contamination and turbidity by utilizing both a flocculent (ferric sulfate) and a chlorine disinfectant (calcium hypochlorite). The ferric sulfate coagulant reduces turbidity by flocculation, providing a medium for the suspended material to adsorb to, resulting in larger and larger particles eventually gaining enough mass to sink to the bottom of a water storage vessel. The calcium hypochlorite addresses issues of microbial contamination. This results in the technology having the maximum score across all water sources considered.

5.4.2.2 Water Source Turbidity

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 3: "Target Population and Current Water Use Practices and Concerns"
 - There is no specific question in the survey alluding to turbidity of raw water sources. This is due to the fact that it was considered more appropriate to include such a question in a "technology survey". Such information was considered too detailed and potentially difficult for an implementing organization to obtain.
- Section 9: "Target: Water Quality"
 - ➤ All Questions Questions pertain to how data is collected for treated water and not what the results are for raw water sources.

Suggested Weight: 40/1000 (4%)

The following two parameters (turbidity and microbial contamination) are merely more elaborate and detailed considerations of the conditions discussed in the previous parameter (water source type). Details pertaining to these parameters will not be discussed as these have been provided in the previous section. Actual raw water testing would need to be conducted to provide the information requested by these two parameters.

Information requested:

_ < 5 NTU

_ 5- 30 NTU

_ > 30 NTU

Suggested scoring:

Table 5.9 – Suggested Scoring for "Water Source Turbidity"

Technology	< 5 NTU	5 – 30 NTU	> 30 NTU
Household Chlorination	40/40	25/40	10/40
Solar Disinfection	40/40	25/40	10/40
Boiling	40/40	40/40	40/40
Ceramic Candle Filtration	40/40	30/40	20/40
BioSand Filtration	40/40	40/40	40/40
Combined Floc/Dis	40/40	40/40	40/40

As discussed previously, household chlorination, SODIS, and ceramic candle filtration all become less effective when high turbidity is present in source waters. If turbidity alone is considered, then boiling, combined flocculation/disinfection, and concrete BioSand filtration would be the most appropriate technologies to consider.

5.4.2.3 Water Source Microbial Contamination

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 3: "Target Population and Current Water Use Practices and Concerns"
 - There is no specific question in the survey alluding to microbial contamination of raw water sources. This is due to the fact that it was considered more appropriate to include in a "technology survey" and such information was considered too detailed and potentially difficult for an implementing organization to obtain.
- Section 9: "Target: Water Quality"
 - ➤ All Questions Questions pertain to how data is collected for treated water and not what the results are for raw water sources.

Suggested Weight: 40/1000 (4%)

Microbial contamination is measured by the concentration of target indicator organisms in the water. Microbiological contaminants include waterborne bacteria, viruses, protozoa, or helminthes. For the purposes of this analysis, *E. coli* bacteria will be the target parameter measured. This target was selected due to the fact that it is the indicator of choice recommended by the WHO 3rd Edition GDWQ because it serves as a good indicator of microbial contamination and is relatively easy to measure in the field and lab. Units for the measurement of *E. coli* by the membrane filtration test are 100 colony forming units (CFU) per 100 milliliters.

Information requested:
__ 0 - 50 CFU/100 ml.
__ 51 - 100 CFU/100 ml.
__ > 100 CFU/100 ml.

Suggested scoring:

Table 5.10 – Suggested Scoring for "Water Source Microbial Contamination"

Technology	0 – 50 CFU/100 milliliters	51 – 100 CFU/100 milliliters	> 100 CFU/100 milliliters
Household Chlorination	40/40	40/40	40/40
Solar Disinfection	40/40	35/40	30/40
Boiling	40/40	40/40	40/40
Ceramic Candle Filtration	40/40	40/40	40/40
BioSand Filtration	40/40	40/40	40/40
Combined Floc/Dis	40/40	40/40	40/40

In this instance, it is only the concrete BioSand filtration and SODIS technologies that are assigned reduced scores with increasing microbial contamination. The BioSand filter has been tested and shown to have lower removal efficiency than other technologies which is why it garners the lowest of the scores assigned. SODIS is assigned a low score as well due to the fact that there isn't a large amount of empirical data available to accurately assess the effectiveness of this technology in addressing microbial contamination. SODIS technology is assumed to have a higher efficiency in removal than concrete BioSand filtration.

If testing of the water source is not a viable alternative, there are other less quantitative methods to assess microbial contamination. For instance, if the water source is observed to be in close proximity to potential areas of fecal contamination, then judgment may be used to estimate the scores above. Another indicator is the odor of a water source; one can often tell from smell alone that a source is contaminated. The scoring system is not meant to be set in stone and allows for personal judgment and additional data to be incorporated into the analysis.

5.4.3 Water Use, Access, and Transport

The parameters considered in this section pertain to how water is transported and stored after collection. A pristine water source can be contaminated by improper water transport and use practices in the home. That is why point-of-use technologies have been determined to be appropriate solutions in areas where community-wide water infrastructure is unavailable. The parameters in this section consist of water storage and hygiene. Access and methods of transport are discussed but are not considered as specific parameters in the selection tool.

5.4.3.1 Water Storage

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 2: "Implementation Program / Product Description"
 - ➤ Question 2.7 The question asks if safe storage is used and implemented with the HWTS technology in question but does not go into detail as to what type of safe storage containers are used.
- Section 3: "Target Population and Current Water Use Practices and Concerns"
 - There is no specific question in this section of the survey referring to storage of water in the home. This is due to the fact that such information was considered potentially difficult for an implementing organization to obtain. Also, it was considered more appropriate for a "technology survey:"
 - Likewise, safe storage practices in the home were considered a topic that could be addressed by the household survey discussed in Chapter 3. The household survey questions 2.8 to 2.11 prompt the interviewee for information about where the water is stored, how long water is stored, and how water is removed from storage containers prior to use.

Suggested Weight: 50/1000 (5%)

Information requested:
Protected Containers (CDC-type Safe Water Container / Modified Clay Pot / Enclosed
Storage Tank / etc.)
Partially Protected Containers (Buckets with Lids / Storage Tanks with Lids / etc.)
Unprotected Containers (Traditional Clay Pots / Uncovered Buckets / Uncovered
Storage Tanks / etc.)

Suggested scoring:

Table 5.11 – Suggested Scoring for "Water Storage"

Technology	Protected Containers	Partially Protected Containers	Unprotected Containers
Household Chlorination	40/40	40/40	35/40
Solar Disinfection	40/40	40/40	35/40
Boiling	40/40	40/40	40/40
Ceramic Candle Filtration	40/40	40/40	40/40
BioSand Filtration	40/40	30/40	20/40
Combined Floc/Dis	40/40	40/40	40/40

Water storage at the home is very important. The main concern in storage is that the water is not exposed to possible sources of contamination. Open containers are considered the worst type of storage in that water is continuously exposed to the atmosphere and is easily accessible by children. Furthermore, these containers go hand in hand with unsafe methods of transferring water from storage to drinking containers. Oftentimes drinking cups are dipped directly into the storage container resulting in potential contamination from the cup itself or unwashed hands coming into contact with the stored water. Partially protected containers, such as buckets with lids, provide more protection from contamination but are still susceptible. Completely protected sources are those that completely limit access to the water except through the use of a spigot.

Since microbial contamination is once again the primary concern, technologies such as SODIS and the concrete BioSand filter are those that would receive the greatest decrease in score with decreasingly protected storage vessels. It must be noted that in this case, SODIS is not reduced in score as excessively as previous parameters concerned with microbial contamination. This is due to the fact that more often than not water is typically used directly out of the SODIS bottles and not stored in a container prior to use. Also, household chlorination experiences some deduction as retreatment can oftentimes become an issue.

Lastly, an important factor to consider is that water storage typically becomes an issue only **after** HWTS technologies have been implemented. Typically a technology would be used to treat water and only then would the water potentially be transferred into another container. Alternately, many HWTS technologies treat water and contain treated water as well; such is the case with SODIS, ceramic candle filtration, and household chlorination. That being said, the effectiveness of technologies is still considered in the process in that the initial quality of the water being stored still plays a role in water storage. Additionally, since this factor is true across all technologies, the scores for each technology still remain relative to one another, resulting in a reasonable overall comparison.

5.4.3.2 *Hygiene*

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 2: "Implementation Program / Product Description"
 - ➤ Question 2.7 The question asks if hygiene and sanitation awareness and education are implemented with the HWTS technology in question.
- Section 3: "Target Population and Current Water Use Practices and Concerns"
 - There is no specific question in this section of the survey alluding to hygiene practices in the home. This is due to the fact that such information was considered potentially difficult for an implementing organization to obtain.
 - ➤ However, hygiene practices in the home were considered a topic that could be addressed by the household survey discussed in Chapter 3. The household survey Sections 2 and 4 attempted to gauge whether certain aspects of hygiene and sanitation were practice in the home.

Suggested Weight: 50/1000 (5%)

Information requested:

- __ Hand-washing practiced and sanitation facilities sited sufficient distance from water storage containers (sufficient distance: >15 meters)
- __ Hand-washing NOT practiced and sanitation facilities sited sufficient distance from water storage containers (sufficient distance: >15 meters)
- __ Hand-washing practiced and sanitation facilities NOT sited sufficient distance from water storage containers (sufficient distance: >15 meters)
- __ Hand-washing NOT practiced and sanitation facilities NOT sited sufficient distance from water storage containers (sufficient distance: >15 meters)

Suggested scoring:

Table 5.12 – Suggested Scoring for "Hygiene"

Technology	Hand-washing & Sufficient Sanitation Siting	Hand-washing Only	Sufficient Sanitation Siting Only	Neither
Household Chlorination	40/40	40/40	35/40	30/40
Solar Disinfection	40/40	40/40	35/40	30/40
Boiling	40/40	40/40	40/40	40/40
Ceramic Candle Filtration	40/40	40/40	40/40	40/40
BioSand Filtration	40/40	35/40	30/40	20/40
Combined Floc/Dis	40/40	40/40	40/40	40/40

Hand-washing and sanitation facility siting relate directly to exposure of stored water to potential contamination. Whereas the previous parameter addressed the route of contamination, this parameter addresses extent of contamination. Hand-washing, especially after using sanitation facilities, can have a large impact on reducing diarrheal disease (Esrey et al., 1998). Sanitation facilities should also be located away from households as these facilities are the direct sources of contamination. Flies and other insects that might be found near these facilities are also potential sources of contamination.

As reflected in the score, hand-washing practices are given more importance than sanitation facility siting. Sanitation facility siting is important, but direct contamination from these sources is not as likely as that from unwashed hands. The rest of the scoring considerations follow the same rationale as the previous parameter.

5.4.3.3 Water Access and Transport

Water access and transport pertain to the proximity of water sources and the methods used to transport water. Both of these parameters are not considered to affect HWTS technologies and do not feed into the calculations utilized by the selection tool. Although access can result in excessive distances traveled and therefore greater potential for transported water to be contaminated, it is assumed that transport is performed with closed containers that reduce spillage and subsequently reduce exposure to any microbial contamination.

This is not to say that access and transport are not important factors considered in the overall water scenario affecting a particular community. It is recognized that access can result in less water being delivered to the home, which in turn can affect health in that proper hygiene, drinking, and washing water needs are not satisfied. Furthermore, access in regards to fetching water, especially if performed by women and children, also results in loss of valuable time that could be spent at school or in the pursuit of other worthwhile endeavors.

5.4.4 Disease Occurrence

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 3: "Target Population and Current Water Use Practices and Concerns"
 - > Questions 3.4 and 3.5
- Section 8: "Target: Health Outcomes"
 - ➤ All Questions

Disease occurrence is another related parameter pertaining to water quality generally and microbial contamination specifically. Although water source considerations take into account the potential for disease, it is through water-borne disease health outcomes in a community that one may anticipate high levels of microbial contamination. Sources of the said data might be formal health surveys conducted for a community or formal health records kept by local clinics in the area. Alternatively, one could also conduct informal interviews of households in the target area, getting users' perceptions of the instances of disease on a monthly or yearly basis.

The parameter to be measured is annual instances of diarrhea for children under five. Diarrhea is considered a relatively good indicator of water-borne disease in a community.

Information requested:

- 0 5 cases of diarrhea/children < 5/year
- 6 10 cases of diarrhea/ children < 5/year
- ___ > 10 cases of diarrhea/ children < 5/year

Suggested scoring:

Table 5.13 – Suggested Scoring for "Disease Occurrence"

Technology	0 – 5 cases of diarrhea/ children < 5/year	6 – 10 cases of diarrhea/ children < 5/year	> 10 cases of diarrhea/ children < 5/year
Household Chlorination	40/40	40/40	40/40
Solar Disinfection	40/40	40/40	35/40
Boiling	40/40	40/40	40/40
Ceramic Candle Filtration	40/40	40/40	40/40
BioSand Filtration	40/40	30/40	20/40
Combined Floc/Dis	40/40	40/40	40/40

SODIS and the concrete BioSand filter are the technologies that receive the highest decrease in score since the parameter is addressing concerns of microbial contamination. One last note is that this parameter could be seen as an indication of the overall need for water treatment in a community. Excessive occurrences of water-borne disease in a community should serve as a red-flag and a motivation for implementing some form of water treatment, whether on a community-wide or household level.

5.4.5 Local Government (Structure and Involvement)

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 2: "Implementation Program / Product Description"
 - ➤ Question 2.11
- Section 11: "Target: Behavior/Use (Social Acceptability)"
 - ➤ Question 11.21
- Section 12: "Target: Costs"
 - > Ouestions 12.12 to 12.15

Suggested Weight: 60/1000 (6%)

Local government plays a key role in the implementation of HWTS technologies. This was witnessed in the site visit to Kenya in January 2005. The term "local government" in this instance pertains to governments at both the national and community level.

The Ministries of Water and Health were both cited by implementing agencies as being important in the overall process of introducing technologies to a particular area. Organizations cited policy-support as having an especially significant impact on operations. In certain cases, these ministries also aid organizations by giving financial and logistical support. In addition to this, the ministries aid implementing organizations indirectly through spreading awareness of water quality issues and educating communities about the availability of HWTS technologies. The Ministries typically have regional offices that work more closely with communities.

Local government at the community level also stands to further the progress of HWTS technologies. Local government on this level pertains to some sort of administrative structure governing a particular community. It was witnessed in Kenya that this type of structure was oftentimes not present in communities. When present, the administrative structure was observed to be in the form of tribal chiefs and elders that had been selected to be the *bona fide* leaders of the community. The leaders were respected throughout communities and had the ability to influence community members to a great extent. In some cases, the homes of these leaders were used as demonstrative cases for certain products. It was intended that residents in communities would be assured of a product's effectiveness simply by its being utilized by these leaders. These leaders are differentiated from those discussed later in regards to local community groups in that these leaders are acting in a more official capacity. Local groups also have people that are well-respected in a community but it was noted that these people, although also possessing the ability to influence members in a community, were not officially selected to act in an administrative capacity.

It is difficult to quantify local government involvement in a particular community. Due to this, a simple approach was taken to prompt the user of the selection tool for the following information:

Information requested:
Local Government Involvement at the Community Level Alone (Tribal Leaders /
Elected Officials / Etc.)
Local Government Involvement at the National Level Alone (Ministry of Water /
Ministry of Health / Etc.)
Both
Neither

Suggested scoring:

Table 5.14 – Suggested Scoring for "Local Government"

Technology	Community Level Local Government Alone	National Level Local Government Alone	Both	Neither
Household Chlorination	15/60	25/60	40/60	0/60
Solar Disinfection	30/60	30/60	60/60	0/60
Boiling	10/60	20/60	30/60	0/60
Ceramic Candle Filtration	15/60	25/60	40/60	0/60
BioSand Filtration	30/60	30/60	60/60	0/60
Combined Floc/Dis	15/60	25/60	40/60	0/60

In this case, scores are still assigned with respect to how the technologies are affected by the presence of local governments in a particular community. It is noted that national support is given a higher score in that resources and reach are greater with national level organizational support. This is not to say that the presence of local organizations does not garner an increase in score as well.

Additionally, it is noted that technologies that are marketable on a commercial level (e.g. ceramic candle filtration, household chlorination, & combined flocculation/disinfection) stand to benefit slightly less that those that are implemented on a grassroots level in typically rural areas (e.g. concrete BioSand filtration and SODIS). It was observed in Kenya that these technologies were being implemented extensively through the efforts of local organizations that could benefit greatly from support from local and national government. Lastly, boiling is once again given a low score because of the relatively basic nature of this treatment process and the fact that it is already well-known and practiced.

5.4.6 Presence of Implementing Organizations (NGOs)

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 2: "Implementation Program / Product Description"
 - ➤ Question 2.11 The question addressed whether there are **other** organizations involved in the implementation of the HWTS technology.
- Section 12: "Target: Costs"
 - > Questions 12.12 to 12.15

The consideration of implementing organizations, such as non-government organizations or church organizations, mirrors that provided for the parameter of local government involvement in that the presence of these organizations greatly facilitates the implementation of HWTS technologies. The same considerations are applied to the technologies that stand to benefit more from these organizations. These organizations can be considered as those that already implement similar technologies or those that have the potential to implement these technologies on a community level.

Information requested:

- Presence of implementing organization(s) (NGO / Church Organization / Etc.) in community
- __ No presence of implementing organization(s) (NGO / Church Organization / Etc.) in community

Suggested scoring:

Table 5.15 – Suggested Scoring for "Implementing Organizations (NGOs)"

Technology	Presence of Implementing Org.	No Presence of Implementing Org.
Household Chlorination	40/60	0/60
Solar Disinfection	60/60	0/60
Boiling	30/60	0/60
Ceramic Candle Filtration	40/60	0/60
BioSand Filtration	60/60	0/60
Combined Floc/Dis	40/60	0/60

5.4.7 Presence of Local Community Groups

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 2: "Implementation Program / Product Description"
 - ➤ Question 2.11
- Section 12: "Target: Costs"
 - > Questions 12.12 to 12.15

Local community groups are those that that are comprised entirely of local members of a community banded together to aid in the welfare of the community as a whole. These groups are considered different from NGO's, government-affiliated organizations, and even institutionalized groups such as churches. These groups were observed in Kenya to have a large impact on the implementation of technologies at the grassroots level. The Society for Women and Aids in Kenya (SWAK) in Nyanza is an example of one of these groups; the organization is credited as being responsible for a large percentage of PSI Waterguard® sales in rural areas in the Nyanza Province. In Kibera, KWAHO utilizes community members as promoters of the technology as well. These recognized and trusted members of the community make the acceptance of HWTS products more likely; in addition to this, these members of the community can potentially provide training service and other basic support throughout the use of a product to ensure proper operation and maintenance.

Scoring for the technologies is performed in the same manner used for the previous two parameters.

Information requested:

- __ Presence of local community groups (Self-help Groups / Women's Groups / Etc.) in community
- __ No Presence of local community groups (Self-help Groups / Women's Groups / Etc.) in community

Suggested scoring:

Table 5.16 – Suggested Scoring for "Local Community Groups"

Technology	Presence of Local Groups	No Presence of Local Groups
Household Chlorination	40/60	0/60
Solar Disinfection	60/60	0/60
Boiling	30/60	0/60
Ceramic Candle Filtration	40/60	0/60
BioSand Filtration	60/60	0/60
Combined Floc/Dis	40/60	0/60

5.4.8 Presence of Schools (Education)

Relevant Section(s) and Question(s) in Implementation Organization Survey:

• There are no specific sections or questions in the survey pertaining to the presence of schools in the community. Although numerous questions are asked in regard to training education, these questions pertain more to how implementing organizations train and educate a community on the correct use and O&M of HWTS technologies and do not ask details about the presence of schools in the community.

The presence of schools has two implications: (1) as a means of spreading information about HWTS technologies and (2) as a means of promoting literacy, which in turn is presumed to assist users in properly using technically challenging HWTS products.

Schools are effective forums for spreading awareness of hygiene and safe water practices. Implementing organizations in Kenya often target these educational institutions in marketing technologies. Children are considered effective promoters of technologies as they take lessons learned in school back to their homes. This was seen in Kibera, where KWAHO was heavily involved in promoting SODIS through school programs, and in Naivasha, where CDN actually had one of their defluoridation filter prototypes located at a local secondary school.

Schools are also directly responsible for rates of literacy in a community. The importance of literacy is discussed in more detail in Section 5.4.1.5 (Population Literacy Rate). To simplify the calculation of scores for this parameter, the same scoring approach utilized for the last three sections will be employed. Only in this instance, the technically-challenging technologies such as household chlorination, ceramic candle filtration, and combined flocculation/disinfection are also considered in regards to implications of literacy.

Information requested:

- __ Presence of schools (Primary and Secondary) in community
- ___ No Presence of schools (Primary and Secondary) in community

Suggested scoring:

Table 5.17 – Suggested Scoring for "Presence of Schools"

Technology	Presence of Schools	No Presence of Schools
Household Chlorination	50/60	0/60
Solar Disinfection	60/60	0/60
Boiling	30/60	0/60
Ceramic Candle Filtration	50/60	0/60
BioSand Filtration	60/60	0/60
Combined Floc/Dis	50/60	0/60

5.4.9 Presence of Health Clinics

Relevant Section(s) and Question(s) in Implementation Organization Survey:

• There are no specific sections or questions in the survey pertaining to the presence of health clinics in the community.

The presence of health clinics is another means of spreading information about HWTS technologies. The scoring is similar to that presented in previous sections.

Information requested:

- __ Presence of health clinics in community
- __ No Presence of health clinics in the community

Suggested scoring:

Table 5.18 – Suggested Scoring for "Presence of Health Clinics"

Technology	Presence of Health Clinics	No Presence of Health Clinics
Household Chlorination	40/60	0/60
Solar Disinfection	60/60	0/60
Boiling	30/60	0/60
Ceramic Candle Filtration	40/60	0/60
BioSand Filtration	60/60	0/60
Combined Floc/Dis	40/60	0/60

5.4.10 Presence of Infrastructure (Access and Roads)

Relevant Section(s) and Question(s) in Implementation Organization Survey:

• There are no specific sections or questions in the survey pertaining to the presence of infrastructure in the community.

Suggested Weight: 30/1000 (3%)

Roads and access pertain to large-scale transportation infrastructure to communities. Roads and access to a particular community are more important to certain technologies than others. Technologies such as ceramic candle filtration, household chlorination, and combined flocculation/disinfection all require resources to be transported to a particular community from outside suppliers. Additionally, these technologies often rely on marketing methods requiring that access to a particular community be provided. To a certain extent, technologies like concrete BioSand filtration and SODIS technologies also require that materials be transported into a community; however, the implementation of these technologies is not as transportation-dependent as those commercially available technologies. These technologies (concrete BioSand filters and SODIS) are better suited for manufacture in the area in which these technologies are being implemented.

One example of this access and transportation issue observed in the field during the site visit was in regard to the PSI Waterguard® implementation in the Kwale District of the Coast Province. Marketability and sales in this rural district were severely impacted by the fact that access was restricted to the area. Roads were of poor quality and most of the community was located large distances off the region's central arteries. The scores assigned reflect these considerations.

Information requested:

- Paved roads available to access the community
- __ Gravel and dirt roads available to access the community
- __ No roads available to access the community

One note is that the roads considered above do not necessarily pertain to elaborate road networks serving the entire community but instead consider even just the presence of a central artery passing through the recognized town center. It is assumed that the conditions of these roads (paved versus gravel) directly impact the efficiency of transport and access to the community.

Suggested scoring:

Table 5.19 – Suggested Scoring for "Presence of Infrastructure"

Technology	Paved Roads	Gravel or Dirt Roads	No Roads
Household Chlorination	30/30	15/30	0/30
Solar Disinfection	30/30	25/30	20/30
Boiling	30/30	30/30	30/30
Ceramic Candle Filtration	30/30	15/30	0/30
BioSand Filtration	30/30	25/30	20/30
Combined Floc/Dis	30/30	15/30	0/30

5.4.11 Economic Considerations

Economic considerations are difficult to quantify in that there is a high level of variability in (1) how much technologies cost in a given area and (2) how much money a typical household in that particular area has available to spend on the said technology. An effort is made to consider the relative households capital and operational costs of each of the technologies. This cost ranking is based on the following costs determined in Kenya:

Table 5.20 - Capital and Annual O&M Costs assumed for Technologies Considered

Technology	Capital		Annual Operation and Maintenance	
	Costs	Rank	Costs	Rank
Household Chlorination	KSh 45 (US\$0.6)	3	KSh 540 (US\$7)	5
Solar Disinfection	KSh 40 (US\$0.5)	2	KSh 40 (US\$1)	2
Boiling	KSh 40 (US\$0.5)	2	KSh 480 (US\$6)	3
Ceramic Candle Filtration	KSh 900 (US\$12)	5	KSh 520 (US\$7)	4
BioSand Filtration	KSh 800 (US\$11)	4	KSh 0 (US\$0)	1
Combined Floc/Dis	KSh 8 (US\$0.1)	1	KSh 2,920 (US\$39)	5

Some assumptions and notes pertaining to the above costs:

- Costs are based on data collected from the field during the site visit to Kenya in January, 2005. It is assumed that even though costs are specific to Kenya, the relative ranking of the technologies according to these costs is sufficient for the calculations of the selection tool and that this ranking would therefore be relatively applicable to other areas as well.
- Household chlorination O&M costs are based on one bottle of Waterguard® being purchased at KSh 45 (US\$ 0.5) every month.
- SODIS assumes costs based on information received from the Anglican Church of Kenya. Capital costs assume two bottles to start with while O&M costs assume that bottles are replaced every eight months.
- Costs for boiling water were not ascertained in the field. It was only reported that costs per month were comparable to those of Waterguard in that with the price increase of Waterguard from KSh 35 (US\$ 0.47) to KSh 45 (US\$ 0.6) might cause people to revert to boiling, the cheaper alternative of the two. For the purposes of the ranking the cost of boiling water is assumed to be Ksh 40 (US\$ 0.5) per month.
- Ceramic candle filtration capital costs are based on the total costs required for an entire system which includes buckets and a spigot. The costs are not due to the ceramic candle filters alone.
- Ceramic candle filtration O&M costs are assuming that two filter candles are replaced every six months.
- Combined flocculation/disinfection costs are based on one packet of PuR® being purchased at KSh 8 (US\$ 0.1) per day. This is the cost at which SWAK intends to sell the product.

Economic considerations are comprised of three individual parameters: family wealth information, willingness-to-pay, and available funding. These parameters will be explained further in the following sections. Throughout the remaining analysis there will be no effort to combine capital and O&M cost considerations; instead, unique scoring methodologies will be suggested for each of these costs.

5.4.11.1 Family Wealth Information

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 6: "Funding"
 - ➤ Question 6.5
- Section 12: "Target: Costs"
 - ➤ Question 12.9
- Household Survey
 - > Section 8: Household Composition and Wealth Information

Family wealth pertains to the money a family has available to spend on water treatment. This must be differentiated from willingness-to-pay in that the latter takes into account other variables unrelated to cost; i.e. although a family may have the wealth to purchase a technology, the family may not necessarily be willing to purchase the technology due to personal views and reasons. Family wealth is a more approximate method of gauging whether a particular target population can afford to pay for a technology. Such information can be obtained through average community incomes or even through visual inspection of family-owned goods.

After determining a relative idea of income per household, the question now becomes: what percent of that income should households be expected to spend on water treatment? The method in water and sanitation policy planning that is often used to gauge fair prices for water and sanitation services is the five percent rule; in this rule, five percent is a fair cutoff or maximum portion of income that can be spent on water and sanitation. However, the US Environmental Protection Agency (US EPA) employs a "four percent benchmark" as a cutoff for affordable water and sewer tariffs (US Congress, 2002). This four percent value is for both water and sanitation, so only a portion of that sum would be allotted to water quality. For the purposes of the selection tool, a value of one percent will be used in the analysis for the family wealth parameter. This one percent is considered in its entirety for both capital and O&M costs. This is because the capital costs are assumed to be a one time cost for which the four percent rule might be exceeded.

Information requested:

- __ US\$ <1/person/day
- __ US\$ 1-2/person/ day
- US\$ 2-3/person/day
- __ US\$ >3/person/day

Suggested scoring, capital costs:

Table 5.21 – Suggested Scoring for "Family Wealth Information (Capital Costs)"

Technology	US\$ <1	US\$ 1–2	US\$ 2–3	US\$ >3
Household Chlorination	25/25	25/25	25/25	25/25
Solar Disinfection	25/25	25/25	25/25	25/25
Boiling	25/25	25/25	25/25	25/25
Ceramic Candle Filtration	0/25	0/25	0/25	25/25
BioSand Filtration	0/25	25/25	25/25	25/25
Combined Floc/Dis	25/25	25/25	25/25	25/25

Suggested scoring, operation and maintenance costs:

Table 5.22 – Suggested Scoring for "Family Wealth Information (O&M Costs)"

Technology	US\$ <1	US\$ 1–2	US\$ 2–3	US\$ >3
Household Chlorination	0/25	25/25	25/25	25/25
Solar Disinfection	25/25	25/25	25/25	25/25
Boiling	0/25	25/25	25/25	25/25
Ceramic Candle Filtration	0/25	25/25	25/25	25/25
BioSand Filtration	25/25	25/25	25/25	0/25
Combined Floc/Dis	0/25	0/25	0/25	25/25

Based on the previous ranking and the scores assigned, it may be observed that though concrete BioSand filters have high start-up (capital) costs, this technology also has the lowest operation and maintenance costs. Additionally, though considered among the technologies to be the most effective in terms of bacterial indicator and turbidity removal, combined flocculation/disinfection is also the most expensive technology in terms of continued costs of operation and maintenance. This is also the pattern for the other two commercially-available technologies (ceramic candle filtration and household chlorination).

5.4.11.2 Willingness-to-Pay

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 6: "Funding"
 - ➤ Question 6.6
- Section 12: "Target: Costs"
 - ➤ Question12.10
- Household Survey
 - > Section 7: Willingness-to-Pay

Suggested Weight: 50/1000 (5%)

As previously discussed, willingness-to-pay is fundamentally different from family wealth in that it is potentially a more accurate gauge of the actual amount that a family is willing to pay for a technology. The information is typically collected through an indepth survey process which allows interviewees to select, from a range of costs, a price that they feel they would be willing to pay for a particular technology. The scoring presented here is similar to that of the previous section. The information collection process is facilitated by the fact that interviewers can ask for a range of prices specific to a particular technology versus utilizing the percent assumptions used for the family wealth parameter.

Information requested:

- $_$ US\$ 0 1/technology
- $_$ US\$ 1 10/technology
- $_$ US\$ 10 20/technology
- __ US\$ 20 30/technology
- $_$ US\$ > 30/technology

Suggested scoring, capital costs:

Table 5.23 – Suggested Scoring for "Willingness-to-Pay (Capital Costs)"

Technology	US\$ 0 – 1	US\$ 1 – 10	US\$ 10 – 20	US\$ 20 – 30	US\$ >30
Household Chlorination	25/25	25/25	25/25	25/25	25/25
Solar Disinfection	25/25	25/25	25/25	25/25	25/25
Boiling	25/25	25/25	25/25	25/25	25/25
Ceramic Candle Filtration	0/25	0/25	0/25	0/25	25/25
BioSand Filtration	0/25	0/25	25/25	25/25	25/25
Combined Floc/Dis	25/25	25/25	25/25	25/25	25/25

Suggested scoring, operation and maintenance costs:

Table 5.24 – Suggested Scoring for "Willingness-to-Pay (O&M Costs)"

Technology	US\$ 0 – 1	US\$ 1 – 10	US\$ 10 – 20	US\$ 20 – 30	US\$ >30
Household Chlorination	0/25	25/25	25/25	25/25	25/25
Solar Disinfection	25/25	25/25	25/25	25/25	25/25
Boiling	0/25	25/25	25/25	25/25	25/25
Ceramic Candle Filtration	0/25	25/25	25/25	25/25	25/25
BioSand Filtration	25/25	25/25	25/25	25/25	0/25
Combined Floc/Dis	0/25	0/25	0/25	0/25	25/25

5.4.11. 3 Available Funding

Section 6: "Funding"
Questions 6.1 to 6.5
Section 12: "Target: Costs"

Questions 12.1 to 12.9

Suggested Weight: 50/1000 (5%)

This parameter addresses situations in which funding in the form of partial subsidies has been allotted to a particular community for household water treatment purposes. Funding could come from a host of sources, such as international aid organization grants or government subsidies. The funding is meant to address and lower costs of HWTS technologies and is therefore treated in the same manner as other economic considerations.

Information requested:

- $_$ US\$ 0 1/household/year
- $_$ US\$ 1 10/household/year
- $_$ US\$ 10 20/household/year
- $_$ US\$ 20 30/household/year
- $_$ US\$ > 30/household/year

Suggested scoring, capital costs:

Table 5.25 – Suggested Scoring for "Available Funding (Capital Costs)"

Technology	US\$ 0 – 1	US\$ 1 – 10	US\$ 10 – 20	US\$ 20 – 30	US\$ >30
Household Chlorination	25/25	25/25	25/25	25/25	25/25
Solar Disinfection	25/25	25/25	25/25	25/25	25/25
Boiling	25/25	25/25	25/25	25/25	25/25
Ceramic Candle Filtration	0/25	0/25	0/25	0/25	25/25
BioSand Filtration	0/25	0/25	25/25	25/25	25/25
Combined Floc/Dis	25/25	25/25	25/25	25/25	25/25

Suggested scoring, operation and maintenance costs:

Table 5.26 – Suggested Scoring for "Available Funding (O&M Costs)"

Technology	US\$ 0 – 1	US\$ 1 – 10	US\$ 10 – 20	US\$ 20 – 30	US\$ >30
Household Chlorination	0/25	25/25	25/25	25/25	25/25
Solar Disinfection	25/25	25/25	25/25	25/25	25/25
Boiling	0/25	25/25	25/25	25/25	25/25
Ceramic Candle Filtration	0/25	25/25	25/25	25/25	25/25
BioSand Filtration	25/25	25/25	25/25	25/25	0/25
Combined Floc/Dis	0/25	0/25	0/25	0/25	25/25

5.5 Technology-Specific Parameters

The following discussion focuses more on the rationale behind the scoring and weighting of each parameter and does not go into specific details as to what each parameter means. More details about the parameters are discussed in the "HWTS Technologies" chapter of the thesis (Chapter 2).

Technology-specific parameters are "add-on" types of parameters to the site-specific parameters discussed previously. The parameters are grouped by the technologies and subsequently prompt for information pertaining only to these specific technologies. Each technology is given a score over 100 points which is added to the score received for site-specific parameters. The following sections discuss this process in more detail.

There are three technologies that are currently widely available commercially in Kenya and some other low income countries; these are ceramic candle filtration, household chlorination, and combined flocculation/disinfection. This means that these technologies need to be evaluated in regards to parameters that take marketing and distribution into account. These "commercial" parameters are given more consideration than the parameter of resource availability as will be explained in the following sections.

It must be noted that marketability and distribution are all somewhat accounted for in the consideration of site-specific parameters. For instance, parameters such as population density (urban/rural) and infrastructure both score technologies partially in consideration of marketing and distribution issues. The parameters in the following section take a more focused approach at scoring these considerations.

5.5.1 Household Chlorination

Since the manufacturing of these technologies is assumed to be accomplished on a medium or large-scale at a centralized manufacturing plant, the impacts of resource availability are not determined to be necessarily site-specific. In other words, we are not giving particular weight to the raw materials involved in the production of this technology, as we would do if the technology were being locally produced, but are instead concerned with processes of marketing and distribution. This is different from technologies such as concrete BioSand filtration, which needs to be produced at or close to the site of implementation, necessitating that raw materials be readily available in close proximity to the target area.

In this regard, we look at resource availability on a national level, considering that it would be very beneficial for the technology to be manufactured in-country as opposed to importing the technology in from another country. This would greatly reduce transportation costs, subsequently reducing prices, and may have other indirect benefits such as providing employment opportunities.

Ceramic candle filtration and combined flocculation/disinfection (PuR®), also being commercially available technologies, will be considered in the exact same capacity as household chlorination in terms of the parameters considered and scoring assigned.

5.5.1.1 Resource Availability

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 4: "Resource Availability"
 - ➤ Question 4.1

Suggested Weight: 20/100 (20%)

Information requested:

___ In-Country Manufactured (20/20)

__ Imported (0/20)

It must be noted further that the "In-Country Manufactured" option above pertains to either of the following conditions: (1) the technology is currently manufactured incountry or (2) the technology is intended to be manufactured in-country in the future.

5.5.1.2 Mass Media Presence

Relevant Section(s) and Question(s) in Implementation Organization Survey:

• Section 12: "Target: Costs"
➤ Questions 12.12 to 12.14

Suggested Weight: 40/100 (40%)

This is once again related directed to the marketing of the technology. It is noted that since this technology is commercially available, marketing in turn is essential in promoting knowledge about the product. It is therefore important that marketing be implemented through certain avenues such as mass media. It is difficult to quantify this type of parameter as it is hard to determine what mass media processes are most effective at reaching people. So instead, a more simple approach is employed in which the following information is sought:

Information requested:
Television (+10/40)
Radio (+10/40)
Billboards and Posters (+10/40)
Print Media (+10/40)
None of the Above $(0/40)$

For each of the media presented above ten points are added out of a total of 40. If all four are used as outlets for marketing then this parameter is scored as a perfect 40/40. These choices are considered to be a good estimate of mass media presence in a community that may be ascertained through simple observation. For instance, the "Television" may be allotted ten points if it is simply observed that residents in the community own televisions. Or ten points may be allotted to "Billboards and Posters" if it is observed that these types of media are present throughout the community, especially in the popular areas such as the town centers and markets. It must be made clear here that one is not necessarily looking for media advertising a specific technology, only that the media is present in the community for the potential promotion of the technology, should it be implemented in that region.

5.5.1.3 Available Local Distributors

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 12: "Target: Costs"
 - ➤ Questions 12.16

As much as mass media presence supports the promotion of a technology, one also requires that necessary systems be in place for the proper distribution of a technology. Central facilities such as local stores and markets should be present and accessible to community residents so that a technology and its spare parts are made readily available. This is considered in the following suggested scoring for the parameter:

Suggested Weight: 40/100 (40%)
Information requested:

_ Local Distributors Available (40/40)
No Local Distributors Available (0/40)

Local distributors play an essential role in the implementation of commercially available technologies. These distributors not only get the technology to shops, which in turn sell to residents, but to a certain extent serve as promoters and technical support for the technologies as well. If local distributors of a technology are not available in a community, or if such distributors are located in areas inaccessible to residents, it is very

unlikely that commercially available technologies will be implemented successfully.

5.5.2 **SODIS**

As opposed to technologies cited as being commercially available; SODIS, concrete BioSand filtration, and boiling are typically available in a highly localized capacity. For all three technologies, resource availability, as opposed to marketing and available local distributors, is a parameter given importance. In the case of SODIS, this means that bottles used for the technology should typically be manufactured at a site in close proximity to the community.

This is not to say that these technologies could not benefit from marketing and distribution methods typically employed by the aforementioned commercially available technologies, only that these technologies require that local availability of raw materials (e.g. PET bottles, concrete, sand, gravel, fuel for boiling) be considered as more important in the overall scoring process. Technical support throughout the operation and maintenance of these technologies is also a parameters that needs to be accounted for. This is discussed in the following sections.

Concrete BioSand filtration and boiling, also being resource-intensive technologies, will be considered in a similar capacity as SODIS in terms of the parameters considered and scoring assigned. However, for SODIS, an additional parameter addressing adequate exposure to sunlight is included.

5.5.2.1 Resource Availability

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 4: "Resource Availability"
 - ➤ Ouestion 4.1

The only critical resource for SODIS implementation is PET plastic (or glass) bottles. This differentiates SODIS somewhat from the concrete BioSand filter in that the resources required are not actually raw materials. Instead, the parameter focuses on the availability of local manufacturers or "other" bottle sources.

Suggested Weight: 40/100 (40%)

Information requested:

- __ Available Sources of PET Plastic or Glass Bottles in the Community (Local Manufacturers or Other bottle sources) (+30/30)
- __ No Available Sources of PET Plastic or Glass Bottles in the Community (Local Manufacturers or Other bottle sources) (0/30)

The term "local manufacturers" does not require that there is a manufacturing plant right in the middle of the target area but instead requires that efficient and cheap transportation be available to deliver bottles to a centralized location in the community. "Other bottle sources" could include restaurants or other manufacturing plants that might have bottles that are typically thrown away after use.

5.5.2.2 Technical Support Availability

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 4: "Resource Availability"
 - ➤ Question 4.2

The technology does require some continued effort by implementers to ensure that the technology is being properly employed, especially during the early stages of implementation, and until good habits are established. This effort is not entirely technical in nature, but also pertains to motivational aspects encouraging continued use.

Suggested Weight: 20/100 (20%)

Information requested:

- __ Available Technical Support in the Community (+20/20)
- No Available Technical Support in the Community (0/20)

5.5.2.3 Exposure to Sunlight

Relevant Section(s) and Question(s) in Implementation Organization Survey:

• There are no questions in the survey that address exposure to sunlight because this parameter is considered specific to SODIS.

SODIS is unique in that it requires that bottles have an area in which exposure to sunlight is sufficient over a predetermined period of time. Without this proper exposure, SODIS cannot adequately disinfect water from microbial contamination. In prompting the user for "Adequate Exposure to Sunlight" the selection tool is considering the availability of a surface which is exposed to sunlight during all hours of the day. The bottles do not necessarily need to be exposed during all daylight hours but this parameter is given as a conservative indication of whether conditions in the community are conducive to SODIS implementation.

Suggested Weight: 40/100 (40%)
Information requested:
Adequate Exposure to Sunlight (+40/40)
Inadequate Exposure to Sunlight (0/40)

It is recognized that this parameter is not easily applied over an entire community, but an effort should be made to make a general assumption as to whether households typically have available exposure to sunlight.

5.5.3 Boiling

Boiling is a unique technology in that it is potentially the least demanding in terms of considerations of technical support, marketing, and distribution. The technology really only requires two things: fuel and a pot. So long as a fuel source and a pot are available, the technology is easily employed and requires little, if any technical support. Although it is recognized that the technology can be employed improperly wherein users make mistakes if they do not boil water long enough or store boiled water improperly, this is not given enough weight to be considered in the analysis employed by the selection tool

5.5.3.1 Resource Availability

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 4: "Resource Availability"
 - ➤ Question 4.1

Fuel is required to boil water properly. The fuel source could be locally available wood or charcoal. In considering the "availability" of these sources one looks at both quantity and accessibility. In the event that fuel is purchased from local vendors, one might also consider price in the scoring of the technology.

Suggested Weight: 100/100 (100%)	
Information requested:	
Locally Available Fuel Source (100/1	00)
Vendor-provided Fuel Source (75/100))
No Available Fuel Source (0/100)	

5.5.4 Ceramic Candle Filtration

Ceramic candle filtration, being a commercially available technology, will be considered in the exact same capacity as household chlorination in terms of the parameters considered and scoring assigned.

5.5.4.1 Resource Availability

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 4: "Resource Availability"
 - ➤ Question 4.1

Suggested Weight: 20/100 (20%)	
Information requested: Locally Manufactured (20/20) Imported (0/20)	

It must be noted further that the "In-Country Manufactured" option above pertains to either of the following conditions: (1) the technology is currently manufactured incountry or (2) the technology is intended to be manufactured in-country in the future.

5.5.4.2 Mass Media Presence

Relevant Section(s) and Question(s) in Implementation Organization Survey:

Section 12: "Target: Costs"➤ Questions 12.12 to 12.14

Suggested Weight: 40/100 (40%)

Information requested:
__ Television (+10/40)
__ Radio (+10/40)
__ Billboards and Posters (+10/40)
__ Print Media (+10/40)
__ None of the Above (0/40)

5.5.4.3 Available Local Distributors

Relevant Section(s) and Question(s) in Implementation Organization Survey:

Section 12: "Target: Costs"Questions 12.16

Suggested Weight: 40/100 (40%)

Information requested:	
Local Distributors Available (40	0/40)
No Local Distributors Available	e(0/40)
5.5.5 Concrete BioSand Filtration	on

Concrete BioSand filtration is considered in the same capacity as SODIS in that it is not a commercially available technology. Resource availability and technical support are also considered for this technology and are scored in a similar fashion as SODIS. However, unlike SODIS, the technology does require skilled labor to construct.

5.5.5.1 Resource Availability

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 4: "Resource Availability"
 - ➤ Ouestion 4.1

Resource availability for the concrete BioSand filter is a very important parameter. During the site visit to Kenya in January the technicians implementing the filters in the Machakos District cited resource availability as a primary concern for the production of the technology. The materials typically dictated the cost of producing the filter and the technicians even employed a construction method in which buyers of the filter were given opportunity to collect and sieve sand. In other words, buyers were allowed to substitute their own local raw materials and labor for part of the capital cost. The following scoring is suggested for the parameter.

Suggested Weight: 30/100 (30%)

Information requested:
Are the following raw materials available in close proximity to the community?

__ Sand and Gravel (+10/30)

__ Water (+5/30)

__ Concrete (+10/30)

__ PVC Pipe (+5/30)

In considering the "availability" of these materials one not only considers sufficient quantity but also the accessibility of these materials. The materials should be available in adequate supply to ensure complete implementation throughout the community; in addition to this, one should also consider the long-term implementation of the technology. This means that one should plan for the repair and even, ideally, the eventual replacement of these technologies at the end of useful life. Accessibility is also a consideration as transport of heavy materials can be a limiting factor in the production process. Water, sand, and gravel should be accessible from natural sources, while concrete and PVC pipe should be available from a centralized local distributor or hardware store.

5.5.5.2 Skilled Labor Availability

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 4: "Resource Availability"
 - ➤ Question 4.2

Skilled labor is another important consideration in both the production and distribution of the concrete BioSand filter. The technology is technically intensive during construction and requires skilled concrete work. This was apparent in Machakos where the technicians implementing the technology were also responsible for building other concrete structures throughout the community. Concrete BioSand filters require quality control in production, as filters are typically dependent on accurate mixture of materials. This parameter is scored based on the availability of skilled concrete workers in the community; it is assumed that skills in concrete construction are easily transferred to additional skills required for concrete BioSand production.

Suggested Weight: 30/100 (30%)

Information requested:

- __ Available Skilled Concrete Workers in the Community (+30/30)
- __ No Available Skilled Concrete Workers in the Community (0/30)

5.5.3 Technical Support Availability

Relevant Section(s) and Question(s) in Implementation Organization Survey:

- Section 2: "Implementation Program / Product Description"
 - ➤ Ouestion 2.6
- Section 11: "Target: Behavior/Use (Social Acceptability)"
 - ➤ Ouestion 11.2

The concrete BioSand filter requires technical support throughout operation and maintenance for the technology to remain effective. The actual use of the filter does not require as much technical support as the maintenance required for the filter to continue to operate properly. The filter initially requires close monitoring during its introduction to a particular household, especially during the first several weeks as this is the time required for the filter to "ripen" and properly remove microbial contamination. From this point forward, technical support is required to teach users how to maintain the filter, especially during instances in which the filter becomes clogged. If residents do not have technical support they are likely to discontinue use of the filter when clogging occurs. A large portion of the success of the concrete BioSand filter in Machakos was attributed to the continued involvement of the technicians responsible for implementing the filters.

Suggested Weight: 40/100 (40%)

Information requested: Available Technical Support in the Community (+40/40) No Available Technical Support in the Community (0/40)
It must be noted that technical support for the technology does not have to come specifically from the people implementing the technology. The support could come from other institutions in the community such as local governments, church groups, health clinics, or NGOs, so long as these groups are reliable and willing to provide guidance for the technology.
5.5.6 Combined Flocculation/Disinfection
Combined Flocculation/Disinfection, being a commercially available technology, will be considered in the exact same capacity as ceramic candle filtration and household chlorination in terms of the parameters considered and scoring assigned.
5.5.6.1 Resource Availability
Relevant Section(s) and Question(s) in Implementation Organization Survey: • Section 4: "Resource Availability" > Question 4.1
Suggested Weight: 20/100 (20%)
Information requested: In-Country Manufactured (20/20) Imported (0/20)
It must be noted further that the "In-Country Manufactured" option above pertains to either of the following conditions: (1) the technology is currently manufactured incountry or (2) the technology is intended to be manufactured in-country in the future.
5.5.6.2 Mass Media Presence
Relevant Section(s) and Question(s) in Implementation Organization Survey: • Section 12: "Target: Costs" ➤ Questions 12.12 to 12.14
Suggested Weight: 40/100 (40%)
Information requested: Television (+10/40) Radio (+10/40) Billboards and Posters (+10/40) Print Media (+10/40) None of the Above (0/40)

5.5.6.3 Available Local Distributors

 $Relevant\ Section(s)\ and\ Question(s)\ in\ Implementation\ Organization\ Survey:$

- Section 12: "Target: Costs"
 - > Questions 12.16

Suggested	Weight:	40/100	(40%))
Duggostou	TT CIGITE.	10/100	1 10 /0 /	,

Information requested:	
Local Distributors Available (40/40)	
No Local Distributors Available (0/40	1)

CHAPTER 6 – CONCLUSIONS, RESULTS, AND RECOMMENDATIONS

6.1 HWTS Implementation Organization Survey

The HWTS Implementation Organization Survey was intended as a collection instrument to be utilized primarily for gathering information on currently implemented HWTS programs, but it is also applicable for pre-implementation scenarios. The survey was vetted and iterated through interactions with eleven different HWTS implementing program groups working in five of Kenya's seven provinces and one area, who are applying eight different HWTS technologies: household chlorination (Waterguard®), solar disinfection (SODIS), boiling, ceramic candle filtration, concrete BioSand filtration, combined flocculation/disinfection (PuR®), defluoridation with bone char, and the modified clay pot.

Throughout the next sections, conclusions about the effectiveness of the survey will be provided based specifically upon the application of the survey in Kenya. Section 6.1.1 will provide general conclusions and recommendations regarding the application of the survey, while Section 6.1.2 will provide conclusions and recommendations for each of the specific sections included in the survey.

As the basis for these conclusions is the application of the survey to various HWTS implementation organizations in Kenya, efforts will be made to summarize how each of the organizations responded to specific sections of the survey.

Complete versions of the survey are included in Appendix B.

6.1.1 General Conclusions and Recommendations

The overall objective of the survey was to aid in achieving WHO IWG Activity 1b: Create Web-based database of implementation experience of the Members. In order to develop a good web database of implementation experience it was determined that a thorough survey of a set of implementing organizations was called for. IWG network members were asked for input on the survey; once received, input was incorporated in various iterations. The survey, initially a 36-page document, was significantly narrowed in scope and detail through these iterations and is now in its eighth version containing only 19 pages. The survey acts as a collection instrument on which the said web-based tool is based.

While input was received from IWG network members, the survey was taken to Kenya for use on a number of HWTS implementing organizations. The survey was conducted by the author, Robert Baffrey, and his colleague, Jill Baumgartner, a student with the Harvard School of Public Health. The following are general conclusions made based on the application of the survey in Kenya:

- The survey is conducted more efficiently by two people. One person can take the lead on asking and explaining questions while the other can focus on recording answers either by hand or directly onto a laptop.
- Should the survey be conducted by one person, it is helpful that the person have an audio recording device to aid in the recording of answers. The survey is lengthy and it is cumbersome for one person to both ask questions and record answers.
- The survey took approximately one to two hours to complete.
- Without adequate time the survey could not be completed effectively. This is not an overwhelming concern as the survey is in fact intended to be used in scenarios where time is readily available.
- When sufficient time was allowed, the survey was conducted in an efficient manner. Questions were typically straightforward and clear, although some did require clarification in order to be comprehended fully.
- The survey warrants some knowledge of HWTS technologies and implementation practices from the standpoint of both the interviewer and the interviewee.
- Specific parts of the survey may be tailored to organization members having different responsibilities in HWTS implementation. In this case, the interviewer may need to interview two separate parties to gain a comprehensive evaluation of the organization.
- Considering the survey was in its early stages during this process, it performed relatively well in obtaining a large amount of data on the HWTS implementing organizations visited.

It must also be mentioned that the survey was modified for use on a household level. The team did not originally intend to conduct household surveys but thought it pertinent to have a survey on hand should the opportunity to interview households arise. The household survey was used on about fifteen households in Machakos and Mathuru and, like the organization-based survey, held up relatively well and took about 45 minutes to complete. The household survey is included in Appendix B.

General Recommendations for the HWTS implementation organization survey are presented as follows:

- Refinement of the survey through review and evaluation by various experts and professionals involved in different facets of HWTS implementation.
- Refinement of the survey through application to HWTS implementation organizations in other developing countries.
- Streamlining of the survey to be applied more efficiently in the field.
- Simplification of the survey to be more readily used by individuals with limited knowledge of HWTS technologies.
- Standardization and acceptance of the survey for global use and applicability.
- Modification of the survey to suit other programs, and not just those dealing specifically with HWTS technologies.

The following sections discuss conclusions and recommendations about the specific sections included in the survey. Detailed discussion of these sections has been included in Chapter 3.

6.1.2 Section-Specific Conclusions and Recommendations

6.1.2.1 Background Sections

6.1.2.1.1 General Information

Conclusions:

• There were no problems encountered in this section of the survey.

Recommendations:

• The interviewer should attempt to obtain the information on this section prior to the actual survey. A large portion of this information is readily available through sources such as the Internet and passing this section would expedite the survey and allow the interviewer to move on to other more important sections.

6.1.2.1.2 Implementation Program/Product Description

Conclusions:

- There were no major problems encountered in this section of the survey. For the most part, the questions were very well received. Organizations had no trouble answering questions specific to the technologies.
- Questions regarding the overall implementation of the program were found to be more difficult to answer. In particular, the organizations oftentimes did not have accurate numbers on the extent of implementation in terms of how many people were impacted by the technologies. This number often had to be estimated from the number of units manufactured or distributed, which was a value more easily obtained.
- Question in regards to pre-implementation of water and sanitation were also answered with difficulty as it was often the case that target areas had too many variations of water sources for easy generalizations to be made.
- Some of the tables are technical in nature and required the interviewer to explain options in detail; this took up some time in the field and it is not expected that an organization would be able to easily comprehend the options without assistance.

Recommendations:

- Some restructuring of the section might be required to address some of the conclusion made above.
- The interviewer should attempt to obtain the information on this section prior to the actual survey.

6.1.2.2 Pre-Implementation Sections

Table 6.1 presents the answers collected from the HWTS implementing organizations in Kenya for the sections of the survey pertaining to pre-implementation considerations. The table summarizes relevant information collected; more detailed information collected for the organizations is included in Chapter 4.

Table 6.1 – Summary of Answers Received from Organizations in Kenya (Pre-Implementation Section)

Question	NETWAS	CDN	Bushproof	KWAHO	ACK	PSI	SWAK
Water Supply	Natural Springs / Boreholes	Groundwater Wells	Dams / River / Wells	Piped Water (Vendors)	Protected Wells	Various	Various
Urban/Rural	Rural	Both	Rural	Urban	Rural	Both	Rural
Population Size	-	-	54,000	500,000 – 700,000	-	-	-
Baseline Health Study?	Yes	No	No	No	Yes	No	No
Raw Materials?	NA	Yes	Yes	Yes	Yes	NA	Yes
Skilled Labor?	NA	Yes	Yes	NA	NA	NA	Yes
Education and Training?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Funding Source	AQUAPOL	Self-Sustaining	MedAir	SANDEC	-	PSI Washington	EED / CDC / SWAK
Total Funding to Date?	-	-	-	US\$ 15,000	-	-	-
Cost-Benefit Analysis Conducted?	No	No	No	Cursory	No	Cursory	Cursory
Willingness-to-Pay Conducted?	No	No	No	Cursory	No	Cursory	Cursory

NA – not applicable

The term "cursory" in Table 6.1 means that the organization is addressing the question topic of to a certain extent but not in a manner considered to be complete. For example, PSI did not conduct a formal cost-benefit analysis but did consider past financial studies conducted by other organizations for similar products (CDC/CARE studies conducted for "Klorin", the household predecessor of Waterguard).

Conclusions and recommendations made based on these results are presented in the following sections.

6.1.2.2.1 Target Population and Current Water Use Practices and Concerns

Conclusions:

- The questions for this section posed no problems in terms of being clear and understandable.
- Information regarding water practices and access was often not known by the organizations interviewed. The same could be said for the demographics of the target population.
- Water supplies were varied among the organizations visited.
- Most of the organizations visited were implementing technologies in rural settings.
- It was also notable, with the exception of the Anglican Church of Kenya's SODIS implementation project and the NETWAS ceramic candle filter study, that there were very little, if any, baseline health studies conducted prior to system implementation. Target population and water use practices, as well as health information, are the main topics addressed by the "Household Survey".

Recommendations:

• The section may be further modified with additional information pertaining to water quality such as microbial contamination and turbidity.

6.1.2.2.2 Resource Availability

Conclusions:

- The questions for this section posed no problems in terms of being clear and understandable.
- All of the organizations visited had adequate resource availability and skilled labor when required.

Recommendations:

• There are no recommendations made for this section.

6.1.2.2.3 Education and Training

Conclusions:

- The questions for this section posed no problems in terms of being clear and understandable.
- All organizations utilized education and training in the implementation of HWTS technologies.

Recommendations:

• There are no recommendations made for this section.

6.1.2.2.4 Funding

Conclusions:

- The questions for this section posed no problems in terms of being clear and understandable.
- Organizations in Kenya were surprisingly open to providing financial information about their operations.
- Some of the financial information was not readily available. This required that additional time be given for the organizations to locate the said information. Oftentimes, organizations just gave the interviewers documents containing the financial information being requested.
- Most of the organizations visited were funded to a certain extent by international aid agencies. Some received funding from organizations based in Kenya while others were somewhat self-sustaining, relying on revenue generated from product sales to account for operation and maintenance costs.
- Most of the organizations did not conduct pre-implementation financial studies, such as cost-benefit analysis and willingness-to-pay studies, on the target populations for which the technologies were intended. KWAHO conducted a cursory interview of households to gauge how much families were willing to pay for SODIS while both PSI and SWAK relied upon past studies conducted by the CDC to gain an idea of the financial situation of target populations.

Recommendations:

• There are no recommendations made for this section.

6.1.2.3 Implementation Sections (Evaluation Methodologies and Targets)

The following sections of the survey address considerations during implementation of the program. Of specific interest in these sections are the evaluation methodologies or "targets" employed by various organizations to determine if programs are being implemented successfully. The targets considered: Health Outcome, Water Quality, Technology Performance and Behavior/Use, are those identified by either the World Health Organization (WHO) 3rd Edition Guidelines for Drinking Water Quality and/or the Implementation Working Group of the WHO Network. Additionally, another potential target, "Costs" (Finances and Economics) has also been included in the survey instrument. Table 6.2 presents the answers collected from the HWTS implementing organizations in Kenya for the sections of the survey pertaining to implementation considerations. The table summarizes relevant information collected; more detailed information collected for the organizations is included in Chapter 4.

Table 6.2 – Summary of Answers Received from Organizations in Kenya (Implementation Section)

Question	NETWAS	CDN	Bushproof	KWAHO	ACK	PSI	SWAK
O&M Conducted?	NA	Yes	Yes	Yes	Yes	No	Yes
O&M Frequency?	NA	2 – 4 times/year	Once/year	8 times/month	Varies	-	Varies
Target: Health Outcome utilized?	NA	No	Cursory	Cursory	Yes	Cursory	Cursory
Target: Water Quality utilized?	NA	Yes	Yes	Yes	Yes	Yes	Cursory
Water Quality Standards utilized?	NA	WHO Guidelines	Kenya Bureau of Standards	Kenya Bureau of Standards	-	Kenya Bureau of Standards	-
Target: System Performance utilized?	NA	Cursory	Cursory	No	No	No	Cursory
Target: Rate of Adoption and Sustained Use utilized?	NA	No	Yes	Yes	Yes	Cursory	Cursory
Rate if Adoption	NA	-	100%	88%	-	-	-
Rate of Sustained Use	NA	-	100%	-	-	-	-
Environmental Sustainability considered?	NA	No	No	Cursory	No	No	No
User Input considered?	NA	Cursory	Cursory	Yes	Cursory	No	Yes
Education, Training, and Awareness utilized?	NA	Yes	Yes	Yes	Yes	Yes	Yes
Social Acceptance considered?	NA	Cursory	Yes	Yes	Cursory	No	Yes
Target: Costs utilized?	NA	Yes	Yes	Yes	Yes	Yes	Yes
Marketing and Distribution Method utilized?	NA	Social Marketing	Social Marketing	Social Marketing	Social Marketing	Commercial	Social Marketing

NA – Not Applicable

The term "cursory" in Table 6.2 means that the organization is addressing the question topic to a certain extent but not in a manner considered to be complete. For example, KWAHO does intend to conduct a health study on the community in which SODIS has been implemented; however, the said health study is not formal in that the main method for determining the reduction in incidence of disease is merely through observation and informal interviews with households using the technology.

Conclusions and recommendations made based on these results are presented in the following sections.

6.1.2.3.1 Operational Monitoring

Conclusions:

- The section poses no problems as questions were easily answered by
 organizations when the survey was tested in the field. The section also serves as a
 good indication to the interviewer on how to go about following sections of the
 survey.
- Most of the organizations conducted some form of operational monitoring of their implemented systems.

Recommendations:

• There are no recommendations made for this section.

6.1.2.3.2 Target: Health Outcomes

Conclusions:

Only a few of the HWTS implementing organizations in Kenya had conducted a
health outcomes study. The commonly stated reasons for not conducting a health
outcomes study included cost of study design and implementation, personnel
limitations, and time constraints.

Recommendations:

• Organizations concerned with chronic diseases resulting from long-term exposure (i.e. skeletal fluorosis) will need to wait many years before being able to assess the health outcomes of their particular interventions.

6.1.2.3.3 Target: Water Quality

Conclusions:

- This section was applied with varying success in the field. Some organizations
 had difficulty providing the technical information requested in the section.
 Although most organizations recognized the importance of water quality, more
 often than not the interviewee was not technically knowledgeable of the
 laboratory analysis performed on raw or treated water.
- All of the organizations used water quality as a target to varying extents. The
 organizations typically utilized water quality targets in the introductory stages of
 technology implementation as this was often the most effective method to
 convince users of the effectiveness of the technology in "cleaning" water. Most
 relied on the Kenya Water Resources Authority to conduct water quality testing,
 although some organizations had in-house laboratories.

Recommendations:

• This section is technical in nature and it must be ascertained by the interviewer if the interviewee has an adequate knowledge of water quality parameters and laboratory testing methods. If the interviewee cannot provide answers to these questions then it might be worthwhile for the interviewer to find another member of the organization more proficient in answering these questions.

6.1.2.3.4 Target: HWTS System Performance

Conclusions:

- This section of the survey experienced some difficulty during application in the field. The main constraint of the section was explaining to organizations the distinction between system performance and water quality targets.
- Oftentimes, the technologies were not of the type where the performance data was readily available. For example, the concrete BioSand filter project in Machakos was very much a local undertaking and did not have the resources to disseminate literature on the filters installed. In addition to this, it was recognized by a number of organizations that the target population using these technologies often did not possess the capacity or need for this type of instructional information.
- Organizations recognized that instruction through personal contact with users was the most effective method of gauging system performance.
- A number of technologies are in their early stages of development and have not been distributed on a wide enough scale to have a set document with established standards pertaining to system performance. This is not to say that organizations interviewed did not recognize system performance as an important variable to consider in program implementation. In fact, for organizations implementing technologies employing somewhat larger physical units, such as concrete BioSand and defluoridation filters, it was observed that the structural performance of these units was In other words, this section of the survey led us to conclude that the organizations evaluated do utilize system performance as a target for evaluation.

Recommendations:

• It is proposed that this section of the survey be improved to be better able to collect information regarding this particular target.

6.1.2.3.5 Target: Behavior/Use (Social Acceptability)

Rate of Adoption and Sustained Use

Conclusions:

• There were no problems encountered in applying these questions in the field. Although most organizations did not apply this target in the defined manner, several organizations did have some means of evaluating if the technology was being used properly and used continuously in the community.

Recommendations:

• There are no recommendations made for this section.

Environmental Sustainability

Conclusions:

- There were no problems encountered in applying these questions in the field.
- Most organizations did express some concern about the renewability of resources used for construction and maintenance of these units but did not consider the impacts of technologies as waste products.

Recommendations:

• There are no recommendations made for this section.

User Input

Conclusions:

- There were no problems encountered in applying these questions in the field.
- It was noticeable that organizations providing commercially available technologies were in many ways much more concerned with user input than those produced locally in the community. This might be due to the overall approach in supply and demand marketing, which has a specific focus on the needs of consumers.

Recommendations:

• There are no recommendations made for this section.

Education, Training, and Awareness

Conclusions:

- There were no problems encountered in applying these questions in the field.
- Most organizations continue to spread awareness and education about the technologies even after implementation. These efforts are often combined with education about sanitation and hygiene.
- Organizations also continue to train staff members to varying extents.

Recommendations:

• There are no recommendations made for this section.

Social Acceptance

Conclusions:

- There were no problems encountered in applying these questions in the field.
- Organizations in Kenya typically cite the Ministry of Water and The Ministry of Health as being integral to "political considerations" in the implementation of technologies in the field.

Recommendations:

 The section poses very general questions which led to lengthy explanations in some instances. Some thought might be given to making these questions more specific.

6.1.2.3.6 Target: Costs

Conclusions:

- This section was somewhat difficult to apply in the field, first and foremost because organizations were typically not aware of costs incurred by households during the actual operation of the system. This information was cited as being too comprehensive and exhaustive in nature, sometimes being beyond the knowledge of interviewees.
- Unless organizations were at the location where records were kept, it was very hard to come up with the specific numbers being asked for.
- This section of the survey was the most tedious to apply. However, it must be noted that this section of the survey was obtained from the "Cost Assessment for Selected Household Water Treatment Interventions" (Clasen and Haller, 2004), which is intended to be provided to a respondent to be answered at their own leisure. In other words, it was not intended that the information be obtained during an interview.
- All organizations considered cost as a target to varying extents.

Recommendations:

- For household costs, questions might be better suited for interviews on a household level.
- A more effective approach regarding program costs might be to ask for financial data in the form of documents from the organization, and, upon review of the data, follow-up with the organization if there are any additional questions.

Marketing and Distribution

Conclusions:

- There were no problems encountered in applying these questions in the field.
- Most organizations promote technologies through social marketing utilizing local residents and known members of the community as the primary medium by which awareness of technologies is spread.
- Technologies that are available commercially subsequently utilize mass marketing approaches in promotion and distribution of technologies.

Recommendations:

• There are no recommendations made for this section.

6.1.2.4 Other Sections

6.1.2.4.1 Other Types of Approaches and Questions

The section was not applied in the field.

6.1.2.4.2 Final Thoughts

Conclusions:

• There were no problems encountered in applying these questions in the field.

Recommendations:

• The scaling questions can be excluded if time is a constraint. This section in its entirety is merely meant to provide an opportunity to tie up loose ends and allow for a more informal exchange between the interviewer and the organization being interviewed.

6.1.2.4.3 Publications

Conclusions:

• There were no problems encountered in applying these questions in the field.

Recommendations:

• There are no recommendations made for this section.

6.2 HWTS Technology Selection Tool

The HWTS technology selection tool is meant to aid stakeholders in the choice of the most appropriate HWTS technology, or combination of technologies for a given potential implementation area. In this context, all of the data collected in Kenya using the HWTS organization implementation survey have aided in the creation of the selection tool. The six HWTS technologies considered by the selection tool are ones currently available in Kenya. They are:

- 1. Household chlorination (Waterguard®)
- 2. Solar Disinfection (SODIS)
- 3. Boiling
- 4. Ceramic Candle Filtration
- 5. Concrete BioSand Filtration
- 6. Combined Flocculation/Disinfection (PuR®)

It should be noted that these are technologies which solely address microbial contamination of drinking water. Contamination by other chemicals such as fluoride or arsenic is not considered even though HWTS technologies for removal of chemical contaminants were also observed in Kenya. Additionally, these are water treatment technologies and not technologies addressing the issues of safe storage.

The selection tool is intended to have a wide range of applications. Local communities may use the tool to determine the appropriate type of technology for their particular situation. Implementing organizations operating on a national (government and non-government) or international level may also use the tool to determine if a particular technology is suitable for implementation in a particular target area. The technology selection tool is designed to prompt users (such as communities or implementation organizations) for information pertaining to certain parameters. As parameters are filled-out in the document, relevant scores will be recorded and tallied in order to calculate a score for each of the HWTS technologies considered. These scores will be an effective ranking of each technology in regards to applicability to the target area in question. The parameters considered are divided into two main categories: site-specific parameters and technology-specific parameters.

The selection tool presented in this thesis is considered to be a prototype and is intended to serve as a basis for further versions, which will incorporate more detailed or more refined information into the scoring system presented. The selection tool is designed to be transparent in providing assumptions utilized and straightforward in its design so as to be easily modified for specific conditions. The selection tool is presented in Appendix E.

6.2.1 Results and Conclusions

The tool is presented in two formats: paper and electronic (Appendix E). The paper format of the selection tool is a document meant to be used in the field or in areas where computer facilities are not readily available. The paper format will take the form of an 18-page checklist or questionnaire that may be filled out by hand. The electronic format of the selection tool is provided in the form of an MS Excel spreadsheet intended for use by organizations with access to the software. The spreadsheet is also in the form of a questionnaire essentially identical to that utilized for the paper format of the tool.

For trial purposes, the tool was applied to three areas in Kenya in which HWTS technologies were being implemented by organizations visited by the MIT team. Information collected from these organizations was entered into the tool and the results were compared to actual implementation of the HWTS technologies. These applications serve as a demonstration of how the tool may be applied. The three organizations selected to demonstrate the application of the selection tool are:

- 1. PSI Mombasa Implementing household chlorination (Waterguard®) in the Kwale District, Coast Province.
- 2. KWAHO Implementing SODIS in Kibera, Nairobi Area.
- 3. Bushproof / MEDAIR Implementing concrete BioSand filtration in the Machakos District, Eastern Province.

The electronic version of the selection tool was applied to these three areas. A summary of the results is presented in Table 6.3 while complete versions of these applications have been included in Appendix E.

	PSI Mombasa	KWAHO	Bushproof
	(Kwale District)	(Kibera)	(Machakos District)
Household Chlorination	675	775	580
SODIS	785	945	720
Boiling	665	730	600
Ceramic Candle Filtration	630	730	515
Concrete BioSand Filtration	660	870	730
Combined Flocculation/Disinfection	670	790	625

The above results are somewhat tempered by the fact that a portion of the information required to apply the selection tool was not accessible. In these instances, a best effort was made to input the most likely information expected for these areas. That being said, the application of the selection tool to these areas did serve as an adequate demonstration for which the following conclusions were drawn:

- The selection tool generated results comparable to actual implementation of HWTS technologies in the field. The results indicate that KWAHO and Bushproof are both implementing the most applicable technologies (SODIS and concrete BioSand Filtration) for their respective target areas. Both organizations are considered to have successful implementation programs. The results for PSI Mombasa indicate that household chlorination is not the most applicable technology for the target area considered. This is still consistent with implementation in the field as the organization did express dissatisfaction with the sales of Waterguard® in this rural area.
- SODIS garners high scores for all of the cases considered. This is attributed to the fact that the technology is the cheapest of all those considered by the tool. SODIS also managed to garner a high score despite receiving a low score for the parameter considering resource availability i.e. the availability of plastic bottles. This led the author to question whether a sufficient weight was given to this parameter as currently resource availability only accounts for less than four percent of the total score calculated for the technology. This will be considered in future iterations of the selection tool. Furthermore, SODIS still received a relatively high score for the Machakos District, which was the only area considered to have highly turbid water. As SODIS is dependent on turbidity, such a high score was not expected. This will likewise be evaluated in further iterations of the tool.
- The results generated are sensitive to cost. Cost of the technologies was considered in assigning scores for the "economic considerations" parameters of family wealth information, willingness-to-pay, and available funding.
- The results generated indicate that commercially available technologies are more applicable to urban areas as household chlorination, ceramic candle filtration, and combined flocculation/disinfection all garnered their highest individual scores for Kibera (KWAHO), which is the only urban area considered.
- A measure of the sensitivity of results to the parameters related to raw water source was not determined as two of the areas considered (Kwale and Kibera) were both considered to have relatively safe water received from piped distribution systems. Machakos was considered as an area predominantly utilizing surface water sources such as dams and rivers. It was noticeable that two of the three technologies considered to be most affected by raw water turbidity (household chlorination and ceramic candle filtration) garnered the two lowest scores for this area. As mentioned previously, SODIS managed to garner a high score despite the turbidity of raw water in this area.

The tool was administered effectively with each application taking about 30 minutes to complete. It must be reiterated that the application of the selection tool to these three areas is by no way conclusive in terms of the results obtained. The application was carried out merely for demonstrative purposes and is not meant as a critique of the organizations implementing technologies in these areas. Furthermore, the selection tool is still in its first iteration and it is fully expected that improvements will be made in terms of content, clarity, and ease of use.

6.2.2 Recommendations

The technology selection tool developed in this chapter is not intended to be complete in terms of being suitable for direct application in the field. Instead, the tool is developed to present a framework that welcomes and encourages further revision and iteration. The tool in its present state may be considered as a "test model". The selection tool is presented as a proposed method of determining the applicability of certain HWTS technologies to specific target areas; the underlying rationale behind the creation of the tool originates solely from the author's own ideas and observations during the site visit to Kenya in January of 2005. The tool is not meant to critique methodologies or HWTS technologies currently being implemented. It is intended that the tool may act as a springboard for the consideration, discussion, and identification of parameters that need to be evaluated prior to the implementation of HWTS programs.

For the purposes of this thesis, both the paper and electronic form of the tool are presented in as simple a format as possible in order to make transparent the calculations used for determining the applicability of the HWTS technologies; it is intended in the future that these formats be modified even further and supplemented with descriptive information such as pictures and typical examples regarding the parameters to be entered.

Recommendations for further development of the selection tool are presented as follows:

- Refinement of the selection tool through detailed review and evaluation by organizations with experience in HWTS technology implementation.
- Improvement of the tool through trial application to HWTS implementation organizations in other developing nations.
- Streamlining of the selection tool for more efficient application in the field.
- Further modification of formats through supplemental descriptive information such as pictures and typical examples regarding the parameters to be entered.
- Standardization and acceptance of the selection tool for global use and applicability.
- Modification of the selection tool to suit other programs, and not just those dealing specifically with HWTS technologies.

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APPENDIX A – ADDITIONAL DATA ON HWTS TECHNOLOGIES

Several sections adapted directly from "Household Water Treatment and Safe Storage in Kenya" by Susan Murcott and Isaac Kilonzo (Murcott and Kilonzo, 2005). Please see this document for a full list of references.

A brief introduction to HWTS technologies and the role of these technologies in the provision of safe water in developing countries was provided in Chapter 1. This appendix focuses on HWTS technologies in more detail. Only the technologies researched in the site visit to Kenya are included here as these are the primary technologies of interest and hence those considered in the selection tool developed in Chapter 5. These technologies are household chlorination (Section A.1), solar disinfection (Section A.2), boiling (Section A.3), ceramic candle filtration (Section A.4), BioSand filtration (Section A.5), combined flocculation/disinfection (Section A.6), defluoridation with bone char (Section A.7), and the modified clay pot (Section A.8).

A.1 Household Chlorination (Waterguard®)

A.1.1 Technology Description

Beginning in the early 1990s, the Centers for Disease Control and Prevention (CDC) and the U.S Pan American Health Organization (PAHO) developed the "Safe Water System" (SWS). The SWS consists of three parts: 1) household disinfection of drinking water supplies using a low concentration sodium hypochlorite solution; 2) safe water storage; and; 3) behavior change via water, sanitation, and hygiene education (CDC, 2005). Of concern in this thesis is the first component of the system, referred to throughout the document as "household chlorination".

Household chlorination is one of the HWTS technologies that has been adapted from treatment typically utilized for large-scale community-wide systems. Disinfection of drinking water or wastewater refers to the destruction of disease-causing organisms. Disinfection does not necessary result in the complete sterilization of a water supply but rather in the destruction of bacteria, viruses, and amoebic cysts, the principal organisms responsible for waterborne disease (Sullivan, 2002). Disinfectants, such as chlorine, destroy these organisms by several means, including damage to cell walls, alteration of the cell membrane, destroying selective permeability, alteration of the colloidal nature of the protoplasm, causing protein denature, and the inhibition of enzyme activity (Metcalf & Eddy, 1991).

Chlorination for large scale systems may include "primary disinfection" which addresses the initial elimination of water-borne-pathogens and "secondary disinfection" which is required to prevent the recontamination of waters. If previously treated waters are allowed to sit for extended periods of time, chlorine residual often dissipates, allowing the water to once again be susceptible to contamination by micro-organisms. In a household setting this may occur if households are too small to consume the dosed amount of treated water in adequate time, requiring the retreatment of drinking water after 24 hours in order to ensure water safety.

Chlorine dose efficacy is typically measured in terms of concentration and contact time. In general, the longer the contact time up to a certain maximum the greater the level of disinfection. Similarly, the higher the concentration of chlorine available for disinfection, the greater the level of disinfection up to a certain maximum. Other factors can affect the efficiency of chlorine disinfection, such as pH, temperature, and turbidity of the raw water.

Population Services International (PSI) markets the branded household chlorine product Waterguard® in Kenya. The organization works closely with the CDC.



Photo A.1 – Waterguard® Bottle

A.1.2 Cost in Kenya

The following costs were obtained from the report "Household Water Treatment and Safe Storage in Kenya" (Murcott and Kilonzo, 2005).

- Annual Operation and Maintenance Costs: KSh 270 (US\$3.60)
- Replacement Period: Every 2 months a new bottle is purchased.

A.1.3 Advantages and Disadvantages

The following advantages and disadvantages were obtained from the report "Household Water Treatment and Safe Storage in Kenya" (Murcott and Kilonzo, 2005).

Advantages

- Extensive studies have demonstrated improved health outcomes among regular users of household chlorination;
- Disinfects water, rendering it safe from many microbial contaminants;
- Simple and relatively inexpensive;
- A marketable product that can create jobs while serving the community;
- Leaves a chlorine residual that can be monitored by simple methods to ascertain proper dosage and protects against recontamination.

Disadvantages

- Educational messages are important to ensure correct dosing;
- The product has a relatively short shelf-life of 12-18 months, which can be too short if the distribution chain is disturbed;
- Some users dislike the taste and smell of chlorinated water;
- Perceptions of danger from "chemicals" prevent some users from using the product;
- Although Waterguard® reduces diarrheal disease incidence in users with
 extremely turbid water, it does not remove any of the particles in the water or
 improve the color of the water. This is not ideal, and with highly turbid water, the
 SWS program recommends a filtration step before treating the water with chlorine
 to inactivate the bacteria.

A.2 Solar Disinfection (SODIS)

A.2.1 Technology Description

Solar Disinfection (SODIS) uses 1-2 liter PET (Polyethylene Terephthalate) plastic bottles and energy from the sun to disinfect water. The bottles are filled with water, shaken to induce aeration with oxygen, and left in the sun for one to two days prior to use depending on latitude, cloud cover, and a number of other factors. Microbially contaminated water is disinfected by ultraviolet (UV) light and by thermal disinfection as a result of this process. Studies show that various bacteria of serious concern in different populations are reduced extensively when exposed to solar radiation (Sobsey, 2002).



Photo A.2 – SODIS bottle in Mathuru, Kenya

The technology was pioneered in the late 1970s by Acra *et al.* at the American University of Beirut, Lebanon, who sought to find an inexpensive disinfection method for oral rehydration solutions (Acra *et al.*, 1984). SANDEC/EAWAG (Swiss Federal Institute for Environmental Science and Technology) started to investigate the SODIS process in 1991. Their findings were encouraging and field-tests where launched to include several countries: Columbia, Bolivia, Burkina Faso, Togo, Indonesia, Thailand, and China (EAWAG/SANDEC, 1998). The most compelling aspects of this technology are the low investment costs of plastic bottles and the disinfection energy that is provided free of charge by the sun. (Flores, 2003)

The organizations implementing the technology in Kenya are the Kenya Water for Health Organization (KWAHO) and the Anglican Church of Kenya (ACK).

A.2.2 Advantages and Disadvantages

Turbidity is a critical variable with regard to the efficiency of solar radiation for inactivation of microorganisms. The presence of suspended solids scatters and impedes penetration of the solar radiation that enters in the water, thus reducing the inactivation effect of solar disinfection (Flores, 2003). Many researches who have performed solar disinfection studies have agreed that solar disinfection should only be used for water with turbidity below 30 NTU (Sobsey, 2002).

The following advantages and disadvantages were obtained from the report "Household Water Treatment and Safe Storage in Kenya" (Murcott and Kilonzo, 2005).

Advantages

- Inactivates or destroys pathogenic organisms;
- Uses PET plastic bottles which are easy to handle, transport, and store and usually readily available;
- Very low cost;
- Very simple;
- Does not require chemical addition, or change water taste and smell;
- The water is often protected from post-treatment recontamination because users drink directly from the bottles;
- Water is "served" directly from PET plastic bottles, which is associated with much higher-priced bottled water.

Disadvantages

- Does not improve the chemical water quality;
- One cannot visually see the effect of treatment;
- Some people prefer cooler water in tropical areas (however, the SODIS water could be stored after treatment in safe storage containers);
- Requires favorable climate conditions: 5 hours of radiation above 500 W/m2;
- Should not be applied to raw water of turbidity greater than 30 NTU unless applied in conjunction with a method of particle removal;
- Offers limited production capacity.

A.3 Boiling

A.3.1 Technology Description

Boiling or heating of water with fuel has been used to disinfect household water since ancient times. It is effective in destroying all classes of waterborne pathogens and can be effectively applied to all waters, including those high in turbidity or dissolved constituents. Although some authorities recommend that water be brought to a rolling boil for one to five minutes, the WHO Guidelines for Drinking Water Quality recommend bringing the water to a rolling boil as an indication that a high temperature has been achieved (WHO, 2004). These boiling requirements are likely to be well in excess of the heating conditions needed to dramatically reduce most waterborne pathogens, but observing a rolling boil assures that sufficiently high temperatures have been reached to achieve pathogen destruction. Although boiling is the preferred thermal treatment for contaminated water, heating to pasteurization temperatures (generally 60 degrees Celsius) for periods of minutes to tens of minutes will destroy most waterborne pathogens of concern. However, unless temperature monitoring is possible, caution is recommended in attempting to pasteurize waters at non-boiling temperatures. (Adapted from Murcott and Kilonzo, 2005)

The boiling approach is already commonly used throughout developing nations of the world and may be considered the most basic form of water treatment. Implementation of the technology is performed through simple awareness creation. In Kenya, the Ministries of Health and Water are the primary organizations disseminating knowledge about boiling as an effective method of water treatment.

A.3.2 Advantages and Disadvantages

The following advantages and disadvantages were obtained from the report "Household Water Treatment and Safe Storage in Kenya" (Murcott and Kilonzo, 2005).

Advantages

- Highly effective at destroying microorganisms;
- Simple and well-known, boiling can be readily incorporated into daily cooking routines;
- Only requires a pot and fuel source.

Disadvantages

- Typically uses wood for fuel, which is often limited in supply and exacerbates deforestation;
- Leaves no residual protection, and water can become recontaminated in storage;
- If fossil fuels are used, they are expensive and non-renewable;
- Leaves a flat, unpalatable taste to some users.

A.4 Ceramic Candle Filtration

A.4.1 Technology Description

A number of ceramic filters are currently available in a wide range of shapes, sizes, and applications. Among the most popular of these are the candle and pot filters. What makes these filters "ceramic" is the material from which these are composed, namely clay, and the process by which these are made, namely through molding and firing. The filters are constructed from a mixture of clay, water, sand, and combustible material such as sawdust or rice husk. The mixture is formed into the desired shape (candle, pot, disk, etc.) and subsequently fired at high temperatures (about 900 degrees Celsius) for a prolonged period of time. During the firing process, combustible materials in the mixture are removed, leaving pores in the filter media. These pores serve to obstruct the flow of micro-organisms as raw water is passed through the filter.

These filters can have secondary objectives such as odor removal and taste improvement of the filtered water. Materials such as activated carbon or silver nitrate are sometimes added to the mixture to provide additional treatment and possibly some disinfection.

There are a variety of filters commercially available on international and local levels. The primary countries currently manufacturing these ceramic candle filter technologies are the United Kingdom, India, China, and Brazil. Ceramic candle filter elements are typically part of a system comprised of two containers, one on top of the other with the candle filter being located in the upper vessel. Raw water is poured into the top container, flowing through the filter element, and collected as treated water in the bottom vessel. Vessels can be made of steel, plastic, or clay and are oftentimes fitted with spigots to avoid recontamination.





Photo A.3 – Kisii Ceramic Candle Water Filter (left) and British Doulton Filter (right) (Source: http://www.kentainers.com/kentainers/waterfilters.html)

The organization implementing the ceramic candle filter technology in Kenya, and interviewed by the project team, is the Network for Water and Sanitation (NETWAS). It should also be mentioned that a large number of different brands of these filters are commercially available in Nairobi, therefore it is also fair to say that the technology is being implemented by some businesses in the country that were not included in the research conducted for this thesis.

Research on these ceramic candle filters was conducted in Kenya by Amber Franz, a fellow MIT Master of Engineering student and Kenya team member. During the time spent in Kenya, Franz performed testing of several locally available brands of ceramic water filters. Franz examined flow rate, turbidity removal, and bacterial removal for each of the filters while in Kenya. The following table presents some results of the research conducted (Franz, 2005):

Table A.1: Summary of Data Obtained for Each Brand of Filter Tested

	Turbidity Removal (%)		Flow Rate (L/hr)		Total Coliform Removal (%)		E. coli Removal (%)		
Filter	Kenya	MIT	Kenya	MIT	Kenya	MIT	Kenya	MIT	Cost (\$)
AquaMaster	98.3	88.6	0.093	0.160	99.835	99.6	99.995	99.95	10.00
Doulton	98.3	92	0.235	0.546	99.831	99.0	99.993	99.7	40.00
Stefani	98.8	93.1	0.101	0.241	99.694	97.5	99.967	97.6	2.25
Pelikan	98.3	97.3	0.182	0.203	99.982	99.6	99.985	99.9	2.00
Pozzani	97.1	89.9	0.101	0.180	99.653	95.6	99.769	93	20.00

Adapted from: Franz, 2005

A.4.2 Maintenance

The ceramic filter candle must be boiled for 15 to 20 minutes prior to the assembly for sterilization and also to remove any fine clay particles from the ceramic candle. The individual users must keep the ceramic filter candles clean by regularly brushing the surface gently under clean flowing water. When the rate of filtration slows, the filter must once again be sterilized by boiling it. The filter should be replaced after 8 to 12 months of continuous use, depending on the amount of use and the turbidity of the feed water (Sagara, 1999).

A.4.3 Costs in Kenya

The following costs were obtained from the report "Household Water Treatment and Safe Storage in Kenya" by Susan Murcott and Isaac Kilonzo (Murcott and Kilonzo, 2005).

- Capital Costs: KSh 2,325 (US\$31)
- Annual Operation and Maintenance Cost: KSh 520 (US\$7)

Assumptions:

- Capital costs are derived for the entire filter system, including two small buckets and a spigot.
- Annual operation and maintenance costs are derived assuming filter replacement every six months at KSh 260 (US\$3.5) per filter.

A.4.4 Advantages and Disadvantages

Flow rate is the main problem encountered with ceramic candle filters. Filters are easily clogged by turbid waters and is reported that waters with greater than 15 NTU turbidity block filters rapidly enough for these to be considered less effective than alternative technologies (Koestler, 2002). A high level of maintenance is required when filters experience frequent clogging.

The following advantages and disadvantages were obtained from the report "Household Water Treatment and Safe Storage in Kenya" (Murcott and Kilonzo, 2005).

Advantages

- Studies have demonstrated improved health outcomes among regular users of high-tech ceramic candle filters combined with safe storage (Clasen et al, 2004);
- Relatively simple to use;
- A marketable product that can create jobs while serving the community;
- Can remove turbidity and a certain level of bacterial contamination, depending on quality of the ceramic candle;
- Works best when treating groundwater and piped supplies;
- Visually, one can see the water become cleaner on account of the treatment. This can be convincing to users of the efficacy of the product.

Disadvantages

- Flow rates can be extremely slow with ceramic candles, especially clogging readily and requiring frequent cleanings, especially if the water supply is turbid. This can mean that a single ceramic candle filter unit does not provide sufficient safe water for an average-sized family;
- Candles are fragile and can break during transport, cleaning and use;
- Recontamination is possible if water is not stored safely after filtration.
- Potential growth of biofilms inside candle filter elements.

A.5 BioSand Filtration

A.5.1 Technology Description

Dr. David Manz of the University of Calgary, Alberta, driven by the desire to help the developing world find a better way to purify drinking water, developed a simple, cheap and effective filtration system based on the concept of slow sand filtration (Legge, 1996). The result of these investigations was the BioSand Filter, an intermittently operated slow sand filter specifically designed for use by poor people in developing countries. The filter operates by gravity; being open to the atmosphere at both ends, the water flow is determined by the elevation differences at the influent and effluent ends of the filter. Particle removal occurs both at some depth and at the surface of the filter media (Pincus, 2003).

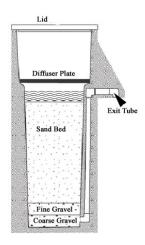


Figure A.1 – Schematic of BioSand Filter

The actual filter bed consists of medium sand above a layer of coarse sand which in turn lies above a layer of gravel in which the lower portion of the effluent pipe is located (Figure 2.1). The BioSand filter contains a lid on top and a diffuser plate which is typically a sheet of wood, plastic, tin, or concrete with holes drilled in a grid pattern. The diffuser plate spreads water evenly over the surface of the sand, minimizing disturbance of the *schmutzdecke*. The filter media is typically enclosed in either a plastic or concrete casing.

Microbial contamination is partially removed on account of the *schmutzdecke*, a thin biological layer at the water/sand interface that is thought to eliminate pathogens in the influent water. Subsequently, a design parameter for the systems is a five centimeter layer of standing water, above the top layer of sand, which allows adequate oxygen diffusion to the biological layer during periods in which the filter is not being used. Other assumed removal mechanisms are bacteviory (death of influent bacteria), adsorption, and mechanical straining. (Pincus, 2003)

The filter has achieved wide-scale implementation. Various church groups and NGOs, including Samaritan's Purse and the Center for Water and Sanitation Technology (CAWST), have installed more than 57,500 BioSand filters in more than 28 countries worldwide, including Haiti, the Dominican Republic, Nepal, Nicaragua, Mozambique, and Kenya (CAWST, 2005). The organizations implementing the technology in Kenya are the NGO "BushProof", together with Samaritan's Purse and MedAir.



Photo A.4 – BioSand Filter in Machakos, Kenya (2005)

A.5.2 Maintenance

Water should be poured into the filter's head space slowly with the diffuser plate in place, and separate buckets should be used for pouring source water into the filter and collecting filtered water. The collection vessel should ideally be a safe storage container such as those indicated in Figure A.2.

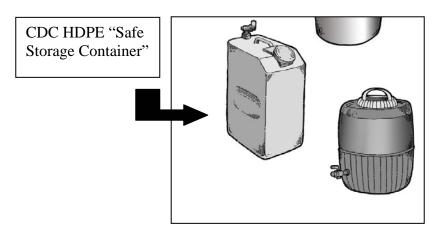


Figure A.2 Typical Safe Storage Containers

Other aspects of operation and maintenance of the BioSand filter include the fact that the lid should be kept on the filter during use. Adults should tell children to keep their fingers away from the outflow pipe and/or collection bucket, and animals should be kept away from the filter.

When the BioSand filter's flow rate slows from 1 to close to 0.3 liter/minute, it is necessary to clean the sand (Pincus, 2003). After setting aside enough clean water for two days, the user should remove the diffuser plate from the filter. The user should swirl the water in the head space with one's fingers to resuspend the settled particles until turbidity is visible in the water. The dirty water (but not the sand) should be removed with a cup. All of the turbid water above the sand should be removed in this manner. Next, the diffuser plate should be replaced, more water should be added, the diffuser plate should be removed, and the dirt removal process is repeated until the water above the sand is clear. (Adapted directly from Murcott and Kilonzo, 2005)

A.5.3 Costs in Kenya

The following costs were obtained for the BioSand filter project in Machakos, being implemented by Bushproof, from the report "Household Water Treatment and Safe Storage in Kenya" (Murcott and Kilonzo, 2005).

- Capital Costs: KSh 800 (US\$10.7)
- Annual Operation and Maintenance Cost: KSh 9 (US\$0.10)

Assumptions:

- Only replacement part is the diffuser plate, which needs replacement approximately every two years
- It should be mentioned that no profit margin is incorporated into these costs and that various subsidies such as those for worker's labor are assumed in the costs as well.

A.5.4 Advantages and Disadvantages

The following advantages and disadvantages were obtained from the report "Household Water Treatment and Safe Storage in Kenya" (Murcott and Kilonzo, 2005).

Advantages

- Constructed from locally available materials, including sand, gravel;
- Concrete filters are extremely durable and can last indefinitely;
- Few replacement parts. In Machakos District, only the diffuser breaks approximately every two years, and costs Ksh 18 to replace;
- No chemicals need to be added to the filter, which saves money and does not result in possible negative health effects;
- Removes bacteria, parasites and certain toxins;
- Simple to operate and maintain;
- High flow rate of the filter, considerably higher than most other household filters;
- Visually, one can see the water become cleaner on account of the treatment. This can be convincing to users of the efficacy of the product;
- A marketable product that can create jobs while serving the community.

Disadvantages

- There is a lag time after start up and after disturbance or removal of the sand during cleaning before the filter attains its good level of bacterial removal (about 90%):
- The filter must be used on a regular basis to maintain removal efficiency;
- The filter cannot remove viruses, color or dissolved compounds;
- The BSF has yet not been proven to reduce diarrheal diseases, but these studies are underway;
- There is no residual protection with the BSF and safe storage is necessary after filtration to prevent recontamination;
- The filter cannot be easily moved once it is put in place because it is extremely heavy. Moreover, moving the filter may disrupt the carefully leveled sand and gravel beds.

A.6 Combined Flocculation/Disinfection

A.6.1 Technology Description

Combined flocculation and disinfection pertains to a two-pronged approach to water treatment in which large suspended particles are first coagulated and settled out prior to the elimination or inactivation of water-borne pathogens. Flocculation is the process by which particles agglomerate into larger particles, this is achieved by the addition of a chemical coagulant which causes adsorbtion of particles to one another creating "flocs" which progressively gain enough mass to settle down to the bottom of the water storage vessel. Disinfection is then achieved through the same process discussed in the section pertaining to household chlorination.

On the household level this process has been researched and marketed by Procter and Gamble (P&G), which has developed a sachet registered under the brand name PuR®, comprised principally of ferrous sulfate as the chemical coagulant and calcium hypochlorite as the household chlorination product. PuR® was developed as part of a collaborative effort between P&G and the Centers for Disease Control and Prevention.

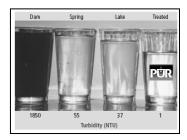


Photo A.5 – Procter and Gamble's PuR

The product uses the same ingredients as applied in municipal water systems; but it is reverse engineered to effectively be a mini water treatment plant in a sachet. The product's efficacy is easily demonstrated through visible signals that water is cleaner; it also performs much better than simple chlorination in applications to turbid water. PuR® is also capable of reducing metals (e.g. arsenic, lead), pesticide contaminants (e.g. DDT) and other organic chemicals (P&G, 2005).

A single sachet of PuR® purifies 10 liters of drinking water. The sachet is cut open and the contents are poured into a bucket filled with 10 liters of water. Jerry cans are not appropriate, as water cannot be stirred properly. The contents are manually mixed rapidly with a large, clean spoon, then allowed to precipitate and settle for five minutes. Next, the 10 liters of water are decanted by pouring into a second safe storage container which has been covered by a piece of cloth or clean cotton material. After 20 minutes, the water is safe to drink. The sludge that has collected in the bottom of the first bucket can be discarded into a latrine.

PuR® is marketed in Kenya, Uganda, Haiti, Pakistan, Philippines, Guatemala and Morocco. In Nyanza Province, PuR® has been introduced by the Society for Women and Aids in Kenya (SWAK).

A.6.2 Costs in Kenya

SWAK initially sold donated sachets, manufactured in the UK, left over from clinical trials in Central America. SWAK sold these initially at KSh 2.7 (US\$0.036; now at KSh 5 or US\$0.067). In 2005, SWAK is planning to buy PuR® from the NGO, Population Services International (PSI) - Uganda, and resell the product for KSh 8 (US\$0.11) per sachet. PSI-Kenya may sell at a different price from SWAK once it introduces the product into their markets (Chasse et al, 2005).

A.6.3 Advantages and Disadvantages

The biggest challenges to this product are cost and behavioral change. Currently, the product is the most expensive (in terms of annual operation and maintenance costs) of all the technologies available in Kenya. This poses a challenge to the implementation of the product in impoverished communities. Behavioral change is also a recognized problem in terms of user acceptance and the requirement that current water treatment practices (boiling) need to be changed. However, this problem of behavioral change is not unique to this HWTS treatment method and may be said to be applicable, to varying extents, for all of the HWTS presented thus far.

The following advantages and disadvantages were obtained from the report "Household Water Treatment and Safe Storage in Kenya" (Murcott and Kilonzo, 2005).

Advantages

- About equal health protection as chlorine disinfection alone;
- Locally available in Kenya through the distribution network;
- Expensive;
- Can remove turbidity, precipitate metals and removes some organic chemicals as well as disinfect the water.
- Visually, one can see the water become clearer on account of the treatment. This can be convincing to users of the efficacy of the product.

Disadvantages

- Comparatively expensive;
- Requires behavior change in usual water handling practices;
- Requires well-established distribution channels
- Some users find the process of stirring, pouring and waiting tedious.

A.7 Defluoridation with Bone Char

A.7.1 Technology Description

Bone char filtration technology is different from the rest of the technologies presented in this document due to the fact that it addresses chemical (i.e. fluoride) contamination rather than microbial contamination of raw water. Fluoride is a naturally occurring contaminant which can cause dental and skeletal fluorosis upon consumption. Both diseases can be life-long afflictions.

Bone char has been determined to be a medium capable of absorbing high amounts of fluoride. In order to produce this absorbent medium, animal bones are fired at high temperatures, removing organics, and then crushed to produce the said "bone char". In the site visit to Kenya, the Catholic Diocese of Nakuru had done extensive research on the bone char process. After crushing, the bone char is sieved to select sizes, processed further, and then installed in tall cylindrical water storage tanks through which raw water passes. These vessels may range in size from community-scale to household-scale applications. A bone char filter is simple to operate and has high efficiency.

The following sections detail the different available sizes of these filters, using information directly received from the Catholic Diocese of Nakuru (Murcott and Kilonzo, 2005) for the report entitled "Household Water Treatment and Safe Storage in Kenya".



Photo A.6 – Bone char filter media)



Photo A.7 – Community-scale defluoridation filter)

A.7.1.1 Household Scale

Depending on the design, the household bone char defluoridation systems are comprised of one or two 20 liter buckets and can filter 10-40 liters per day. This household filter is designed to supply a household (5 to 12 people) with fluoride free water for drinking and cooking. The filters are robust and inexpensive, but they do not utilize the filter material as efficiently as the community scale filters because the filter material cannot be easily regenerated, but must be changed completely after saturation. The household filters are made in two sizes. The small type contains 12 liters of absorption media and the bigger one contains 24 liters of absorption media. The bone char media reduces fluoride concentration from an initial concentration of 5-15 mg/l to less than 1.5 mg/l. Changing the media to new media in a household bone char filter requires no technical skill.

A.7.1.2 Institutional Scale

The institutional scale systems are designed for institutions or larger kitchens where filters can be connected to the normal piped networks. These filters are constructed using standard PVC tanks of 650 liters. The cost is currently KSh 39,000 (US\$ 520), not including installation. No regular maintenance is required; the daily operation does not differ from operating a standard water storage tank. Depending on the concentration of fluoride in the raw water and the filter size, the filter material needs regeneration or changing at regular intervals, typically once every ½ to 3 years.

A.7.1.3 Community Scale

These community scale bone char defluoridation systems supply 1,000 to 5,000 or more people. They are suitable where users collect their water at a central water point. The community plant is basically a 4 or 12 cubic meter ferro-cement tank filled with filter material and equipped with screen and connections for regenerating the filter. The structure is quite solid and suitable for public places. The sizes range from 2,500, 5,000 or 10,000 liters of absorption media. The appropriate choice depends on the rate of consumption and the fluoride concentration in the water.

A.7.2 Maintenance

The filters are typically not maintenance-intensive. The primary maintenance required is the regeneration of the bone char which is typically performed by complete replacement of media in the household filters or through media regeneration by the addition of caustic soda and acid (sulphuric acid) to the media in larger scale filters. Caustic soda and acid are added to raise pH in a process similar to the regeneration of activated alumina.

A.7.3 Costs in Kenya

The following costs were obtained from the report "Household Water Treatment and Safe Storage in Kenya" (Murcott and Kilonzo, 2005).

- Capital Costs: Household Filter (small) = KSh 1,200 (US\$ 16); Household Filter (large) = KSh 1,800 (US\$ 24); Institutional filter (w/installation) = KSh 39,000 (US\$ 520); Community filters = KSh 280,000 (US\$ 3,730), Ksh 420,000 (US\$ 5,600) and 680,000 (US\$ 9,070) for 3 sizes
- Annual Operation and Maintenance Costs: Household Filter = KSh 90 (US\$ 1.2) per liter of filter material; Community filters = Annual costs < 1 KSh (US\$ 1) per 20 liters of water treated.

Assumptions (Replacement Period):

- Household Filters = 6 months, depending on consumption and fluoride concentration.
- Institutional Filters = 6 months to 3 years, depending on consumption and fluoride concentration.
- Community Filters = 3 to 2 years, depending on consumption and fluoride concentration.

A.7.4 Advantages and Disadvantages

The following advantages and disadvantages were obtained from the report "Household Water Treatment and Safe Storage in Kenya" (Murcott and Kilonzo, 2005).

Advantages

- All materials are locally available. Except for the bones, all chemicals and spare parts can be purchased in local hardware stores in Kenya;
- The required maintenance is extremely minimal. There is no addition of chemicals, no cleaning is needed;
- High efficiency, regardless of the fluoride in the raw water, practically all fluoride is removed;
- Low cost;
- No hazardous chemicals used;
- No health risks involved;
- The Catholic Diocese of Nakuru Programme has simplified a relatively high tech process and is able to produce and sell bone char media at 20% of the price of the European manufacturers.

Disadvantages

- Very little experience using bone char in rural settings
- Regeneration of bone char requires caustic soda and acid and must be done by technically trained people, not by local communities.
- Regeneration must be carried out regularly, perhaps a few times per year, depending on the size and usage rate of the system.

A.8 The Modified Clay Pot

A.8.1 Technology Description

The modified clay pot is different from the various HWTS technologies presented in that it addresses safe storage and not water treatment. This is not to imply that the technology is any less important in the overall process of household treatment and storage. The aforementioned CDC Safe Water System includes the provision of a safe water storage vessel. This vessel is constructed of plastic and was designed to be easily transportable, from both a bulk transportation and manual transportation standpoint, durable, and restrictive in terms of access by children and human contact. The same philosophy is utilized by the modified clay pot, only this case makes use of locally available resources, such as clay and indigenous ceramic craft traditions instead of plastic molding.

Traditional clay storage pots (Photo A.8) are widely used throughout developing nations. These pots are hand-crafted from clay and fired in kilns. The pots typically possess large openings to provide access to water through the use of a calabash or cup. Users enjoy these containers because of the evaporative cooling effect they have on the stored water. These vessels are effective in storing water but provide limited protection from microbial contamination.



Photo A.8 – Traditional Clay Pot)

These traditional vessels are the basis for the design of the modified clay pot (Photo 2.9), which utilizes similar production processes while improving upon design to include a more narrow opening, lid, spigot, and a wider base to reduce the potential of the vessels tipping over. The vessel also has a space at the bottom, below the spigot, to retain sediment. The form, color, and function of the modified clay pots are essentially identical to the traditional ones.



Photo A.9 - Modified Clay Pots

Whereas a number of countries have elected to use the CDC's HDPE (High Density Polyethylene) plastic safe storage vessel, the preference in Kenya for traditional clay vessels led to the changes discussed above (CARE, 2003). Pottery shops in Nyanza are producing the "modified clay pots" at the Oriang Women's Pottery Group in Homa Bay and at the SWAK-affiliated workshops in Siaya and Asembo. Aside from SWAK, CARE-Kenya is also actively involved in the implementation of this technology.

The modified clay pots typically cost KSh 3000 - 500 (US\$4 - 6.67) depending on size. Each pot is anticipated to last ten years. A 40 liter modified clay pot sells for about KSh 500 (US\$ 6.67).

A.8.2 Advantages and Disadvantages

The following advantages and disadvantages were obtained from the report "Household Water Treatment and Safe Storage in Kenya" (Murcott and Kilonzo, 2005).

Advantages

- Simple and builds on traditional practices.
- Combines nicely with other household practices, such as coagulation, filtration or chlorination in an "integrated" approach that will have beneficial health effects.

Disadvantages

• Modified clay pots or plastic safe storage containers are more expensive in Kenya than traditional clay pots or jerry cans.

APPENDIX B – HWTS IMPLEMENTATION ORGANIZATION SURVEY

The following documents are included in this Appendix:

	Document	Total Pages	Page Numbering in Thesis
1.	HWTS Implementation Organization Survey Version 8 (Long Form)	19	Pages 254 – 272
2.	WHO Network Implementation Working Group Survey (Web-based Collection Tool / Survey Short Form)	4	Pages 274 – 277
3.	HWTS Household Survey Version 3	10	Pages 279 – 288
4.	Sample of completed HWTS Implementation Organization Survey Version 2 as applied to the Kenya Water for Health Organization	19	Pages 290 – 308
5.	Sample of completed HWTS Household Survey Version 3 as applied to a household in Mathuru, Kenya.	10	Pages 310 – 319

DEVELOPMENT OF PROGRAM IMPLEMENTATION, EVALUATION, AND SELECTION TOOLS FOR HWTS SYSTEMS IN DEVELOPING COUNTRIES

HWTS Implementation Organization Survey Version 8 (Long For	m)
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Thesis Pages: 254 - 272

Household Water Treatment and Safe Storage (HWTS) Implementation Program/Product Survey Version 8 – Long Form March 7, 2005

1 General Information

The following section has the purpose of determining basic background information on the organization. Obtain simple answers to these questions as most will be tackled in more detail in later portions of the survey.

Date and Time:
Location:
Name of interviewer:
1.1
Interviewee Name/Position:
Organization:
Address:
Telephone(s):
Fax:
Email:
Website:
1.2 Type of organization: (e.g. Non-Governmental Organization (NGO), Business, Government Agency, Academic Institution, Other?)

- 1.3 Organization's general history and mission statement?

For the following questions (1.4 and 1.5) we need only ask briefly about these topics and explain that the topics will be addressed in more detail at a later section of the survey.

- 1.4 Organization's specific activities with regards to implementation of one or multiple HWTS systems?
- 1.5. How does your organization measure progress towards these specific goal(s)? What specific tools, programs, and methodologies do you employ?
- 1.6 Number of staff members working on HWTS implementation?

2 Implementation Program / Product Description

The following section has the purpose of obtaining information specific to the program or product being implemented. .

- 2.1 HWTS Implementation Program/Product Name:
- 2.2 Brief (1-2 sentences) Description:
- 2.3 Why did your organization select this HWTS technology for implementation (as opposed to other community-wide technologies)?
- 2.4 Who brought this technology to your attention?
- 2.5 Where is the HWTS technology manufactured? Who distributes it?
- 2.6 Where do you obtain technical support for this HWTS technology?
- 2.7 Baseline Conditions:

Describe the current setting in which the program is being undertaken.

I Region or Primary Community	
II Predominant Exposure Scenario existing in the program setting <u>before introduction</u> of the program	Water: 10 d. Not Improved e. Improved
	f. Regulated Sanitation: 11 d. Not Improved e. Improved f. Full Coverage
III Month and Year of commencement of program	Month Year
IV Start-up and Post-Start Up Periods	Start-up began Post-start up (ongoing) period began Program terminated Program ongoing

 $^{^{10}\} Joint\ Monitoring\ Program\ definitions\ (http:/www/wssinfo.org/en/122_definitions_en.html:$

[&]quot;Not improved water" = unprotected well, unprotected spring, vendor provided water, tanker truck water "Improved water" = household connection, public standpipe, borehole, protected dug well, protected spring, rainwater collection

¹¹ Joint Monitoring Program definitions:

[&]quot;Not improved sanitation" = service or bucket latrines (where excreta are manually removed), shared and public latrines, latrines with an open pit

[&]quot;Improved sanitation" = connection to a public sewer, connection to a septic system, pour-flush latrines, simple pit latrine, ventilated improved pit latrine

2.7 HWTS Implementation Program/Product Details:

To date, several types of HWTS systems have had randomized, controlled epidemiological studies performed to provide evidence of their efficacy. These are: solar disinfection (SODIS), household chlorination (the "Safe Water System"), combined flocculation/disinfection (PuR), cloth filtration (for guinea worm eradiation) and certain types of ceramic filtration (ceramic candles manufactured by Berkenfeld or Katadyn). Identify if your organization is using one of these five HWTS approaches or another type of system. Identify HWTS based on the dominant treatment process(es)

process(es)				
II HWTS system(s) described	1. Safe Storage			
by its/their dominant	2. Sedimentation and other pre-treatment approaches			
treatment process(es)	3. Coagulation/Flocculation			
	Examples:			
	* Iron Salts			
	* Alum Salts			
	* Natural polymers			
	4. Particle Filtration			
	Examples:			
	* Cloth			
	* Ceramic water filters (candles, pot, disks)			
	* Sand			
	* Intermittent household slow sand filters			
	5. Absorption			
	Examples:			
	* Granular activated carbon			
	* Activated alumina or other metals			
	6. Membrane Processes (microfiltration, ultrafiltration,			
	electrodialysis, nanofiltraton, reverse osmosis)			
	7. Disinfection			
	Examples			
	* Boiling			
	* Household Chlorination (the "Safe Water System")			
	* Solar Disinfection (SODIS) * Other LIV Disinfection Systems			
	* Other UV Disinfection Systems			
	* Other disinfection methods			
	8. Combined (multiple process) HWTS Systems			
	Examples:			
	* Combined flocculation/disinfection (e.g. PuR)			
	* Rough filter + granular activated carbon filter +			
	chlorine			
	* Ceramic candle + sand + chlorine disinfection			
	9. Other			
	Storage vessel			
	Education to encourage adoption or use of HWTS			
	Hygiene instruction (independent of HWTS)			
	Sanitation intervention			
	Water supply intervention			
	Marketing			
IV Predominant	Other (describe)			
Dissemination Model /	Public (i.e., government or NGO-funded program)			
	Quasi-Commercial (social marketing)			
Method of Implementation	Commercial			

29	Provide a	more detailed	description	of the	HWTS	(ontional)	
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2.10 Extent of current implementation (locations and number of units):

I Number of persons in the program.	persons
II Number of households include in the program.	households
III Average number of persons per household included in the program.	persons per household
IV Maximum coverage assuming no increase in fixed costs and 80% utilization	persons

2.11 What role do other organizations play in the implementation of the program/product? In your opinion, how important is the relationship to other organizations to program success?

~PRE-IMPLEMENTATION CONSIDERATIONS (Sections 3 – 6)~

The following sections have the purpose of obtaining information specific to the manner in which the program/product was implemented.

3 Target Population and Current Water Use Practices and Concerns

3.1 What are the major types of water supply/supplies in your implementation area?

(Indicate answer by checkmarks or percentages)
Piped water supply inside the house (private)	
Piped water supply outside the house (public)	
Borehole well	
* private	
* public	
Dug well	
Spring	
* protected	
* unprotected	
Surface water	
* creek or river	
* lake, pool or pond	
* canal or ditch	
Hole	
Water Vendor (indicate cost if possible)	
* standpipe or watering point	
* truck-delivered water	
Rainwater harvesting	
Other	

- 3.2 Percentage of people in target population lacking "access" where access means greater than 1 km or 30 minutes travel time to obtain water:
- 3.3 Demographics of target population:
 - a. Urban / Rural:
 - b. Literacy Rate:
 - c. Size of Population:
- 3.4 Was a baseline health survey carried out prior to HWTS intervention? If yes, please describe the key results:
- 3.5 Incidence of diarrhea in children under 5 in target population:

If answer to 3.4 was "yes" then neglect the following question (3.6).

- 3.6 Source of data other than baseline survey?
- 3.7 How much does your organization utilize the above information prior to implementation? Do you feel the information is important to program success?

4 Resource Availability

- 4.1 Are resources and raw materials to construct, operate and maintain the HWTS locally available and accessible? Are they utilized in manufacturing the HWTS technology?
- 4.2 Is skilled labor available to locally manufacture HWTS technologies?
- 4.3 How important is the availability of local materials and labor to the success of programs?

5 Education and Training

- 5.1 Are training/education programs a part of the pre-implementation activities?
- 5.2 If yes, please describe the specific training/education program given in pre-implementation:

6 Funding

- 6.1 What is the primary source of funding for the program/product implementation?
- 6.2 To date, how much total funding have you received?
- 6.3 What is the cost to the user of the HWTS you are implementing? How much of the total cost is paid by the user? How much is provided in subsidy (i) by your organization?

 (ii) by another organization?
- 6.4 Is funding primarily for implementation alone or for maintenance and operation as well?
- 6.5 Were any cost-benefit analyses conducted on the target population prior to implementation? If yes, what were the primary results of these analyses?
- 6.6 Were efforts made to determine the target populations wealth information and "willingness to pay" prior to program implementation? If yes, what were the primary results of these efforts?

IMPLEMENTATION SECTION~ (Monitoring and Evaluation; Sections 7– 15)

7 Operational Monitoring

The following section has the purpose of obtaining basic information on the operational monitoring procedures employed by an organization. The standards by which the programs are measured and indicators by which program success is evaluated are addressed in subsequent sections.

- 7.1 Is operational monitoring conducted? (IF NO, MOVE TO QUESTION 7.9)
- 7.2 If yes, please describe briefly:
- 7.3 What is the frequency of operational monitoring?
- 7.4 What is the extent of operational monitoring? (average number of households/total number in given implementation area)
- 7.5 Who conducts operational monitoring?
- 7.6 Who funds operational monitoring?
- 7.7 What is the reporting hierarchy of the operational monitoring?
- 7.8 Are other organizations involved in operational monitoring?
- 7.9 Briefly, what standards are used as a basis for adequate **water quality**? (e.g. WHO guidelines, National Standards, NSF standards, etc.)
- 7.10 Briefly, what parameters are used to assess **system performance?** (e.g. pH, turbidity, chlorine residual, flow, presence/absence bacterial testing, etc)

~HWTS Process Validation/Verification of Health-Based Targets~

The following sections take a specific look at the "targets" that might be used to ascertain technology validation/verification. At least five different types of health-based targets are identified by either the WHO Guidelines for Drinking Water Quality and/or the Implementation Working Group of the WHO Network. They are:

- 1. Health Outcome
- 2. Water Quality
- 3. Performance
- 4. Specified Technology
- 5. Behavior/use (Social Acceptability)

The following sections provide questions specific to each of these targets. As much as possible the definition of each target was adhered to. However, several sections, such as "behavior/use" have been expanded to take other concerns into account. Additionally, another potential target "Cost" has also been included in the survey.

8 Target: Health Outcomes

Do you think that health outcomes are an important indicator of program/product success?

Was a cohort study conducted to evaluate the impact of the program/product? If yes, go on to the rest of section 9.

Cohort Study Questions	
(from Jim Wright and Stephen Gundry – IWA –Marrakech	Special Session on HWTS -
Questionnaire)	

- 8.1 Age cohort studied (e.g. children 24-59 months; all participants, or children 5-14 years) (General diarrhea / cholera / other (please specify: _____)
- 8.2 Health outcome studied:
- 8.3 Definition of health outcome (e.g. how was diarrhea defined in study?):
- 8.4 Method of assessing health outcome (e.g. weekly interviews, through diary, etc.):
- 8.5 Number of individuals within age cohort in intervention group:
- 8.6 Number of individuals within age cohort in control group:
- 8.7 Number of individuals suffering health outcome in intervention group:
- 8.8 Number of individuals suffering health outcome in control group:
- 8.9 Number of person-days of health outcome monitoring in intervention group:

- 8.10 Number of person-days of health outcome monitoring in control group:
- 8.11 Number of person-days of ill health in intervention group:
- 8.12 Number of person-days of ill health in control group:

Characteristics of Study Setting

- 8.13 Type of study area (rural / urban / peri-urban):
- 8.14 Percent of participants (in both groups) with access to sanitation:
- 8.15 Percent of participants (in both intervention & control groups) using improved water supplies (i.e. protected wells, boreholes, protected springs or standpipes):
- 8.16 Percent of participants treating water (e.g. by boiling) before the start of the intervention:
- 8.17 Percent of participants using covered water vessels before onset of study:

9 Target: Water Quality

How important are water quality targets in evaluating program success?

Was water quality tested to evaluate the impact of the program/product? If yes, go on to the rest of section 9.

- 9.1 What standards are used to measure water quality?
- 9.2 Indicator bacterial removal: Initial and final concentration (CFU E.Coli or thermotolerant coliform bacteria/100 ml) and % removal.
- 9.3 Analytic Method (Standard Methods, ISO, etc), Lab or Field Instrument(s) and Detection Limit:
- 9.4 Indicator for viral removal (e.g. F-RNA coliphage):
- 9.5 Analytic Method (Standard Methods, ISO, etc), Lab or Field Instrument(s) and Detection Limit:
- 9.6 Protozoa removal (e.g. cryptosporidium, giardia):
- 9.7 Analytic Method (Standard Methods, ISO, etc), Lab or Field Instrument(s) and Detection Limit:
- 9.8 Helminth removal (e.g. ascaris):
- 9.9 Analytic Method (Standard Methods, ISO, etc), Lab or Field Instrument(s) and Det.Limit:
- 9.10 Laboratory Site:
- # HWTS units tested

HWTS unit Volume (L) or Flow rate (L/day): Duration:

9.11 Pilot Test Field Site(s):

HWTS units tested:

HWTS unit Volume (L) or Flow rate (L/day):

Duration:

9.13 Full-Scale Application Site(s):

Units installed:

Unit Volume (L) or Flow rate (L/day):

Duration:

- 9.14 Procedures used for Lab Test of this Technology:
- 9.15 Procedures used for Field Test of this Technology:
- 9.16 Sludge or other Disposal Issues:
- 9.17 Contact Person (Principal Investigator or other person(s) responsible for validation studies):

10 Target: HWTS System Performance

Performance is defined as a target specific to the technology being employed in that it "performs" as intended according to its specifications. Performance targets should not to be confused with water quality targets which are concerned specifically with the quality of water produced by the system.

Is "system performance" used as a target/indicator to ascertain if a HWTS program/technology is being utilized effectively?

If yes, please answer the following specific questions:

- 10.1 What standards are used to measure system performance?
- 10.2 Is a performance data sheet with the following information available to potential buyers for each system?

Source: National Sanitation Foundation's "Drinking Water Treatment Unit-Heath Effects" ANSI/NSF 53-1999, Section 7.4 Performance Data Sheet:

- 1. Complete name, address, and telephone number of manufacturer
- 2. Model number and trade designation
- 3. Reduction capabilities of specific contaminants in Table 3 (pH, temperature, total dissolved solids, total organic carbon, turbidity) and Table 4 (alkalinity, hardness, pH, polyphosphate as P, total dissolved solids, temperature, turbidity)
 - * name of contaminant
 - * average influent and effluent concentration(s) during test period and percent reductions (NOTE: Average concentrations shall be the arithmetic mean of all reported influent or effluent concentrations the detection limit value shall be used for any nondetectable concentrations. The percent reduction shall be calculated from the arithmetic mean of the influent and effluent concentrations)

- * US EPA maximum contaminant level
- * VOC claims
- * testing parameters
- *rated service flow rate in L/min or L/day (gpm or gpd)
- * maximum working pressure in kPa (psig)
- * general installation conditions
- * general operation, maintenance requirements including, but not limited to:
 - frequency of component change or service to system
 - user responsibility
 - parts and service availability
- * manufacturers limited warranty
- * statement that the system conforms to the ANSI/NSF 53 for the specific performance claims as verified and substantiated by test data."
- 10.3 Are the requirements of the said data sheet met for most households?
- 10.4 How important are performance targets in evaluating program success?

11 Target: Behavior/Use (Social Acceptability)

The following section has the purpose of obtaining information on how the system changes the behavior of users, if the system is used properly by users, how it is accepted, and if it is sustainable.

- 11.1 To what extent does available support for operation and maintenance determine program/product success?
- 11.2 Do you use frequency of break-downs and requirements of technical support as a basis for evaluating if a program/product is effective and successful?

Rate of Adoption and Sustained Use

We define "rate of adoption (ROA)" as the percentage of uptake of a HWTS practice or product after an initial period of training/education and/or marketing:

We define "rate of sustained use (ROSU)" as the percentage of continued use of a HWTS practice or product after a 1 year of ownership.

- 11.3 Do you keep records of the people who initially obtain, use and/or continue to use the HWTS intervention?
- 11.4. What is the rate of adoption for the HWTS under discussion?
- 11.5. What is the rate of sustained use for the HWTS under discussion?

- 11.4 Do you keep records of the people who are maintaining use of the system after one month of ownership? After one year?
- 11.5 Do you maintain those records in a database?

Environmental Sustainability

- 11.7 What are the wastes created during the entire life cycle of the product? Can these wastes be quantified in terms of cost? (cost/kg waste generated).
- 11.8 Are the raw materials used for this technology accounted for in terms of potential environmental impacts? Are these resources renewable?
- 11.9 Are there any other environmental impacts of the HWTS system?
- 11.10 How important are environmental considerations in evaluating if a program/product is effective and successful?

User Input

- 11.11 How frequently is user input obtained after a program/product has been employed?
- 11.12 Do users comment on the ease of operation and maintenance of the program/product? If so, what is their common perception?
- 11.13 Do users comment on how much their water has improved due to the program/product? If so, what is their common perception?
- 11.14 How important is user input in evaluating whether a program/product is effective and successful?

Education, Training, and Awareness

- 11.15 Are education and training available to users AFTER program implementation? To what extent? Who implements education and training? Who funds it?
- 11.16 In your opinion, how aware are community members of the current threats to health posed by untreated water sources? How aware are they of the technologies available to treat water on a household level?
- 11.17 How important are these factors in determining program/product effectiveness and success?
- 11.18 Are ongoing training programs provided for staff members?

Social Acceptance

- 11.19 How do users receive the program/product? Are they eager or wary of the new technology?
- 11.20 In your opinion, does the program fit well in the culture of the target population?

- 11.21 Do political considerations ever come into play during implementation? Does local government and community support typically aid in the implementation of these programs/products?
- 11.22 How important are these factors in determining program/product effectiveness and success?

12 Costs

Individual (Household) Costs

Report any and all costs of the intervention incurred by the target population. Include annual quantities for the population covered by the program, description and unit costs. Expand this spreadsheet as necessary by adding rows under each cost category.

	Quantity	Description	Unit Cost	Annual Cost		
12.1Capital costs ³		Item	Useful Life	Residual Value		
1 Equipment						
2 Other						
10.0 P						
12.2 Recurrent						
costs						
1 Supplies						
2 Labour						
2 Labour						
3 Utilities						
3 Cunices						
					l	

Program Costs

Report all costs of the intervention incurred other than by the target population. These costs should be accumulated and allocated to the national (N), regional (R), community(C) and household (H) level. Include annual quantities for the population covered by the program, description and unit costs. Code for the party responsible for payment as follows: National or local government (G), Donor or other funding agency (D), program implementer (P), business (B). Do not include householder expenditures that were separately reported. Expand these spreadsheets as necessary by adding rows under each cost category.

Start Up Program Costs:

_	Quantity	Description			Level Code	Payer Code	Unit Cost	Annual Cost
12.3 Capital costs ³		Item	Useful Life	Residual Value	Use N, R, C or H for each	Use G, D or P for each		
1 Building								
2 Transport								
3 Equipment								
4 Other								
12.4 Recurrent costs				•				
1 Personnel								
2 Materials/Supplies								
3 Media & IEC								
4 Transportation								
5 Equipment								
6 Maintenance								
7 Utilities								
8 Rented Space								
9 Other Recurrent								

Post Start Up Costs:

1 ost start ep e	Quantity	Description			Level Code	Payer Code	Unit Cost	Annual Cost
12.5 Capital costs ³		Item	Useful Life	Residual Value	Use N, R, C or H for each	Use G, D or P for each		
1 Building								
2 Transport								
3 Equipment								
4 Other								
12.6 Recurrent costs				-1				
1 Personnel								
2 Materials/Supplies								
3 Media & IEC								
4 Transportation								
5 Equipment								
6 Maintenance								
7 Utilities								
8 Rented Space								
9 Other Recurrent								

- 12.7 Who is typically responsible for costs incurred during the operation and maintenance of programs and products? What percent of costs are shouldered by each?
- 12.8 Are the costs incurred for the operation and maintenance typically affordable by responsible entities?
- 12.9 Is a cost-benefit analysis conducted for the program/product? Or alternatively, if a cost-benefit (or cost effectiveness) analysis was conducted prior to program/product implementation were the results of the said analysis ever verified with up-to-date field data?
- 12.10 Was a willingness to pay study ever conducted for the target population? If so, what were the methods employed and the results obtained?
- 13.11 How important are economic considerations in evaluating program/product effectiveness and success?

Marketing and Distribution

- 12.12 Are marketing activities a part of the implementation activities of your business or program?
- 12.13 If yes, please describe the specific marketing activities:
- 12.14 In your opinion. Which method of information dissemination is most effective?
 - 13.14.1 Public Government
 - 13.14.2 Public NGO
 - 13.14.3 Quasi-Commercial Social Marketing
 - 13.14.4 Commercial Private

Why do you find this method to be most effective?

- 12.15 What role do other organizations play in the implementation of the program/product? In your opinion, how important is the relationship to other organizations to program success?
- 12.16 Are local distributors and business playing a role in the implementation of the program/product? Do you feel that these distributors are important to program success?

13 Other Types of Approaches and Questions

HWTS implementation activities run as for-profit business enterprises will have an extensive set of additional or alternative targets, related to sales, marketing, supply chain, labor, quality control/quality assurance, product safety, etc. that have NOT been covered here. We will need to address for-profit implementation models in later iterations...

14 Final Thoughts

- 14.1 Achievements to date of this program/product implementation?
- 14.2 Failures or limitations to date of this program/production implementation. What improvements might be suggested? Research to be conducted?
- 14.3 Please Rate the Following on a Scale of 1 to 4 (1=low, 4 = high) in terms of:

Importance in Pre-Implementation of the Program/Product:

- 20. Current Scenario or Region Designated for Implementation:
- 21. Household Practices of Region Designated for Implementation:
- 22. Availability of Resources:
- 23. Training and Education Programs:
- 24. Available Marketing/Distribution Methods:
- 25. Funding:

Importance in Implementation / Monitoring / Evaluation of the Program/Product:

- 26. Health Outcome:
- 27. Water Quality:
- 28. Performance:
- 29. Frequency of Required Maintenance:
- 30. Available Support for Operation and Maintenance:
- 31. Rate of Adoption and Sustained Use:
- 32. Environmental Sustainability:
- 33. User Acceptance:
- 34. User Education and Awareness:
- 35. Involvement/Partnership with Other Organizations:
- 36. Political Climate:
- 37. Financial
- 38. User Willingness to Pay:
- 14.4 Any additional comments:

15 Publications

Please List All References to Published Studies (s) describing program/product implementation (please provide electronic or hard copy if possible). Include the following information:

15.1	Principal author	
15.2	Principal author email address	
15.3	Name of study as it appears in source	
15.4	Complete citation of publication or other source from which information is extracted	
15.5	Publication status	Published in journalPublished in conference proceedingPublished on Internet onlyPublished elsewhere (designate)Not published
15.6	Country/countries of study	
15.7	Type of home treatment and safe storage intervention	
15.8	Period of intervention	
15.9	Details of any contact with author(s) to obtain supplemental information on study.	
15.10	Relevant Websites	

DEVELOPMENT OF PROGRAM IMPLEMENTATION, EVALUATION, AND SELECTION TOOLS FOR HWTS SYSTEMS IN DEVELOPING COUNTRIES

WHO Network Implementation Working Group Survey (Web-based Collection Tool / Survey Short Form)

Thesis Pages: 274 – 277

DEVELOPMENT OF PROGRAM IMPLEMENTATION, EVALUATION, AND SELECTION TOOLS FOR HWTS SYSTEMS IN DEVELOPING COUNTRIES

HWTS	Household	Survey	Version	3
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Thesis Pages: 279 – 288

WHO IWG Household Survey Tool: Version 3 January, 2005

		ue and I are working to improve water systems in area using that helped
	w to imp	prove these systems. In this survey we would like
Is that person currently available to tal		
Yes	1	CONTINUE TO NEXT SECTION
No	2	CONTINUE TO NEAT SECTION
When would be a good time to come b	ack to tal	lk to that person? (Write this down).
Day		
Time: Hrs Minu	tes	
•		We promise that neither your name nor your ople here. Only a number will be used to identify
1 BACKGROUND INFORMATION		
Date and Time: Location:		
1.1 Number of the questionnaire City: Province:		
First, we will ask you some general inf	formation	about yourself:
1.2 Respondent's status in the house	hold. (W	rite this down).
Father		1
Mother		2
Grandfather		3
Grandmother		4
Other		15
1.3 What is your age, please? (Wr. (ESTIMATE IF AGE IS STA		, =:

1.4 Sex of the respondent (*Record without asking*).

Male	1
Female	2

2 WATER USE PRACTICES

2.1 Where do you collect your drinking water from?

(DO NOT READ, MARK OR WRITE ALL ANSWERS OF THE RESPONDENT.)

Running water supply inside the house	1	Go to question 2.2
Water supply from city outside the house	2	
Own well	3	
Public well	4	
Creek or a river	5	
Lake or a pool	6	Go to question 2.4
Hole	7	
Water vendor	8	
Canal or a ditch	9	
Other (WRITE THIS DOWN):	15	1

2.2 Who usually collects drinking water?

(DO NOT READ, MARK OR WRITE ALL ANSWERS OF THE RESPONDENT.)

Father	1
Mother	2
Grandfather	3
Grandmother	4
Child	5
Other (WRITE THIS DOWN)	15

2.3 Do you store drinking water at home?

Yes	1	
No	2	Go to question 2.8
DIFFICULT TO ANSWER	99	Go to question 2.8

2.4 What containers do you usually store drinking water in?

(MARK THE ANSWERS OF THE RESPONDENTS AND WRITE DOWN NUMBER OF CONTAINERS.)

a) Metal buckets (Go to 2.5)	1	How many?	
b) Plastic buckets (Go to 2.5)	2	How many?	
c) Ceramic vessels (Go to 2.5)	3	How many?	
d) Small pans (Skip to 2.6)	4	How many?	
e) Jerry can (Skip to 2.6)	5	How many?	
Other (WRITE THIS DOWN):	15	How many?	

2.5 Are the buckets and ceramic vessels always covered?

Yes	1
No	2
DIFFICULT TO ANSWER	99

2.6 Approximately how many days do you store drinking water in your containers before it is finished?

(WRITE THIS	DOWN):		
-------------	------	----	--	--

2.7 How do you take drinking water from your containers?

(DO NOT READ, MARK OR WRITE ALL ANSWERS OF THE RESPONDENT.)

Draw water with a small pan	1
Poor directly from it	2
Draw water with a cup	3
Draw water with a scoop	4
Other (WRITE THIS DOWN)	15

2.8 Does anyone ever touch water in your containers with his/her hands? (E.g. when he/she draws water)

Yes	1 1
No	2
DIFFICULT TO ANSWER	99

If the household <u>does not</u> have a HWTS technology, ask the following questions:

2.9 Do you think that the drinking water you use at home is safe/clean to drink?

_ · J · · · · J · · · · · · · · · · · ·			
Yes	1	Move to question 2.10	
No	2	Move to next question	
DIFFICULT TO ANSWER	99	Move to question 2.10	

2.10 Why do you think that the water is unsafe to drink?

(DO NOT READ, MARK OR WRITE ALL ANSWERS OF THE RESPONDENT.)

Water is dirty / turbid	1
Water is infected with microbes	2
Water contains larva, worms etc	3
Causes malaria	4
Other (WRITE THIS DOWN):	15
DIFFICULT TO ANSWER	99

3 HWTS PROGRAM/PRODUCT DESCRIPTION

- 3.1 HWTS Implementation Program/Product Name being used:
- 3.2 Why did you select this HWTS technology for your household as compared to other

3.3 Who brought this technology to your attention?				
3.4 From where do you obtain your HWTS technology and training to use?				
3.5 How long have you used your HWTS technology?				
4 HV	WTS PROGRAM/PRODUCT USE			
4.1 before		the same	e after using the HWTS technology than	
	Better	1		
	Worse	2	1	
	No change	3	The second secon	
	DIFFICULT TO ANSWER	99	The second secon	
	Since you've begun treating your water drinking?	r, do you	use more water, the same amount, or less for	
	More water	1	de la companya de la	
	Less water	2		
	Same amount	3	The state of the s	
	DIFFICULT TO ANSWER	99		
4.3	4.3 Do you treat all the water you and the rest of the family use for drinking?			
	Yes	1	Go to question 4.5	
	No	2	Answer question 4.6	
	DIFFICULT TO ANSWER	99		

4.3 When do you use untreated water for drinking? (WRITE THIS DOWN)

4.4 Do you use treated water to wash the dishes and utensils?

technologies?

Yes	1
No	2
DIFFICULT TO ANSWER	99

4.5 Since you started using the HWTS technology, do you feel better?

Yes	1
No	2
DIFFICULT TO ANSWER	99

4.6 Who is responsible for treating the water?

Father	1
Mother	2
Grandfather	3
Grandmother	4
Child	5
Other (WRITE THIS DOWN)	15

4.7 Do the children in the household know how to treat the water?

Yes	1
No	2
DIFFICULT TO ANSWER	99

5 PERCEPTIONS & ACCEPTABILITY

5.1 Do you think using the HWTS technology is beneficial for your family?

Yes	1
No	2
DIFFICULT TO ANSWER	99

Why or why not? (WRITE THIS DOWN)

5.2 Is it easy to use the HWTS technology?

Yes	1
No	2

DIFFICULT TO ANSWER	99
E	

5.3 Would you recommend the HWTS technology to others?

Yes	1
No	2
DIFFICULT TO ANSWER	99

5.4 Have you had any problems with your HWTS technology?

Yes	1
No	2
DIFFICULT TO ANSWER	99

What problems? (WRITE THIS DOWN)

6 OPERATION AND MAINTENANCE

6.1 Do you perform maintenance on the technology?

Yes	1	Go to next question
No	2	Skip to question 6.3
DIFFICULT TO ANSWER	99	

6.2 How often do you perform maintenance on the technology?

_____ [weeks /months / years / post-construction]

6.3 What kind of water do you drink when your HWTS technology is broken/being repaired?

Direct from source	1
Boiled	2
Store purchased	3
Waterguard treated	4
Other	15

6.4 Can you tell me what kinds of technical assistance that the village receives to keep the

household water treatment and safe storage system running?

Types of	Ever provided?	If so, by whom?	If so, how often do you
technical support	Ever provided:	ii so, by whom:	receive such support?

a. Technical:	Yes		Government ag	gents		time(s) every
In-person visits	No		NGO			[weeks
from external	(:CN 1: / 1	, –	Other			nths / years / post-
agencies?	(if No, skip to b	" -			cons	struction]
b. Technical:	Yes	_	Government ag	gents		time(s) every
Operator(s)	No	_	NGO			[weeks
attend training	(*CN 1 * .	, -	Other			nths / years / post-
workshops?	(if No, skip to	<i>c)</i>				struction
c. Technical:	Yes		Government ag	gents		time(s) every
Written	No		NGO			[weeks
manuals/material supplied?	(if No skip to	<u>d</u>) —	Other		/moi	nths / years / post-
	(if No, skip to					struction
d. Technical:	Yes		Government ag	gents		time(s) every
Spare parts provided to the	No		NGO Other			[weeks
village?	(if No, skip to 6.	.5) -	Other			nths / years / post-
, mage.					cons	struction
6.6 Have you ever h	ad to obtain spare		<u> </u>			
Yes		1	Continue to 6.	4		
No		2	SKIP to Quest	tion 6.9		
DIFFICULT ANSWER	ТО	99				. =
you typically obtain	spare parts?					6.7 Where do
From a gover	nment agency (lo	ocal, sta	ate, or national)	1		
	or donor agenc			2		
From a privat	From a private shop			3		
Other (Specif	Other (Specify)		15			
6.8 On average, how		you to	travel to this supp			
Hours travel of	me way, or			1		

2

3

Days travel one way, or

No travel required: Parts are delivered to village

	:	•
Difficult to answer	99	

6.9 In your experience, have the spare parts you needed typically been available right away, or have you had to wait for them to be sent from somewhere else?

Are available immediately		1
Have to wait		2
DIFFICULT	ТО	99
ANSWER		

6.10 Where does the money come from to

purchase these parts?

Technician collects money from household	1
Technician receives money from an external agent (government agency, NGO, etc)	2
Other (WRITE THIS DOWN)	15

6.11 Do you keep any spare parts on hand?

Yes		1
No		2
DIFFICULT	ТО	99
ANSWER		

6.12 Have you ever requested technical

assistance for a problem with the HWTS system? [Surveyor: Be sure that the respondent understands that you want to know about requests for assistance, whether or not those requests were fulfilled.]

Yes		1	Go to next question
No		2	Go to end of section
DIFFICULT	ТО	99	Go to end of section
ANSWER			

6.13 How many

times in the past year did have you had a problem for which you requested technical assistance?

_____ Times, or _____ Don't know / Not sure

(If zero times, skip to end)

6.14 From whom did you typically request assistance?

Local/District government	1
Local Ministry of Health post	2
State government	3
NGO	4
Other (WRITE THIS DOWN):	15

6.15 Did you receive the assistance you needed the last time you asked?

Yes		1	Continue to 6.13
No		2	Go to end of section
DIFFICULT ANSWER	ТО	99	Go to end of section

6.16 On

average, how long did you have to wait before you received the assistance you needed?)
a b[days / weeks / months / years]	
c Don't know / Not sure	

7 WILLINGNESS TO PAY

7.1 Imagine that your filter is broken and cannot be repaired. Would you buy the new one and, if yes, how much are you willing to pay for it?

For surveyor: we will try to obtain more accurate "willingness to pay information by using a split-case method. Each time you do an interview, start with different initial prices (1000 KS, 1100 KS, 1200 KS) then try to find the maximum price they are willing to pay.

For example in one case you might ask: "Will you pay 1100 KS?" Yes. "Will you pay 1200 KS?" Yes. "Will you pay 1300 KS?" No." Stop here.

The actual price is something in between, in this case, 1200 and 1300. So you will write down the last price 1200 in the answer section.

- 7.2 Do you think that your neighbors will buy HTWS for this price?
- 7.3 How much do you think it costs to produce this product?

8 HOUSEHOLD COMPOSITION AND WEALTH INFORMATION

8.1	Number of people in the household that use the HTWS technology
8.2	Number of children under age 5
8.3	Number of rooms in house?
8.4	Who in the household works outside the home and what does s/he do?
8.5	On average, how much money do you spend each month on necessities for the family (including food, tools, supplies, transportation)?
8.6	Where do you go to buy necessities (food, washing soap, etc)?

- 8.7 How many hours are you normally outside the home per day?
- 8.8 What do you drink when you are not at home?
- 8.9 Do you ever purchase water? If yes, from where?

9 KNOWLEDGE OF DIARRHEA

9.1 What causes diarrhea?

(DO NOT READ, MARK OR WRITE ALL ANSWERS OF THE RESPONDENT.)

Drinking dirty water	1
Eating contaminated food	2
Flies/insects	3
Non-observance of hygiene/poor hygiene	4
Weather	5
Spirits	6
Other (WRITE THIS DOWN):	15
DIFFICULT TO ANSWER	99

- 9.2 At what point (when) do you begin treating diarrhea? (WRITE THIS DOWN)
- 9.3 How do you treat diarrhea in the household?

(DO NOT READ, MARK OR WRITE ALL ANSWERS OF THE RESPONDENT.)

Increase drinking liquids	1
Reduce drinking liquids	2
Use packets with special salt (for rehydration)	3
Make sweet-salty solution	4
Take medicines, (such as antibiotics)	5
Boil water	6
Other (WRITE THIS DOWN):	15
DIFFICULT TO ANSWER	99

9.4 Where do members of your family receive treatment for diarrhea outside the household?

(DO NOT READ, MARK OR WRITE ALL ANSWERS OF THE RESPONDENT.)

In hospital	1
Health center	2
Private clinic/doctor	3
Pharmacy	4
Other healers	5

Other (WRITE THIS DOWN):	15
DO NOT SEEK TREATMENT AT ALL	99

9.5 Who is responsible for caring for the individual with diarrhea?

Father	1
Mother	2
Grandfather	3
Grandmother	4
Child	5
Other (WRITE THIS DOWN)	15

10 OBSERVATION BY THE INTERVIEWER

House type:

Floor type:

How is the toilet /bathroom equipped in the household?

(DO	NOT	READ,	MARK	OR	WRITE	ONLY	ONE	ANSV	VER.)
	-	11.							

Improved latrine	1
Dry cesspool	2
Bathhouse without running water	3
Bathhouse with running water	4
Other (WRITE THIS DOWN):	15
DIFFICULT TO ANSWER	99

Is there a special place for washing hands?	Yes - 1	No-2
Is there soap in the place they wash hands?	Yes - 1	No-2
Does the household have electricity?	Yes - 1	No-2
Does the household have gas?	Yes - 1	No-2

DEVELOPMENT OF PROGRAM IMPLEMENTATION, EVALUATION, AND SELECTION TOOLS FOR HWTS SYSTEMS IN DEVELOPING COUNTRIES

Sample of completed HWTS Implementation Organization S	urvey Version 2 as
applied to the Kenya Water for Health Organization	

Thesis Pages: 290 – 308

HWTS Program/Product Evaluation Organization Survey January 2005

1 General Information

The following section has the purpose of determining basic background information on the organization. Obtain simple answers to these questions as most will be tackled in more detail in later portions of the survey.

Date and Time: January 4, 2005

Location: KWAHO Headquarters, Nairobi

Name of interviewer: Robert Baffrey

1.1

Interviewee Name/Position: Joshua Otiena-Onyango (Project Coordinator)

Organization: KWAHO (Kenya Water for Health Organization)

Address: P.O. Box 61470, Nairobi, Kenya Telephone(s): (254-2) – 552405, 557550

Fax: (254-2) - 543265 Email: To Follow Website: To Follow

- 1.2 Type of organization: (e.g. Non-Governmental Organization (NGO), Business, Government, Agency, Academic Institution, Other?) NGO
- 1.3 Organization's general history and mission statement? To supply water, sanitation, and hygiene at a grassroots level. (Seek out full statement in document given) The organization also works closely with government and community-based organizations. Predominantly involved with SODIS implementation in the Kibira region.

"Working hand in hand with the community to supply water, sanitation, and hygiene at the grassroots level. Supplementing the government's effort. Also works with other international and local organizations and institutions."

Works closely with Ministry of Water. Also community-level work which is actually the groups formed by the communities themselves. KWAHO implements programs by working closely with these local groups.

For the following questions (1.4 and 1.5) we need only ask briefly about these topics and explain that the topic will be addressed in more detail at a later section of the survey.

1.4 Organization's specific goals with regards to implementation of one or multiple HWTS systems?

KWAHO works specifically with SODIS but is also implements the technology with sanitation training and hygiene promotion. SODIS in Kibira. EcoSan in Maseno with the Austrian Development Group.

1.5. How does your organization measure progress towards these specific goal(s)? What specific tools, programs, and methodologies do you employ?

No answer.

1.6 Approximate number of staff members working on HWTS implementation?

50 Employees. 30 working the rural areas. 20 in Kibira slums (headquarters) / urban. 5 main promoters and 15 are peer or part-time promoters.

2 Implementation Program / Product Description

The following section has the purpose of obtaining information specific to the program or product being implemented. Such information extends to the current water scenario or situation in which these programs are being implemented.

Answers for 2.1 and 2.2 are known and may be found in the literature received from KWAHO.

- 2.1 HWTS Implementation Program/Product Name:
- 2.2 Brief (1-2 sentences) Description:
- 2.3 Why did your organization select this HWTS technology for implementation (as opposed to other community-wide technologies)?

First the organization goes into the community and tries to find a way to help. The organization conducted a "community needs assessment". After which the management meets and discusses the options to help the community including costs and other matters of importance. The organization then searched the internet and combined with a suggestion from their executive director (Margaret Mangola? - VERIFY) they selected SODIS. The director had attended a conference in Austria and they had heard about SODIS winning an award. They found that there was a lot of positive information on SODIS on the internet, so they pursued this technology.

2.4 Who brought this technology to your attention?

The organization then searched the internet and combined with a suggestion from their executive director (Margaret Mangola? - VERIFY) they selected SODIS. The director had attended a conference in Austria and they had heard about SODIS winning an award. They found that there was a lot of positive information on SODIS on the internet, so they pursued this technology

2.5 Where is the HWTS technology manufactured? Who distributes it?

Not applicable. The funding was provided by the Austrian Embassy which is actually one of KWAHO's donors. They provided immediate funding for a pilot project which took place in 2001 for a duration of six months. The pilot project consisted of KWAHO going to the community and discussing the project or system. On the onset the community was skeptical, how can solar energy clean water? But KWAHO continued training and a few people accepted the technology. There were still many questions. KWAHO answered these questions by doing water quality testing. The main people that were important to convince in the community are the community leaders. These leaders are those not necessarily elected per se by the community but

are really just those that are respected by the rest of the community members.

There is still a slight tribal culture in this area and tribal elders are still respected. But mostly community leaders are selected based on the fact that they are trusted by community members and they are the main people who people go to for advice. Community leaders are those that are convincing and respected. They talk to the people and "mobilize" the people.

KWAHO buys the bottles from manufacturers in the area but are also starting to ask restaurants to donate the bottles they typically throw away. They are also starting to get the people to get their own bottles so that the systems will be self-sustaining in the future.

KWAHO started with the transparent bottles that were painted black on one side but as time goes they asked about the blue tinted bottles and sent these for testing and these were found to be effective as well. But they still advise the users on what bottles to use.

Initially some users even thought that the bottles themselves were what was responsible for treating the water and not the sunlight.

2.6 Where do you obtain technical support for this HWTS technology?

SANDEC. Testing at the Ministry of Water laboratory.

2.7 Baseline Conditions:

Fill in Later.

Describe the setting in which the program was undertaken. Include all information requested.

I Region or Primary Community	Kibira. (Southwest of Nairobi) Focusing in this area at the moment due to lack of funds to expand.	
II Predominant Exposure Scenario existing in the program setting before introduction of the program	Water: g. Not Improved h. Improved i. Regulated Sanitation: g. Not Improved h. Improved i. Full Coverage	
III Month and Year of commencement of program	Month April 2004Year	
IV Start-up and Post-Start Up Periods	Start-up began Post-start up (ongoing) period began Program terminated Program ongoing Ongoing	

2.7 HWTS Implementation Program/Product Details

Identify the main approach and any additional components included in the implementation of the program/product.

- existing program	Solar Disinfection (SODIS)			
- existing health outcomes study	Combined Flocculation/Disinfection			
	Ceramic Filtration			
	Other			
	Not applicable			
II If you answered "other,"	1. Filtration:			
please describe the type of	Cloth			
HWTS system, based on its	Ceramic water filters			
dominant treatment process(es)	Sand			
	Intermittent household slow sand filters			
	Other			
	2. Coagulation/Flocculation Iron salts			
	Alum salts			
	Natural polymer(s)			
	Synthetic polymers			
	Combined product (metal salt, polymer, weighting agent, etc).			
	Other			
	3. Membrane			
	type			
	4. Disinfection			
	Chlorination (not specifically the Safe Water System)			
	UV Disinfection System			
	5. Combined (multiple barrier) HWTS Systems (e.g. rough filter +			
	granular activated carbon filter + chlorine disinfection; ceramic			
	candle + sand; coagulant + disinfectant)			
	Not applicable			
III Additional components of	Storage vessel			
program.	Educational to encourage adoption or use of HWTS			
	Hygiene instruction (independent of HWTS)			
	Sanitation intervention			
	Water supply intervention			
	Other (describe)			
	EVERYTHING. Including the water tanks which are 10,000 square			
	meters in volume. This was in fact the first approach of the program.			
	But after storage was provided they started to think about whether			
	the water being stored was clean.			
IV Predominant Dissemination	Public (i.e., government or NGO program)			
Model / Method of	Quasi-Commercial (social marketing)			
Implementation	Commercial			
	CODIC Promotors			
	SODIS Promoters			

 $2.8\ Extent$ of current implementation (locations and number of units):

I Number of persons in the program.	persons
II Number of households include in the program.	households
	As of September 2004 – 8000

	January 2005 – 10000 About 5 to 6 people per homes. They expect to be at about 20,000 eventually. Over 50,000 people estimated.
III Average number of persons per household included in	persons per household
the program.	
IV Maximum coverage assuming no increase in fixed costs	persons
and 80% utilization (see Guidelines Section 2.5.1).	_

2.9 What role do other organizations play in the implementation of the program/product? In your opinion, how important is the relationship to other organizations to program success?

They learn with other organizations but mostly they hope that other NGO's pick up the technology and run with it. It is KWAHO's job to teach the NGO's about the system, so they work with them in that regard. The government on the other hand supports the organization in terms of giving them a place to stay and helping with logistics and details whenever this is required. They claim to work with NGO's closely and hope that these pick up the technology although KWAHO deals with the water quality aspects. Security is also provided by the government.

~PRE-IMPLEMENTATION CONSIDERATIONS (Sections 3 – 7)~

The following sections have the purpose of obtaining information specific to the manner in which the program/product was implemented. We are still obtaining somewhat general background information but we now start to look at this information as potential factors considered prior to implementation.

3 Target Population and Current Water Use Practices and Concerns

3.1 Was a baseline health survey carried out prior to HWTS intervention? If yes, please describe the key results:

To a certain extent. What they did was visit clinics in the area and check how many children had cases of diarrhea in the area. With this information they then tried to determine ways on how they would assist the communities. The main problems they saw in this baseline survey, in which they also went to a number of homes, was that at each home they had experienced diarrhea cases for children. This was in 400 homes. The survey basically consisted of KWAHO workers going from home to home and interviewing residents on issues in water quality and sanitation.

- 3.2 Demographics of target population
 - a. Urban / Rural Urban
 - b. Literacy rate 50%
- c. Size of Population 500-700,000 (1979) At this point in time there were only 9 villages and now there are 11 villages.
- 3.3 Source(s) of water? How is water typically delivered to households in target population?

Water is piped to the community but only to certain vendors at water kiosks. These are licensed vendors from the community. They pay 3 to 10 shillings per container. Prices vary based on the availability of water. People come with buckets or jerry cans and carry these by homes before transferring these into the SODIS bottles.

3.4 Percentage of people in target population lacking "access" where access means greater than 1 km or 30 minutes travel time to obtain water? What is their method(s) of transport?

It takes a long time to get water in regards to the length of the line at the water kiosks. Some kiosks are far but it is mostly the waiting time that makes the process difficult. And also the water supply is very inconsistent. Sometimes it takes up to two weeks to get water. Water rationing takes place in which only one half of the community has access to water and there are also water cartels in the area that control the water.

3.5 Incidence of diarrhea in children under 5 in target population?

No information.

If answer to 3.1 was "yes" then neglect the following question (3.6).

3.6 Source of data other than baseline survey?

Salvation: defined as the act of walking across an entire community and just observing general practices. More or less a qualitative survey although some attempts are made to make quantitative surveys as well.

3.7 How much does your organization utilize the above information prior to implementation? Do you feel the information is important to program success?

Any successful program requires a survey to know exactly what the need of a community is. This is very important. You have to know. Unlike before, when the government was giving people water you would find that people do not maintain what is given. So by knowing a community and training them as much as possible you can guarantee that the technology will be maintained and sustainable.

4 Resource Availability

4.1 Are resources and raw materials locally available and accessible? Are they utilized in manufacturing the HWTS technology?

You have to look at this and it is very important to know what technology can be made or is available locally.

4.2 Is skilled labor available to locally manufacture HWTS technologies?

See above.

4.3 How important is the availability of local materials and labor to the success of programs?

See above.

5 Education and Training

See previous notes on this (journal). Promoters educate the community about this including small programs and marketing methods for communities and schools.

- 5.1 Are training/education programs a part of the implementation activities?
- 5.2 If yes, please describe the specific training/education program:
- 5.3 Do you feel that people have an adequate knowledge and awareness of water treatment methods? How important is such knowledge and awareness to program success and sustainability?

Users know very much about the community. Promoters follow-up with users and give them leaflets and training charts to enable them to spread this technology to their neighbors. There is a general awareness of this technology in the community.

6 Marketing and Distribution

6.1 Are marketing activities a part of the implementation activities of your business or program?

See notes on SODIS promoters. They have additional schemes that they discussed in a meeting of promoters. They thought about t-shirts and having competitions at schools with having kids compete to find the most bottles. Also they were talking of giving incentives to families or users that use SODIS the best. They are starting to expand their marketing approach.

6.2 If yes, please describe the specific marketing activities:

See notes and above. They feel that marketing is essential to the program and that it is essential to change attitudes about water. Especially with SODIS which is a new technology, and that which somewhat isn't "natural" so people are initially skeptical. Marketing can change attitudes.

- 6.3 In your opinion. Which method of information dissemination is most effective?
 - 6.3.1 Public Government
 - 6.3.2 Public NGO
 - 6.3.3 Quasi-Commercial Social Marketing
 - 6.3.4 Commercial Private

Why do you find this method to be most effective?

Commercially is ok. But you really have to think about how you can reach the people most effectively. For instance, in Kibira most people do not have televisions so you have to find alternative means to give people knowledge. We found that the best way to reach the people was to use our promoters who reach out to the people on a more personal level. We use meetings and house visits to talk to the people personally. You need to gain their trust. Commercial advertisements for thirty seconds do not allow the people to ask questions whereas our process allows them to.

6.7 What role do other organizations play in the implementation of the program/product? In your opinion, how important is the relationship to other organizations to program success?

Answered by notes.

6.8 Are local distributors and business playing a role in the implementation of the program/product? Do you feel that these distributors are important to program success?

Answered by notes.

7 Funding

The following section has the purpose of obtaining information specific to the manner in which the program or product was funded.

7.1 What is the primary source of funding for the program/product implementation?

Still SANDEC. Solaqua Foundation through SANDEC.

7.2 To date, how much total funding have you received?

3 Quarters of the funding or about 15 thousand dollars. They are going to be searching for funding by February of this year. They need this funding to hit the remaining areas of Kibira as well as other villages.

7.3 What is the average funding cost per family?

No answer.

7.4 Is funding primarily for implementation alone or for maintenance and operation as well?

For both.

7.5 Are any cost-benefit analyses conducted on the target population prior to implementation?

Not really. More based on health and SODIS is a low cost technology. The few people who are employed are learning less that one dollar a day. This was the extent of their analysis.

7.6 Are efforts made to determine the target populations wealth information and "willingness to pay" prior to program implementation?

No.

~POST-IMPLEMENTATION SECTION~ (Monitoring and Evaluation; Sections 8–16)

8 Operational Monitoring and Evaluation

The following section has the purpose of obtaining basic information on the operational monitoring procedures employed by an organization. The standards by which the programs are measured and indicators by which program success is evaluated are addressed in subsequent sections.

8.1 Is operational monitoring conducted?
(IF NO, MOVE TO QUESTION 8.9)

Yes.

8.2 If yes, please describe briefly:

Twice a week. Promoters visit the homes. They make sure the system is being used properly and answer any questions that users might have.

8.3 What is the frequency of operational monitoring?

Twice a week.

8.4 What is the extent of operational monitoring? (average number of households)

All households.

8.5 Who conducts operational monitoring?

Promoters.

8.6 Who funds operational monitoring?

SANDEC.

8.7 What is the reporting hierarchy of the monitoring?

Promoters fill out forms and keep them on file for project manager to review when necessary. The project manager then reports to the head of KWAHO at certain periods during the year.

8.8 Are other organizations involved in operational monitoring?

No.

8.9 Briefly, what standards are used as a basis for adequate **water quality**? (e.g. WHO guidelines, NSF standards, etc.)

Kenya Bureau of Standards

8.10 Briefly, what parameters are used to assess **system performance?** (e.g. pH, turbidity, chlorine residual, flow, presence/absence bacterial testing, etc).

Microbial removal. Total Coliform.

~HWTS Process Validation/Verification of Health-Based Targets~

The following sections take a specific look at the "targets" that might be used to ascertain technology validation/verification. At least five different types of health-based targets are identified by either the WHO Guidelines for Drinking Water Quality and/or the Implementation Working Group of the WHO Network. They are:

- 1. Health Outcome
- 2. Water Quality
- 3. Performance
- 4. Specified Technology
- 5. Behavior/use (Social Acceptability)

The following sections provide questions specific to each of these targets. As much as possible the definition of each target was adhered to although several sections, such as "behavior/use" have been expanded to take other concerns into account. Additionally, another potential target "Finances and Economics" has also been included in the survey.

9 Target: Health Outcomes

Do you think that health outcomes are an important indicator of program/product success?

Yes. That is very important and the goal of our program.

Was a cohort study conducted to evaluate the impact of the program/product? If yes, go on to the rest of section 9.

No. We plan to do a follow-up survey of the system to determine how many cases have been reduced. This would be done in January 2005 and at random households. We track cases of diarrhea for children under five. We would have health based targets and surveys but these are too expensive and take to long to accomplish.

Cohort Study Questions

(from Jim Wright and Stephen Gundry – IWA –Marrakech Special Session on HWTS - Questionnaire)

- 9.1 Age cohort studied (e.g. children 24-59 months; all participants, or children 5-14 years) (General diarrhea / cholera / other (please specify: _____
- 9.2 Health outcome studied:
- 9.3 Definition of health outcome (e.g. how was diarrhea defined in study?)
- 9.4 Method of assessing health outcome (e.g. twice-weekly interviews, through diary, etc.)
- 9.5 Number of individuals within age cohort in intervention group
- 9.6 Number of individuals within age cohort in control group
- 9.7 Number of individuals suffering health outcome in intervention group
- 9.8 Number of individuals suffering health outcome in control group
- 9.9 Number of person-days of health outcome monitoring in intervention group
- 9.10 Number of person-days of health outcome monitoring in control group
- 9.11 Number of person-days of ill health in intervention group
- 9.12 Number of person-days of ill health in control group

Characteristics of Study Setting

- 9.13 Type of study area (rural / urban / peri-urban)
- 9.14 Percent of participants (in both groups) with access to sanitation

- 9.15 Percent of participants (in both intervention & control groups) using improved water supplies (i.e. protected wells, boreholes, protected springs or standpipes)
- 9.16 Percent of participants treating water (e.g. by boiling) before the start of the intervention
- 9.17 Percent of participants using covered water vessels before onset of study

10 Target: Water Quality

10.1 How important are water quality targets in evaluating program success?

Important. These are how we judge the effectiveness of SODIS.

10.2 Was water quality tested to evaluate the impact of the program/product? If yes, go on to the rest of section 10.

Yes. Unfortunately they did not know the exact details of the remaining questions.

10.3 Is "water quality" used as a target/indicator to ascertain if a HWTS program/technology is being utilized effectively?

Yes. See above number.

If yes, please answer the following specific questions:

- 10.4 What standards are used to measure water quality?
- 10.5 Indicator bacterial removal: Initial and final concentration (CFU E.Coli or thermotolerant coliform bacteria/100 ml) and % removal.
- 10.6 Analytic Method (Standard Methods, ISO, etc), Lab or Field Instrument(s) and Detection Limit:
- 10.7 Indicator for viral removal (e.g. F-RNA coliphage)?
- 10.8 Analytic Method (Standard Methods, ISO, etc), Lab or Field Instrument(s) and Detection Limit:
- 10.9 Protozoa removal (e.g. cryptosporidium, giardia)?
- 10.10 Analytic Method (Standard Methods, ISO, etc), Lab or Field Instrument(s) and Detection Limit:
- 10.11 Helminth removal (e.g. ascaris)?
- 10.12 Analytic Method (Standard Methods, ISO, etc), Lab or Field Instrument(s) and Detection Limit:
- 10.13 Laboratory Site:

HWTS units tested
HWTS unit Volume (L) or Flow rate (L/day):
Duration

10.14 Pilot Test Field Site(s):
HWTS units tested:

HWTS units tested: HWTS unit Volume (L) or Flow rate (L/day): Duration:

10.15 Full-Scale Application Site(s): # Units installed: Unit Volume (L) or Flow rate (L/day):

Duration:

- 10.16 Procedures used for Lab Test of this Technology:
- 10.17 Procedures used for Field Test of this Technology:
- 10.18 Sludge or other Disposal Issues:
- 10.19 Contact Person (Principal Investigator or other person(s) responsible for validation studies):

11 Target: HWTS System Performance

No answers here.

Performance is defined as a target specific to the technology being employed in that it "performs" as intended according to its specifications. Not to be confuse with water quality targets which are concerned specifically with the quality of water produced by the system.

11.1 Is "system performance" used as a target/indicator to ascertain if a HWTS program/technology is being utilized effectively?

If yes, please answer the following specific questions:

- 11.2 What standards are used to measure system performance?
- 11.3 Is a performance data sheet with the following information available to potential buyers for each system?

Source: National Sanitation Foundation's "Drinking Water Treatment Unit-Heath Effects" ANSI/NSF 53-1999, Section 7.4 Performance Data Sheet:

- 1. Complete name, address, and telephone number of manufacturer
- 2. Model number and trade designation
- 3. Reduction capabilities of specific contaminants in Table 3 (pH, temperature, total dissolved solids, total organic carbon, turbidity) and Table 4 (alkalinity, hardness, pH, polyphosphate as P, total dissolved solids, temperature, turbidity)
- * name of contaminant

- * average influent and effluent concentration(s) during test period and percent reductions (NOTE: Average concentrations shall be the arithmetic mean of all reported influent or effluent concentrations the detection limit value shall be used for any nondetectable concentrations. The percent reduction shall be calculated from the arithmetic mean of the influent and effluent concentrations)
- * US EPA maximum contaminant level
- * VOC claims
- * testing parameters
- *rated service flow rate in L/min or L/day (gpm or gpd)
- * maximum working pressure in kPa (psig)
- * general installation conditions
- * general operation, maintenance requirements including, but not limited to:
 - frequency of component change or service to system
 - user responsibility
 - parts and service availability
- * manufacturers limited warranty
- * statement that the system conforms to the ANSI/NSF 53 for the specific performance claims as verified and substantiated by test data."
- 11.4 Are the requirements of the said data sheet met for most households?
- 11.5 How important are performance targets in evaluating program success?

12 Target: Behavior/Use (Social Acceptability and Sustainability)

The following section has the purpose of obtaining a large amount of information on how the system changes the behavior of users, if the system is used properly by users, how it is accepted, and if it is sustainable.

12.1 To what extent does available support for operation and maintenance determine program/product success?

This is especially important upon the introduction of the program into a community. Specifically as a family or user begins to learn about a technology that is when it is most important to have technical support available. It is at this time that the SODIS promoters follow-up regularly. Once a user has gotten past this initial stage successfully then it is not as important to have the technical support although KWAHO plans to be always available to the community.

12.2 Do you use frequency of break-downs and requirements of technical support as a basis for evaluating if a program/product is effective and successful?

Not that much.

Rate of Adoption and Sustained Use

We define "rate of adoption (ROA)" as the percentage of uptake of a HWTS practice or product after an initial period of training/education and/or marketing:

We define "rate of sustained use (ROSU)" as the percentage of continued use of a HWTS practice or product after a 1 year of ownership.

ROSU (%) = # of people using the HWTS after 1 year of ownership # of people originally receiving or buying the HWTS

12.3 Do you keep records of the people who initially obtain, use and/or continue to use the HWTS intervention?

Yes we do. This is an important part of determining if the program is successful. In fact we only consider a system successful if it is used continuously by the user. (Note that records/results of uptake have been given to us)

12.4 Do you keep records of the people who are maintaining use of the system after one month of ownership? After one year?

Yes. (See received document)

12.5 Do you maintain those records in a database?

No. We have standard forms for these surveys or records and we keep them as hard copies and files.

12.6 Do you use rate of adoption and sustained use

Yes.

Environmental Sustainability

12.7 What are the wastes created during the entire life cycle of the product? Can these wastes be quantified in terms of cost? (cost/kg waste generated).

We are only now starting to consider the possible wastes of the system. It is expected that the life of these bottles will be 6 months to one year and our initial system. Our initial bottles are only now reaching the end of their useful life and we are waiting to see if the disposal of these bottles will be a problem.

12.8 Are the raw materials used for this technology accounted for in terms of potential environmental impacts? Are these resources renewable?

Answer by Interviewer: the only materials of concern are the plastic bottles which are in fact renewable to a certain extent. Verify this. The organization has not really taken potential environmental wastes into account yet.

12.9 Are there any other environmental cost impacts of the HWTS system?

NA.

12.10 How important are environmental considerations in evaluating if a program/product is effective and successful?

NA.

User Input

12.11 How frequently is user input obtained after a program/product has been employed?

User input is obtained through meetings with the community and through follow-up visits with the users which are conducted twice every week. There are four major zones for the current implementation region to which one principal promoter is assigned. Other promoters are assigned to these zones as well and typically up to 1,500 "users" or households are assigned to each promoter. This is done to achieve the total of 20,000 users currently targeted by the project.

12.12 Do users comment on the ease of operation and maintenance of the program/product? If so, what is their common perception?

The users comment that the system is very easy to use once it has been accepted and understood.

12.13 Do users comment on how much their water has improved due to the program/product? If so, what is their common perception?

Yes they do. In fact it has been said that the water tastes much better. Better than the water treated with watergard.

12.14 How important is user input in evaluating whether a program/product is effective and successful?

Very important. We rely on user comments to make us improve.

Education, Training, and Awareness

12.15 Are education and training available to users even after program implementation? To what extent? Who implements the said education and training? Who funds it?

Yes. We continue with education and training through our follow ups at the households after we introduce the technology.

12.16 In your opinion, how aware are community members of the current threats to health posed by untreated water sources? How aware are they of the technologies available to treat water on a household level?

Not that aware but users of the system are becoming more and more aware of the system and the technology in general.

12.17 How important are these factors in determining program/product effectiveness and success?

Very important. Especially during the early stages of the program.

12.18 Are ongoing training programs provided for staff members?

Yes. As much as possible.

Social Acceptance

12.19 In your opinion, how do users receive the program/product? Are they eager or wary of the new technology?

Answered previously.

12.20 In your opinion, does the program fit well in the culture of the target population?

Yes. Culturally it is not a problem, it only requires a change in attitude.

12.21 Do political considerations ever come into play during implementation? Does local government and community support typically aid in the implementation of these programs/products?

Not that much.

12.22 How important are these factors in determining program/product effectiveness and success?

Important.

13 Target: Economic Sustainability

Not really a consideration with SODIS since the technology system is very cheap. Other questions were addressed in previous sections.

The following section has the purpose of obtaining information on how the system is sustained economically by users and other sources of funding alike. Such information may be used as a target by implementers determining if a program is sustainable financially.

- 13.1 Who is typically responsible for costs incurred during the operation and maintenance of programs and products? What percent of costs are shouldered by each?
- 13.2 Are the costs incurred for the operation and maintenance typically affordable by responsible entities?
- 13.3 Is a cost-benefit analysis conducted for the program/product? Or alternatively, if a cost-benefit (or cost effectiveness) analysis was conducted prior to program/product implementation were the results of the said analysis ever verified with up-to-date field data?
- 13.4 Was a willingness to pay study ever conducted for the target population? If so, what were the methods employed and the results obtained?
- 13.5 How important are economic considerations in evaluating program/product effectiveness and success?

14 Other Types of Approaches and Questions

Section not addressed.

HWTS implementation activities run as for-profit business enterprises will have an extensive set of additional or alternative targets, related to sales, marketing, supply chain, labor, quality control/quality assurance, product safety, etc. that have NOT been covered here. We will need to address for-profit implementation models in later iterations...

15 Qualitative Comments and Final Thoughts

15.1 Achievements to date of this program/product implementation?

They feel that they have achieved all the targets they set out to achieve in the first year of program implementation. These were termed "activities" and they said that they hit 90 to 95 percent of all activities they intended to complete.

15.2 Failures or limitations to date of this program/production implementation. What improvements might be suggested? Research to be conducted?

We want to see a greater expansion and more promoters and bottle distributors.

- 15.3 Comments Pertaining to Social Acceptability/Customer Satisfaction: None.
- 15.4 Comments Pertaining to Financial Viability/ Sustainability: None.
- 15.5 Comments Pertaining to Economic Viability/Sustainability: None.
- 15.6 Comments Pertaining to Institutional Viability/Sustainability: None.
- 15.7 Please Rate the Following on a Scale of 1 to 10 in terms of

Importance in Pre-Implementation of the Program/Product:

- 39. Scenario or Current Situation of Region designated for implementation: 10
- 40. Household Practices of Region designated for implementation: 10
- 41. Availability of Resources: 10
- 42. Training and Education Programs: 9
- 43. Available Marketing/Distribution Methods: 10
- 44. Funding: 10

Importance in Post-Implementation /Monitoring /Evaluation of the Program/Product:

- 45. Health Outcome: 10
- 46. Water Ouality: 10
- 47. Performance: 10
- 48. Frequency of required Maintenance: 9
- 49. Available Support for Operation and Maintenance: 10
- 50. Rate of Adoption and Sustained Use: 10
- 51. Environmental Sustainability: 10

- 52. User Acceptance: 10
- 53. User Education and Awareness: 10
- 54. Involvement of Other Organizations: 9
- 55. Political Climate: 9
- 56. Economic Sustainability: 10
- 57. User Willingness to Pay: 10

15.8 What are the future plans of the organization? What improvements would you like to see or suggest in the current point-of-use water treatment field?

We at KWAHO always like to ask: after water what? Meaning that we want to look at all aspects of life that can make a person more healthy. We want to expand SODIS as much as we can and address other aspects that can help people lead healthier lives. We also want to look into poultry keeping and teaching the woman in the family to make money while the man is away at work.

15.9 Any additional comments:

None.

16 Publications

No direct publications given but there were some SODIS program documents given to us as hard copies and electronically. These need to be assimilated into this survey at a later time along with other project notes.

- 16.1 Please List All References to Published Studies (s) Describing program/product implementation (please provide electronic or hard copy if possible):
- 16.2 Email address of corresponding study author:
- 16.3 Year of study
- 16.4 Country of study
- 16.5 Type of home water treatment and safe storage intervention
- 16.6 Period of intervention study (how long did the intervention study run for?)
- 16.7 Relevant Websites

Sample of completed HWTS Household Survey	Version 3 as applied to a household
in Mathuru, Kenya.	

Thesis Pages: 310 – 319

WHO IWG Household Survey Tool: Version 3 January, 2005

			ue and I are working to improve water systems in
			area using that helped brove these systems. In this survey we would like
	lk a person in the household that u		
Is th	at person currently available to tal	k with us	? (Circle one).
	Yes	1	CONTINUE TO NEXT SECTION
	No	2	
Whe	_	ack to tal	lk to that person? (Write this down).
	Day		
	Time: Hrs Minut	es	
	•		We promise that neither your name nor your ople here. Only a number will be used to identify
1 BA	CKGROUND INFORMATION		
	and Time: 3:40 PM (January 13, ttion: Mathuru	2005)	
City	Number of the questionnaire : <mark>Mathuru</mark> ince: <mark>Central</mark>		
First	, we will ask you some general in	formation	about yourself:
1.2	Respondent's status in the house	ehold. (W	rite this down).
	Father		1
	Mother		2
	Grandfather		3
	Grandmother		4
	Other	-	15
1.3	What is your age, please? (Wr (ESTIMATE IF AGE IS STA		

1.4 Sex of the respondent (*Record without asking*).

Male	1
Female	<mark>2</mark>

2 WATER USE PRACTICES

2.1 Where do you collect your drinking water from?

(DO NOT READ, MARK OR WRITE ALL ANSWERS OF THE RESPONDENT.)

Running water supply inside the house	1	Go to question 2.2
Water supply from city outside the house	2	
Water supply from city outside the house		
Own well	3	
Public well	4	
Creek or a river	5	
Lake or a pool	6	Go to question 2.4
Hole	7	
Water vendor	8	
Canal or a ditch	9	
Other (WRITE THIS DOWN):	15	

2.2 Who usually collects drinking water?

(DO NOT READ, MARK OR WRITE ALL ANSWERS OF THE RESPONDENT.)

Father	1
Mother	2
Grandfather	3
Grandmother	<mark>4</mark>
Child	5
Other (WRITE THIS DOWN)	15

2.3 Do you store drinking water at home?

Yes	1 1	
No	2	Go to question 2.8
DIFFICULT TO ANSWER	99	Go to question 2.8

2.4 What containers do you usually store drinking water in?

(MARK THE ANSWERS OF THE RESPONDENTS AND WRITE DOWN NUMBER OF CONTAINERS.)

a) Metal buckets (Go to 2.5)] 1	How many?	
b) Plastic buckets (Go to 2.5)	<mark>2</mark>	How many?	_ <mark>2</mark> _
c) Ceramic vessels (Go to 2.5)	3	How many?	
d) Small pans (Skip to 2.6)	4	How many?	
e) Jerry can (Skip to 2.6)	5	How many?	
Other (WRITE THIS DOWN):	15	How many?	

2.5 Are the buckets and ceramic vessels always covered?

Yes	1
No	2
DIFFICULT TO ANSWER	99

2.6 Approximately how many days do you store drinking water in your containers before it is finished?

(WRITE THIS DOWN): |____|__0_|

2.7 How do you take drinking water from your containers?

(DO NOT READ, MARK OR WRITE ALL ANSWERS OF THE RESPONDENT.)

Draw water with a small pan	1
Poor directly from it	2
Draw water with a cup	3
Draw water with a scoop	4
Other (WRITE THIS DOWN)	15

2.8 Does anyone ever touch water in your containers with his/her hands? (E.g. when he/she draws water)

Yes	1 1
No	2
DIFFICULT TO ANSWER	99

If the household <u>does not</u> have a HWTS technology, ask the following questions:

2.9 Do you think that the drinking water you use at home is safe/clean to drink?

Yes	1	Move to question 2.10	
No	2	Move to next question	·
DIFFICULT TO ANSWER	99	Move to question 2.10	

2.10 Why do you think that the water is unsafe to drink?

(DO NOT READ, MARK OR WRITE ALL ANSWERS OF THE RESPONDENT.)

Water is dirty / turbid	1
Water is infected with microbes	2
Water contains larva, worms etc	3
Causes malaria	4
Other (WRITE THIS DOWN):	15
DIFFICULT TO ANSWER	99

3 HWTS PROGRAM/PRODUCT DESCRIPTION

3.1 HWTS Implementation Program/Product Name being used:

SODIS

3.2 Why did you select this HWTS technology for your household as compared to other technologies?

Easy, cheap, and safe.

3.3 Who brought this technology to your attention?

Community Groups. ACK.

3.4 From where do you obtain your HWTS technology and training to use?

Community Groups. ACK.

3.5 How long have you used your HWTS technology?

2 Years.

4 HWTS PROGRAM/PRODUCT USE

4.1 Is the taste of the water better, worse or the same after using the HWTS technology than before?

Better	
Worse	2
No change	3
DIFFICULT TO ANSWER	99

4.5 Since you've begun treating your water, do you use more water, the same amount, or less for drinking?

More water	1
Less water	2
Same amount	<mark>3</mark>
DIFFICULT TO ANSWER	99

4.3 Do you treat all the water you and the rest of the family use for drinking?

Yes	<u>1</u>	Go to question 4.5
No	2	Answer question 4.6
DIFFICULT TO ANSWER	99	

- 4.6 When do you use untreated water for drinking? (WRITE THIS DOWN)
- 4.7 Do you use treated water to wash the dishes and utensils?

Yes	1
No	<mark>2</mark>
DIFFICULT TO ANSWER	99

4.5 Since you started using the HWTS technology, do you feel better?

Yes	<mark>1</mark>
No	2
DIFFICULT TO ANSWER	99

4.6 Who is responsible for treating the water?

Father	1
Mother	2
Grandfather	3
Grandmother	4
Child	5
Other (WRITE THIS DOWN)	15

4.7 Do the children in the household know how to treat the water?

Yes	<mark>1</mark>
No	2
DIFFICULT TO ANSWER	99

5 PERCEPTIONS & ACCEPTIBILITY

5.1 Do you think using the HWTS technology is beneficial for your family?

Yes	1
No	2
DIFFICULT TO ANSWER	99

Why or why not? (WRITE THIS DOWN)

Clean healthy water.

5.2 Is it easy to use the HWTS technology?

Yes	1
No	2
DIFFICULT TO ANSWER	99

5.3 Would you recommend the HWTS technology to others?

Yes	<mark>1</mark>
No	2
DIFFICULT TO ANSWER	99

5.4 Have you had any problems with your HWTS technology?

Yes	1
No	2
DIFFICULT TO ANSWER	99

What problems? (WRITE THIS DOWN)

6 OPERATION AND MAINTENANCE

6.1 Do you perform maintenance on the technology?

Yes	1	Go to next question
No	2	Skip to question 6.3
DIFFICULT TO ANSWER	99	

6.2 How often do you perform maintenance on the technology?

____<u>1</u>___ time(s) every

____6___ [weeks /months / years / post-construction]

6.4 What kind of water do you drink when your HWTS technology is broken/being repaired?

Direct from source	1
Boiled	<mark>2</mark>
Store purchased	3
Waterguard treated	4
Other	15

6.4 Can you tell me what kinds of technical assistance that the village receives to keep the

household water treatment and safe storage system running?

Types of	Ever provided?	If so, by whom?	If so, how often do you
technical support	Ever provided:	ii so, by whom:	receive such support?

	1					
a. Technical:	Yes	_	Government ag	ents		time(s) every
In-person visits	No		NGO			[weeks
from external		, _	Other			nths / years / post-
agencies?	(if No, skip to b) -				struction]
b. Technical:	Yes	_	Government ag	ents		time(s) every
Operator(s)	No		_ NGO			[weeks
attend training	CCM 1:	\ 	Other			nths / years / post-
workshops?	(if No, skip to	<i>c)</i> H	usband	-		struction
c. Technical:	Yes		Government ag	ents		time(s) every
Written manuals/material	No	_	NGO Other			[weeks
supplied?	(if No, skip to	_{d)}	Other		/moi	nths / years / post-
					cons	struction
d. Technical:	Yes	_	_ Government ag NGO	ents		time(s) every
Spare parts provided to the	INO	_	NGO Other			[weeks
village?	(if No, skip to 6.	5) -	Other			nths / years / post-
viiiugo:	(g 1,0) ship to of		·		cons	struction
6.6 Have you ever h	au to obtain spare	1	Continue to 6.			
No			SKIP to Quest		5.0	
	TO.		SKIP to Quest	1011 ().7	
DIFFICULT ANSWER	ТО	99				
L	<u></u>					6.7 Where do
you typically obtain	spare parts?					
From a gover	nment agency (lo	ocal, sta	ate, or national)	1		
From an NGO	O or donor agenc	y		2		
From a privat	e shop			3		
Other (Specif	·y)			15		
6.8 On average, how		you to	travel to this supp	lier?		
Hours travel	one way, or			1		

2

3

Days travel one way, or

No travel required: Parts are delivered to village

		•
Difficult to answer	99	

6.9 In your experience, have the spare parts you needed typically been available right away, or have you had to wait for them to be sent from somewhere else?

Are available immediately		1
Have to wait		2
DIFFICULT	ТО	<mark>99</mark>
ANSWER		

6.10 Where does the money come from to

purchase these parts?

Technician collects money from household	<u>1</u>
Technician receives money from an external agent (government agency, NGO, etc)	2
Other (WRITE THIS DOWN)	15

6.11 Do you keep any spare parts on hand?

Yes		1
No		<mark>2</mark>
DIFFICULT	ТО	99
ANSWER	# 1	

6.12 Have you ever requested technical

assistance for a problem with the HWTS system? [Surveyor: Be sure that the respondent understands that you want to know about requests for assistance, whether or not those requests were fulfilled.]

Yes		1	Go to next question
No		2	Go to end of section
DIFFICULT	ТО	99	Go to end of section
ANSWER			

6.13 How many

times in the past year did have you had a problem for which you requested technical assistance?

____ Times, or ____ Don't know / Not sure

(If zero times, skip to end)

6.14 From whom did you typically request assistance?

Local/District government	1
Local Ministry of Health post	2
State government	3
NGO	<mark>4</mark>
Other (WRITE THIS DOWN):	15

6.15 Did you receive the assistance you needed the last time you asked?

Yes		1	Continue to 6.13
No		2	Go to end of section
DIFFICULT ANSWER	ТО	99	Go to end of section

	No	2	Go to end of section	
	DIFFICULT TO ANSWER	99	Go to end of section	
a	rage, how long did you have to w b [days / weeks / Don't know / Not sure			6.16 On you needed?
7 W	VILLINGNESS TO PAY			
7.4	Imagine that your filter is broken yes, how much are you willing to		-	uy the new one and, if
	For surveyor: we will try to obta split-case method. Each time you 1100 KS, 1200 KS) then try to fit	ı do an in	terview, start with different in	nitial prices (1000 KS,
	For example in one case you mig KS?" Yes. "Will you pay 1300 K			"Will you pay 1200
	The actual price is something in the last price 1200 in the answer		in this case,1200 and 1300.	So you will write down
<mark>300</mark>				
7.5	Do you think that your neighbor	s will buy	HTWS for this price?	
Yes	. <mark>.</mark>			
7.6	How much do you think it costs	to produc	ce this product?	
<mark>20.</mark>				
8 E	HOUSEHOLD COMPOSITION	N AND W	VEALTH INFORMATION	
8.1	Number of people in the hou	sehold th	at use the HTWS technology	<u>5</u>
8.2	Number of children under ag	ge 5 <mark>2</mark>		
8.3	Number of rooms in house?	<mark>4</mark>	<u> </u>	
84	Who in the household works	s outside t	he home and what does s/he o	10?

Grandmother and Grandfather both work in farm not too far from home.

8.5 On average, how much money do you spend each month on necessities for the family (including food, tools, supplies, transportation)?

4,000 KSh.

8.6 Where do you go to buy necessities (food, washing soap, etc)?

Town Center.

8.7 How many hours are you normally outside the home per day?

8.

8.8 What do you drink when you are not at home?

Come home to drink.

8.9 Do you ever purchase water? If yes, from where?

No.

9 KNOWLEDGE OF DIARRHEA

9.1 What causes diarrhea?

(DO NOT READ, MARK OR WRITE ALL ANSWERS OF THE RESPONDENT.)

Drinking dirty water	<mark>1</mark>
Eating contaminated food	2
Flies/insects	3
Non-observance of hygiene/poor hygiene	4
Weather	5
Spirits	6
Other (WRITE THIS DOWN):	15
DIFFICULT TO ANSWER	99

9.2 At what point (when) do you begin treating diarrhea? (WRITE THIS DOWN)

Right away.

9.3 How do you treat diarrhea in the household?

(DO NOT READ, MARK OR WRITE ALL ANSWERS OF THE RESPONDENT.)

Increase drinking liquids	1
Reduce drinking liquids	2
Use packets with special salt (for rehydration)	

Make sweet-salty solution	4
Take medicines, (such as antibiotics)	5
Boil water	6
Other (WRITE THIS DOWN): Go to clinic.	1 <u>15</u>
DIFFICULT TO ANSWER	99

9.4 Where do members of your family receive treatment for diarrhea outside the household?

(DO NOT READ, MARK OR WRITE ALL ANSWERS OF THE RESPONDENT.)

In hospital	1
Health center	2
Private clinic/doctor	3
Pharmacy	4
Other healers	5
Other (WRITE THIS DOWN):	15
DO NOT SEEK TREATMENT AT ALL	99

9.5 Who is responsible for caring for the individual with diarrhea?

Father	1
Mother	2
Grandfather	3
Grandmother	4
Child	5
Other (WRITE THIS DOWN)	15

10 OBSERVATION BY THE INTERVIEWER

House type: Floor type:

How is the toilet /bathroom equipped in the household? (DO NOT READ, MARK OR WRITE ONLY ONE ANSWER.)

Improved latrine	1
Dry cesspool	2
Bathhouse without running water	3
Bathhouse with running water	4
Other (WRITE THIS DOWN):	15
DIFFICULT TO ANSWER	99

Is there a special place for washing hands?	Yes - 1	No-2
Is there soap in the place they wash hands?	Yes - 1	No-2
Does the household have electricity?	Yes - 1	No-2
Does the household have gas?	Yes - 1	No-2

APPENDIX C – WHO GUIDELINES FOR DRINKING WATER QUALITY, SUPPLEMENTAL INFORMATION

Sections adapted from:

- 1. World Health Organization (WHO). (2004) "Guidelines for Drinking Water Quality 3rd Edition". Website: http://www.who.int> (Last Accessed: April 7, 2005).
- 2. World Health Organization (WHO). (2001) "Water Quality: Guidelines, Standards, and Health; Assessment of risk and risk management for water-related infectious disease". World Health Organization, Geneva, Switzerland.
- C.1 Harmonized Assessment of Risk and Risk Management for Water-Related Infectious Disease

A group of professionals with expertise in the fields of drinking water, irrigation, wastewater, and recreational water with expertise in public health, epidemiology, risk assessment, management, economics, communications, and the development of standards and regulations met between 1999 and 2001 to discuss approaches to risk assessment and management of water-related microbial hazards. The product of this meeting was a set of efficient and affordable guidelines addressing the principal issues of concern in regards to the impacts of water on health. (WHO Foreword, 2001)

The 3rd Edition GDWQ presents a harmonized framework that consists of an iterative cycle comprising an assessment of risk, health targets linked to the wider public health context, and risk management all being presented in the context of environmental exposure and tolerable risk. Acceptable limits of microbial contamination of drinking water fit into this cycle as a means for quantifying this risk in terms of empirical and measurable data. A key component of the harmonized framework is the use of an inclusive range of tools for the assessment of risk, including epidemiology and information collected during the investigation of outbreaks of waterborne disease, as well as the formal risk assessment process. (WHO Chapter 1, 2001).

The guidelines serve as an international point of reference for water quality issues. Although the guidelines present numerical values for water quality measures, the real intent of the guidelines are to propose "good practice" or "adequate safeguards" in minimizing risk to deleterious health effects attributable to water-borne pathogens. It must be noted that the 3rd Edition GDWQ are not meant to be adopted directly in every scenario across the globe. In fact, the organization recognizes that social and environmental conditions may require standards that vary significantly from those recommended by the guidelines. That being said, the 3rd Edition GDWQ does suggest that a risk-benefit approach be adopted to address water quality related issues.

For more information of the overall risk assessment framework in which the water quality limits were developed, the reader is referred to the second reference above (WHO, 2001).

C.2 Guidelines for Drinking Water Quality (GDWQ)

Microbial risks are concerned with a variety of different pathogenic micro-organisms. However, specific information on these various micro-organisms is not utilized in the derivation of fixed water quality limits. Instead, a generalized approach based on tried and tested principles such as fecal pollution prevention and sound engineering practice are used. As such, the results are end-product fixed water quality limits which can be evaluated by microbial analysis of finished water at the point of consumption. The fixed water quality limits for microbial contamination are divided into three categories: end-product standards for fecal indicator organisms, operational guidelines for source water protection, and adequate treatment. The first two are discussed as follows (WHO, 2001):

Fecal Indicator Organisms. Indicator organisms are used in setting fixed water quality limits due to the inherent difficulty involved in measuring the presence of actual pathogens and determining the probability that these pathogens will actually cause disease. The logic followed by the guidelines is that the absence of these organisms is the best determinant of whether water is safe. Therefore, if indicator organisms are detected above certain accepted limits, water is considered to be contaminated and not suitable for human consumption. Escherichia Coli and to a lesser extent thermotolerant coliform bacteria are considered prime indicators due to the following characteristics displayed by each: (1) universally present in the feces of humans and warm-blooded animals, (2) readily detected by simple methods, (3) do not grow in natural waters, and (4) persistence in water and removal by water treatment similar to water-borne pathogens. Frequent simple tests on a water source are considered more favorably than occasional expensive tests; this is a primary reason why E. coli. is considered an effective indicator organism. The standard set is that there should be no presence of E. coli. in any 100 milliliter sample of water intended for human consumption. The limit set is recognized to be high and the standard allows for this limit to be lowered in areas where practical considerations do not allow for water sources satisfy the standard proposed. (WHO, 2001)

Operational Guidelines. Using the same logic applied previously, operational guidelines serve to address the problem of microbial contamination not through setting fixed water quality limits pertaining specifically to the pathogens but instead by addressing issues of proper source water protection and treatment. This portion of the guidelines sets fixed water quality limits or recommendation for proper treatment methodology or more specifically what treatment should be applied for certain source waters. (WHO, 2001)

The reader is referred specifically to the World Health Organization's "Guidelines for Drinking Water Quality (3rd Edition, 2004)" for specific fixed water quality limits relating to microbial contamination and operational guidelines.

As mentioned previously, the guidelines serve as a comprehensive framework addressing all aspects of water quality from raw water to distribution. The framework has five key components (WHO GDWQ 3rd Edition, 2004):

- **Health-based targets** based on an evaluation of health concerns;
- **System assessment** to determine whether the drinking-water supply (from source through treatment to the point of consumption) as a whole can deliver water that meets the health-based targets;
- **Operational monitoring** of the control measures in the drinking-water supply that are of particular importance in securing drinking-water safety;
- Management plans documenting the system assessment and monitoring plans and describing actions to be taken in normal operation and incident conditions, including upgrade and improvement, documentation and communication; and
- **System of independent surveillance** that verifies that the above are operating properly.

The guidelines also provide a large amount of supporting information in which microbial aspects/fixed water quality limits are included. Other supporting information includes: chemical aspects, radiological aspects, and acceptability aspects.

The control of the microbial and chemical quality of drinking-water requires the development of management plans, which, when implemented, provide the basis for system protection and process control to ensure that numbers of pathogens and concentrations of chemicals present a negligible risk to public health and that water is acceptable to consumers (WHO GDWQ 3rd Edition, 2004). These "water safety plans" comprises system assessment and design, operational monitoring and management plans, including documentation and communication. Water Safety Plans utilize the multiple-barrier principle, the principles of hazard analysis and critical control points (HACCP), and other systematic management approaches. The plan provides for an organized and structured minimizes the chance of system failure and provides contingency plans to respond to system failures or unforeseen hazardous events. (WHO GDWQ 3rd Edition, 2004)

APPENDIX D – ASSORTED INFORMATION RECEIVED FROM ORGANIZATIONS VISITED IN KENYA

The following documents are included in this Appendix:

	Document	Total Pages	Page Numbering in Thesis
1.	NETWAS: Smiley Template	1	Page 325
2.	KWAHO: Updated Version of Table 4.2	4	Pages 327 – 330
3.	Bushproof/MedAir: Information Leaflet	2	Pages 332 – 333
4.	ACK: Monthly Health Monitoring Form	1	Page 335
5.	SWAK: Monitoring Tool	1	Page 337
6.	CDN: Brochure	1	Page 339

NETWAS:	Smilov	Tomn	lata
NETWAS:	Sinney	1 emb	ıate

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KENYA WATER FOR HEALTH ORGANIZATION

(KWAHO)

KIBERA SODIS WATER PROJECT MID TERM REVIEW REPORT

Table II Summarised results (with a brief discussion.

(specify the implementation process for each activity and timeframe	achievement)
 (This will be done in the first 6 weeks of the project implementation) This was done through community meetings, individual discussions and house visits. Through meetings/workshops 	 Enlightened Community about SODIS project Trainers/Supervisors identified with good leadership qualities Peers Promoters identified with good communication skills and leadership qualities. Areas of operation identified. Improved dissemination of SODIS
 The leaflets are used for dissemination of information for SODIS. The posters are used as a teaching tool for diarrhea. 	 The community are enlightened on the issues related to SODIS Improved perceptions Enhancing communication
	This was done through community meetings, individual discussions and house visits. Through meetings/workshops The leaflets are used for dissemination of information for SODIS. The posters are used as a teaching tool

Activity 3 Training of 4 SODIS/Trainers/ Promoter	 Training the Promoters on the principles of SODIS. Awareness creation on hygiene and health matters. Training on monitoring and evaluation Leadership training. Training on communication skills Workshop, visit, demonstration and seminars 	 Promoters with good quality training. Improved communication skills Long Term Promoters Promoters with good leadership skills
Activity 4 Training of 20,000 user Families in 4 zones Activity 5 Training of 3 schools, 71 teachers and 3250 pupils	 This is done throughout the year. Training on principles of SODIS Awareness creation on hygiene and health matters. Training on leadership Training the community on the important of SODIS water quality The first training done in the month of June and July 2004 The second training will be done in September and October 2004 	 Overall improvement on user families health Reduced diarrhea cases in children below five years of age Long term SODIS water dissemination Enlighten families on hygiene and health issues Improved standard of living of the teachers and the pupils Teachers and pupils are able to use SODIS Long term SODIS dissemination and awareness
Activity 6 Follow -up visits of the households - for supports and data collection on bottle supply and acceptance (regular and non-regular users) - continuous evaluation of user acceptance	This is done the first four weeks after training then once a month throughout the year	 That the user families are following the principles of SODIS Knowledgeable SODIS users

Activity 7 Setting up local PET bottle supply schemes in the communities	 To have 10 no. Discussions with the hotels and Restaurant in and around the city. Discuss with shop owners on ways of how to get recycled PET bottle and sell them at a cheaper price. 	 Availability of PET bottles for the community Cheap and affordable PET bottles Alternative supply sources 		
Activity 8 Networking for SODIS users (This will involve user families, Local leaders, Teachers, Health workers, and youths, SODIS groups).	 To hold two seminars for user families selected at random within the 4 zones To share experiences on the principles of SODIS. Discussion among users User groups and user clubs 	 Improved knowledge of the user families on SODIS premonition. To come up with well-structured scheme in collection and constant supply of PET-bottles in and around town. Familiarity with general use of SODIS 		
Objective 2 Assess health benefits of SODIS through reduced diarrhea particularly to children less than five years of age Process (specify the implementat process for each activity and timeframe		Output achieved in Detail and Percent(see indicators on assess th achievement)		
Activity 1 Do occasional and consistent water test of raw water (community water sources) and random testing of SODIS treated water of the user families.	 Collection of water samples at random for testing. Analysis of data 	 Good water quality without microorganism Maintaining Records 		
Activity 2 Survey 1(pre-project) of sample 400 households for baseline data on diarrhea incidences.	 Random data collection within the user families on diarrhea cases and other health related cases compares with post- project data of diarrhea cases within the same areas. Collection of data from the clinics in project zones. 	 Reduced diarrhea cases within the user families and related cases. No. of diarrhea cases recorded from the sample household preproject and post project. No, of diarrhea cases recorded at the clinics. 		
Activity 3 Survey 11(post-project) of sample 400 households for baseline data on diarrhea incidences.	 Random data collection within the user families on diarrhea cases and other health related cases compares with post- project data of diarrhea cases 	• Will be done next month.		

	 within the same areas. Analyzing of data Collection of data from the clinics in project zones. 		
Activity 4 Report Writing	 This is done monthly, quarterly and annually Introduction of Report Formats Setting up date for Reports 	 Project reports are done monthly Dates for report followed Report format followed 	

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SODIS

MONTHLY HEALTH MONITORING FORM

Diseases suffered in the ast one month	red in the disease	Date	AGE BRACKET (YEARS)		Tre: Hospital	atment Herbal	(tick) Nothing	
more the month			Children (Less than 5 yrs.)	Teenagers (6 to 15 yrs.)	Adults (More than 15 yrs.)			
Diarrhoea								
Typhoid								
Dysentery								
Cholera								
Worms								
Malaria								
Others:		-	_					

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Society for Women and AIDS in Kenya

MONTITORING TOOL FOR SWAK GROUPS

Name of the group:
Contact person: Position in the group:
Address: Telephone:
Target group: PLWH / Widows / Women / Orphan caretakers / Youth / others Total number of members:
Registered with Ministry of Cultural and Social Services: yes / no Bank account: yes / no
Major activities: Merry go round / AIDS awareness / Orphan support / Income generating Activities / Widow support / Home Based Care / Feeding program / Safe water / Pottery If others please state which:
Major achievements of the group:
Major challenges of the group:
Any suggestions for SWAK:
Date:

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APPENDIX E – HWTS TECHNOLOGY SELECTION TOOL

The following documents are included in this Appendix:

	Document	Total Pages	Page Numbering in Thesis
1.	HWTS Technology Selection Tool (Paper and Electronic Copy)	18	Pages 342 – 359
2.	Results for Application to PSI Mombasa (Kwale District)	18	Pages 361 – 378
3.	Results for Application to KWAHO (Kibera)	18	Pages 380 – 397
4.	Results for Application to Bushproof/MedAir (Machakos District)	18	Pages 399 – 416

SELECTION TOOLS FOR HWTS SYSTEMS IN DEVELOPING CO	<u>OUNTRIES</u>
HWTS Technology Selection Tool (Paper and Electronic Copy)	
11 vv 15 Technology Selection Tool (Taper and Electronic Copy)	

Results for	Application	to PSI Mombasa	(Kwale District)
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Thesis Pages: 380 – 397

Results for Application to Bushproof/MedAir (Machakos District)					
Thesis Pages: 399 –	416				

APPENDIX F – WATER SOURCE SELECTION CHART

Source: Skinner, Brian. (2003) "Small-scale Water Supply: A Review of Technologies". ITDG Publishing. 103-105 South Hampton Row, London, UK.

Thesis Pages: 418 – 419