# Monitoring Effective Use of Household Water Treatment and Safe Storage Technologies in Ethiopia and Ghana

by

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## ABSTRACT

Household water treatment and storage (HWTS) technologies dissemination is beginning to scale-up to reach the almost 900 million people without access to an improved water supply (WHO/UNICEF/JMP, 2008). Without well-informed and effective use as intended, these promising technologies will not be deployed to maximum advantage. Successful scale-up thus requires monitoring and evaluation (M&E) of behavioral indicators to achieve safe water and improved health. This thesis offers a consistent framework for the operational monitoring of Effective Use of a set of eight HWTS technologies including dilute bleach solution, Aquatabs, solar disinfection (SODIS), cloth filters, the ceramic pot filter, the biosand filter, PUR and associated safe storage practices.

During late 2007, key members of the WHO-hosted International Network to Promote Household Water Treatment and Safe Storage ("The Network") who are involved with M&E of HWTS systems were contacted. A literature search on monitoring efforts involving the eight HWTS followed. The author traveled to Ethiopia and Ghana during January 2008 to investigate multiple HWTS implementations and field-test preliminary monitoring methods as part of that process. Interviews were conducted with HWTS Network partners and the users of their HWTS products, household water quality testing was conducted, and documents on usage and monitoring were collected and compiled.

A framework for operational monitoring of Effective Use behaviors at the household was developed through these efforts. The framework consists of a set of Monitoring Observations specific to each technology, comprised of the five categories of Treatment, Safe Storage, Maintenance, Replacement Period, and Physical Inspection, as well as a set of common Water Quality Monitoring paramaeters. Field methods for measuring turbidity, residual free available chlorine, and *E.coli* as an indicator of microbiological water quality are described that require minimal training, time, and equipment and that are cost-effective (US $3.60 for a complete set of household tests).

**Keywords** household water treatment, safe storage, behavior, monitoring, water quality

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I wish to dedicate this work to my mother, Mara Speiden Stevenson, for whom I took on this degree and have endeavored to finish in her absence.

Thank you to all who have seen me through this year. To Susan for your patience and guidance, and to the Network for your contributions and vigilant service, I thank you.

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| | |
|---|---|
| AED | Academy for Educational Development |
| AWD | Acute Watery Diarrhea |
| BOD | Burden of disease |
| BSF | Biosand Filter |
| CAWST | Center for Affordable Water and Sanitation Technology |
| CFU | Colony forming unit |
| CT | Ceramica Tamakloe |
| CWP | Ceramic Water Purifier |
| DALY | Disability Adjusted Life Year |
| EAWAG | Swiss Federal Institute for Aquatic Science and Technology |
| *E.coli* | *Escherichia coliform* |
| FAC | Free Available Chlorine |
| GDWQ | *Guidelines for Drinking Water Quality* |
| G-Lab | Global Entrepreneurship Lab, a course at Sloan School of Management |
| GWEP | Guinea Worm Eradication Project |
| GWSC | Ghana Water and Sewerage Corporation |
| HDPE | High-Density Polyethylene |
| HIP | Hygiene Improvement Project |
| HWTS | Household Water Treatment and Storage |
| JMP | Joint Monitoring Program |
| KHC | Kale Heywet Church |
| KWAHO | Kenya Water for Health Organization |
| M&E | Monitoring and Evaluation |
| MDG | Millennium Development Goals |
| MF | Membrane Filtration |
| MIT | Massachusetts Institute of Technology |
| MPN | Most Probable Number |
| NGO | Nongovernmental organization |
| NTU | Nephelometric turbidity unit |
| O&M | Operations and Maintenance |
| PF | 3M Petrifilm |
| PFP | Potters for Peace |
| PHAST | Participatory Hygiene and Sanitation Training |
| PHW | Pure Home Water |
| POU | Point of Use |
| PSI | Population Services International |
| QMRA | Quantitative Microbial Risk Assessment |
| RADWQ | Rapid Assessment of Drinking Water Quality |
| SANDEC | Department of Water and Sanitation in Developing Countries at EAWAG |
| SNNPR | Southern Nations, Nationalities and Peoples Region |
| SODIS | Solar Disinfection |
| TC | Total Coliform |
| TSS | Total Suspended Solids |
| TU | Turbidity units |
| U5 | Children under five years of age |
| UNICEF | United Nations Children's Fund |
| USAID | United States Agency for International Development |
| WHO | World Health Organization |
| WSP | Water Safety Plan |

# 1. Introduction

## *1.1 The Need for Safe Drinking Water at the Point of Use*

In 2008 alone, 1.5 million people will perish due to the ravishes of diarrheal diseases, most of them before their fifth birthday (JMP, 2008). This figure has decreased significantly from the five million deaths per year throughout the 1970s, thanks in large part to vigilant implementation of lifesaving technologies such as Oral Re-hydration Therapy and expansion of borehole, piped distribution networks, and other improved water supplies in rural and urban localities, respectively, throughout poor- and middle-income countries. Despite these gains, however, death from dehydration due to diarrhea is still an unacceptably large problem, with impacts disproportionately affecting the poor. Diarrheal diseases in high income countries account for only 418 deaths or 0.2% of the total burden of disease (BOD) as calculated in total Disability Adjusted Life Years (DALYs)[1], while in low- and middle-income countries diarrheal disease accounted for 1.6 million deaths and 3.8% of DALYs in 2001 (Lopez, 2006). The countries of Sub-Saharan Africa shoulder the lion's share of diarrheal disease burden, as shown in Table 1.

**Table 1 Regional Diarrheal DALYs**

| Data from 2001 (Lopez, 2006) | Low/Middle Income Countries (1000s of DALYs) | Latin America and Caribbean (1000s of DALYs) | Sub Saharan Africa (1000s of DALYs) | East Asia and Pacific (1000s of DALYs) |
|---|---|---|---|---|
| **DALY U5*** | **53,000** | **1,888** | **20,707** | **7,017** |
| **DALY Total** | **58,700**<br>4.2% of total BOD**;<br>#6 in rank of total BOD | **2,632** | **22,046**<br>6.4% of BOD, #4 in continental BOD | **8,782** |

*U5 refers to children under five years of age.
** BOD refers to Burden of Disease

Fecal-oral transmission of diarrheal diseases accounts for 85% of all preventable DALYs worldwide due to their significant effect on the population under five years of age. Throughout the past twenty years, a few influential reports on whether the vector path is mostly waterborne or water-washed have produced differing directions in policy and budgetary planning. From a health-based perspective, the best option for securing safe water for domestic use is the same that is available to over 99% of high-income country dwellers: clean piped water consistently available within the household. Water at the household tap eliminates both of the contamination routes identified by Cairncross et al. (1996), namely 'public domain' contamination at the source (including un-safe sources, and the processes of filling and transporting) and 'domestic domain' contamination

[1] Using a cost effectiveness analysis, the health benefits of an intervention are measured in Disability Adjusted Life Years (DALYs) in order to compare diverse waterborne health outcomes ranging from brief self-limiting disease to fatal episodes. DALYs incorporate both a disability weight associated with the outcome (a measure of severity of disease/ disability on a scale of 0 to 1, with 1 symbolizing death) as well as the duration of the outcome's effect in years. The disability weight given to diarrheal diseases is 0.105 in Disease Control Priorities in Developing Countries (Jamison, 2006). Given this weight, one child's death accounts for 30 DALYs (Jamison, 2006). DALYs allow health benefits and cost to be compared across a variety of interventions (Havelaar, 2003).

within the household (through handling, storage and use). Both of these contamination pathways must be dealt with in order to consistently reduce the likelihood of diarrheal disease. However, in low-middle income countries, the capital expenditure required for the large infrastructure projects necessary to treat and pipe water is often unavailable.

## *1.2 Development of Household Water Treatment and Safe Storage (HWTS) Technologies*

In response to the logistical and financial constraints inherent in providing piped or other "improved" supplies to the people of developing countries, a new set of household technologies has been developed and disseminated to many places in the developing world during the past fifteen years. While these methods are employed in the home and can be less costly both in capital expenditure as well as achieving similar health impacts as improved source interventions, they require proper and consistent implementation, use, and maintenance, to achieve effect.

Such products include safe storage containers as distributed by the Centers for Disease Control (CDC) for use in their Safe Water System (SWS), dilute bleach-based chlorinating solutions, solid tablet chlorine disinfectants such as Medentech's Aquatabs, solar disinfection techniques such as SODIS, simple cloth filters as used in the Guinea Worm Eradication Program, ceramic pot filters such as those promoted by Potters for Peace, scaled-down slow sand filters such as the biosand filter, and sachets of solid flocculent and disinfectant such as Proctor and Gamble's PUR™. Among the many HWTS technologies, these are the technologies that will be researched in this thesis. While various HWTS technologies also exist to treat specific chemical constituents such as arsenic and fluoride, these technologies will not be covered in this thesis. All of these HWTS techs are in the scale-up stage throughout the world and are encountering constraints based on distribution, user acceptance, effective use of the products, training methods, sustainability, etc.

## *1.3 The International Network to Promote Household Water Treatment and Safe Storage*

One hundred and seventeen organizations currently comprise the World Health Organization-hosted International Network to Promote Household Water Treatment and Safe Storage. This inter-disciplinary public-private partnership brings together leading proponents of HWTS from government, industry, academic and non-profit sectors. Until now, efforts to monitor and evaluate (M&E) HWTS implementation and scale up have been largely restricted to individual organization's initiatives. Information on M&E methods, targets, indicators, tools and results are few and exist mainly in unpublished literature. While transfer of information is one key constraint to scale-up efforts, there has been little coordination within the Network towards a common set of M&E methods, targets, tools and indicators. In order to improve the implementation and scale up of HWTS, the Network needs to share information and experiences, and this thesis endeavors to develop one opportunity for information sharing on M&E.

## *1.4 The World Health Organization Guidelines for Drinking-Water Quality, 3rd Edition*

This thesis provides a common framework for monitoring HWTS, building on the structure of the WHO 3rd Edition *Guidelines for Drinking-Water Quality* (GDWQ) to derive monitoring frameworks for a range of core HWTS technologies. In the 3rd Edition GDWQ, the WHO lays out a comprehensive framework for ensuring safe drinking-water, comprised of these requirements:

- Well established health-based targets
- Systems that are properly constructed, managed and operationally monitored
- Establishment of an independent system for surveillance monitoring.

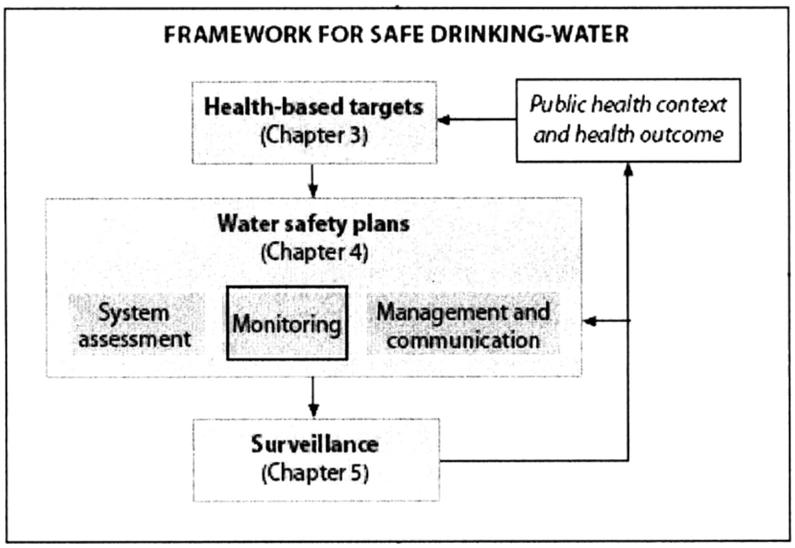


**Figure 1 WHO Framework for Safe Drinking-Water (WHO, 2004)**

### 1.4.1 Health-Based Targets

The health-based targets used by the WHO provide a thorough method with which to ensure drinking water quality. Four types of health based targets are outlined. These targets are arranged from the general to the specific, as described below.

*Health Outcome Targets*

Health outcome targets are specified reductions in prevalence of a given waterborne disease or water-related condition in places with high existent burdens. When disease burden attributable to water-related disease is high (i.e., given an emergency situation, endemic exposure, chemical contamination, etc.), changes in prevalence of such diseases through a given treatment intervention can be measured. If epidemic conditions do not exist, analysis based on exposure estimates and dose-response relationships is conducted in the form of quantitative microbial risk assessment (QMRA) in order to determine tolerable levels of risk in a given population.

*Water Quality Targets*
Many normally occurring components of natural waters as well as anthropogenic chemical pollutants have been shown to be acutely toxic, carcinogenic or otherwise harmful. Chemical contamination of water is of the utmost concern for health-based monitoring. The short and long term acceptable concentrations of over 125 chemical contaminants has been characterized in the WHO 3rd Edition *Guidelines*, as based on consumption levels of drinking water. These recommendations are called "water quality targets" (WQTs) and they aid in the determination of necessary treatment measures.

*Performance targets*
Performance targets refer to intended reductions of microbial concentrations between the feed water and the finished drinking water product. Indicator microbes are measured as proxies for groups of pathogens and are reported as presence/absence, absolute risk, or percent/log reduction from influent. Measurement of more than one indicator is often needed to show different sources of contamination. Developing performance targets relies on knowledge of tolerable disease burden in conjunction with severity of disease outcomes and dose-response relationships for a given pathogen or target microbe (WHO, 2004).

*Specified technology targets*
The regulation of small water treatment systems at the household or community level is hindered by lack of monitoring and oversight. Once these systems are in place, local governments and implementing organizations often lack the capacity to develop functional maintenance and monitoring programs, diminishing the prospects for proper management or effective treatment. Through developing specified technology targets, the WHO notes that national governments can aid community-scale organizations by developing standards and recommendations concerning applicability, implementation, and operation of smaller systems. Because the testing of compliance to these targets is resource intensive, national training protocols and adequate support systems can be developed in order to ensure better results. The WHO 3rd Edition *Guidelines* set no specified technology targets but rather recommends that this work take place at a national level.

### 1.4.2 Water Safety Plans
Health-based targets are very useful in the formulation of Water Safety Plans (WSPs), the WHO recommended methodology for ensuring safe provision of water (see Figure 1 WHO Framework for Safe Drinking-Water (WHO, 2004)). WSPs consist of a comprehensive *system assessment* at the outset of the project, encompassing a thorough investigation of hazard identification and health-based targets. Next, control measures are designated to deal with the hazards laid out in the system assessment. A means of *operational monitoring* is identified to ensure that each control measure is operating adequately. Finally, *management plans* are established for routine maintenance, upgrading or replacing the system, and for operation under normal as well as during hazardous conditions. Through these steps, the WSP identifies hazards to health and sets a plan in motion to adequately deal with those hazards over the lifetime of the treatment system.

### 1.4.3 Applying the GDWQ to HWTS

The framework of health based targets, WSPs and operational monitoring proposed by the WHO GDWQ provides a clear model with which to derive implementation protocols for any given treatment system. Thus, while performance targets are usually applied to microbial contamination in piped supplies, these targets are also useful metrics for monitoring the performance of HWTS technologies. This thesis will designate specific microbial, turbidity, and free available chlorine (FAC) performance targets based on existing literature and expert input for each HWTS. Analogous to specified technology targets, they are intended for use in monitoring and evaluation programs and are for review by national authorities. Feed water quality will be generalized with a focus on fecal contamination and sediment load in the derivation of such targets, with the caveat that these recommendations may warrant adaptation to site-specific contexts. Such specific performance targets will form the basis of the microbial, turbidity, and FAC guidelines recommended in this thesis.

The WHO recommends that governing and operating authorities lay out WSPs for small-scale systems because individuals and communities often lack the capacity to do it themselves. This thesis will use information collected from implementing organizations and experts in order to lay out preliminary WSP-style frameworks for operational monitoring as they apply to specific HWTS technologies. The *system assessment* for most of these self-contained treatment systems has already been conducted by the designer and/or implementing agency.

Treatment processes constitute *control measures* that are designed into HWTS technologies to avert potential dangers from raw source water. While lab-based testing proves the potential treatment characteristics of the technologies, effectiveness of treatment in the home lacks rigorous study. Various agencies have developed operational monitoring techniques to validate the performance of *control measures* in the field, yet these tests lack the precision of lab-based testing. As of yet, many of the HWTS systems are missing a WSP-style analysis in the field, and the literature and experience involving monitoring and evaluation has not been collected and analyzed in a common framework. Collection, development and standardization of information concerning HWTS monitoring and evaluation is one end product of this thesis.

Operational monitoring consists of both physically inspecting contamination prone areas and using a regime of microbiological, turbidity, and residual chlorination testing to validate treatment controls. An emphasis is placed on monitoring during implementation in order to catch shortfalls of construction and/or training and operation (Baker, 2007). *Management plans* consist of a body of literature and promotional material with info on training methods, proper treatment, maintenance, replacement period, and technological alternatives. Effective Use can also be operationally monitored through inspection and informal interview in the house. The WSP framework will be revised in order to standardize the M&E of HWTS, as laid out in the Effective Use Write-ups given in chapter 5.

## *1.5 Consistent, Sustained and Effective Use*

At the June 2005 3rd international meeting of the WHO-hosted Network in Bangkok, Susan Murcott proposed an extension of the WHO GDWQ framework to include HWTS. She presented indicators for all four of the WHO's health-based targets described above in section 1.4 and proposed three additional targets as they pertain to HWTS: (5) Behavioral Outcomes, (6) Coverage, Use and Sustained Use, and (7) Financial Targets (Murcott, 2005). Murcott also reported on the research of MIT Master of Engineering student Robert Baffrey, whose field work involved an investigation of the M&E methods of the eleven organizations implementing HWTS in Kenya (Baffrey, 2005). Murcott and Baffrey developed an extensive survey, which, in a shortened form, was posted on the Network website with responses analyzed and reported in Murcott (2006) and at the Network meeting in London of the same year.

At the Bangkok Network meeting in 2005, Figueroa led a lunch-break discussion that sought to define and measure proper storage and household management (serving) of water. Most notably, this discussion led to defining Consistent Water Treatment as a household with treated water on hand everyday and all of whose members drink that water everyday, as developed in Figure 2 (Figueroa, 2005).

| Definition | Measurement | Data source |
|---|---|---|
| (i) Household has treated water for drinking every day. Treatment may or may not occur every day. Frequency of treatment will depend on type of technology used and number of household members.<br>(ii) All members in the household drink this treated water. | Three measurements are suggested. Preferably get the three of them if time and resources allow. From total households in study area:<br>(i) Number of households that report having treated water for drinking in the house.<br>(ii) Number of households that show treated water in the house.<br>(iii) Number of households with a negative test for E.Coli in their treated water, OR positive test for chlorine residual among those using chlorine-based technology. | Household-based data; preferably population based survey.<br><br>Data will include:<br>(i) self-reported information;<br>(ii) direct observation at end of survey<br>(iii) tests for water safety |

**Figure 2 Consistent water treatment** **(Figueroa, 2005)**

The USAID Hygiene Improvement Project (HIP) Agency for Educational Development (AED) has also actively contributed to the discussion of M&E indicators of HWTS. At the USAID-HIP-AED E-conference in January, 2007, Orlando Hernandez proposed three alternative indicators for measuring the behavioral outcomes target: (1) Volume of sales of HWTS products, (2) Number of liters of water treated, and (3) Percentage of households practicing effective household water management (Hernandez, 2006). Hernandez (2008) has compiled the first multi-system HWTS monitoring survey. Specifically designed for use with AED's work in Ethiopia, his was the first survey to monitor behaviors of the suite of HWTS covered in this document. His survey and definition of Effective Use were used to aid the Effective Use Write-ups of this thesis.

## *1.6 Monitoring and Evaluation Indicator Compendium*

In September 2007, Susan Murcott, Orlando Hernandez, and Boni Matigbay, the Network Secretariat, formed a working group with MIT students to create a compendium of best practices concerning the additional targets and indicators proposed in order to expand the 4 healht-based targets described in the WHO GDWQ 3rd Ed. The compendium idea came about since the Network did not seem ready to adopt common metrics concerning these additional M&E targets.

The MIT team is comprised of two engineering graduate students and four MIT Sloan School students, under the supervision of Senior Lecturer Susan Murcott of the Civil and Environmental Engineering Department. The MIT Sloan team (Udit Patel, Shivani Garg, Geeta Gupta and Eswar Mani) focused on analyzing financial and commercial indicators, presenting their final report in February, 2008. Kate Clopeck of the Technology and Policy Program and the Department of Urban Studies and Planning will spend two years researching behavioral indicators pertaining to Adoption and Sustained Use, including a rate of adoption indicator. Matt Stevenson investigated the target of Effective Use, as presented in this thesis. Susan Murcott, Orlando Hernandez, and Boni Matigbay provided input through meetings, teleconferences, draft reviews, and collaboration with regard to developing survey tools and generating a compendium of M&E tools.

## *1.7 Thesis Purpose and Scope-"Effective Use"*

The intention of this thesis research is to develop a set of categories with which to assess the "Effective Use" of a core group of household water treatment and safe storage technologies (HWTS). "Effective Use" is defined as the proper operation of HWTS technologies in the home, as instructed by the implementing organization, resulting in the production and storage of safe water in order to limit exposure to a variety of waterborne diseases. Two broad categories were developed to check the characteristics of Effective Use through monitoring in the home. *Monitoring Observations* refer to specific observations to make in the households of HTWS users, including the five categories of: (1) Treatment, (2) Safe storage, (3) Maintenance, (4) Replacement period, and (5) Physical inspection. *Water Quality Monitoring* includes specific measurements of turbidity, chlorine residual, and/or microbial water quality for each HWTS technology. While every HWTS technology has its own unique features pertinent to monitoring and evaluation, the intent of this thesis is to provide a common framework across multiple HWTS technologies, fulfilling the needed first step towards the standardization of common metrics for behavioral indicators of HWTS. This practical set of categories will be compiled in brief and then described in detail in the Effective Use Write-ups in Chapter 5, with an associated monitoring checklist for each technology included in *Appendix E: Effective Use Monitoring Checklists* of this document.

This standardized framework for monitoring and evaluation, drawn from global "best practices" will provide a valuable resource for those implementing HWTS within the WHO-hosted Network and around the world. With common monitoring and evaluation tools, results can be compared across HWTS systems and implementing organizations leading to effective handling of the barriers to scale-up.

# 2. Methods – Interviews and Field Trips

## *2.1 Interviews and Correspondence with Network Members*

Preliminary contact was made with a selected group of Network members in order to gain a clearer picture of the existing frameworks, tools and indicators developed for monitoring and evaluation of HWTS, as well as for the author of this thesis to refine the metrics of Effective Use of the various technologies before going into the field. Interviews were conducted using the questionnaire developed by Kate Clopeck and Matt Stevenson (*Appendix A: Behavior and Sustained Use Questionnaire*). During this period, the author contacted Derek Baker of CAWST in early December, 2007 as an expert on cost-effective operational monitoring. A very fruitful discussion ensued, with Baker presenting material about CAWST's current monitoring and evaluation projects in Haiti and Lao PDR, as well as key parameters for operating and monitoring the main HWTS covered in this document. Joe Brown of the University of Alabama was contacted later in December, 2007 and provided information on the methods, failures and error analysis of doing field-based health impact studies, as presented in his PhD thesis (Brown, 2007).

As the research progressed into Effective Use metrics for each of the given technologies, the author contacted a new set of Network members with specific questions about monitoring their given technologies. In May 2008, Rob Quick of the Centers for Disease Control (CDC) and Eric Fewster of Bushproof were interviewed by phone concerning specific monitoring techniques proposed in the Effective Use write-ups for their respective Safe Water System (sodium hypochlorite solution and safe storage) and the biosand filter. Philip Downs of the Carter Center's Guinea Worm Eradication Project (GWEP) was contacted by phone in July, 2008 concerning field practices for training and monitoring cloth filter use. These conversations presented the researcher with a large volume of current research concerning their respective methods of monitoring and evaluating HWTS. Similarly, Joe Moran of Medentech concerning Aquatabs, Jeff Albert of Aquaya and Greg Allgood of P&G concerning PUR™, and Danielle Lantagne of the CDC concerning both the Safe Water System and the ceramic pot filter were contacted with specific technical and monitoring methodology questions during May and July, 2008. These exchanges validated and improved the Effective Use Write-ups as well as provided up-to-date literature on the various systems.

## *2.2 Expert Review of Effective Use Sections*

Following revision of their first drafts, the various Effective Use Write-ups were sent out to the key Network members most involved with a given technology. In response, useful contributions were made by Regula Meierhofer of EAWAG, Matthias Saladin of Fundación SODIS, Ron Lentz of CAWST, Paul Edmondson of Medentech, Tom Mahin of the Massachusetts Department of Environmental Protection, and Greg Allgood of Procter and Gamble. The various Effective Use Write-ups were greatly aided by the review of these experts.

## 2.3 Field Trips –Ethiopia and Ghana

During January 2008, the author spent 10 days in Ethiopia followed by 17 days in Ghana to research existing HWTS implementations in those countries. These two countries were chosen as field trip destinations due to their emerging use of a range of HWTS. Annual per capita rural water procurement expenditures by the Ethiopian government had fallen to US $9 in 1995, with no signs of rising (Shenkut, 1995). Partially in response to the inability to serve the rural poor, in recent years, the government of Ethiopia has helped to promote new treatment technologies. In October, 2007, the Ethiopian government hosted a country meeting of the WHO-hosted Network, showing a willingness to revamp their water sector to be more inclusive of their rural population. In June, 2008, the Ghanaian government hosted the 3rd International Network Symposium in Accra, Ghana. A number of presentations were made at these meetings, which this author has used for background. With the interest in household water quality and treatment growing in these countries, many long-term programs currently operating, and multi-million dollar investments being made by the Hilton Foundation, World Vision, and USAID in Ethiopia in particular, these two countries offered appropriate field sites to investigate Effective Use in scaling-up of HWTS.

### 2.3.1 Ethiopia

The Federal Democratic of Ethiopia lies in the Horn of Africa with an area of 426,000 square miles (roughly twice the size of Texas) and a population of 77 million people, making it the second most populous country in Africa, after Nigeria. Ethiopia is bordered by Sudan, Eritrea, Djibouti, Somalia and Kenya. Ethiopia's long-standing isolation from surrounding economies and the Western World stalled the installation of infrastructure projects throughout the country. The citizens of Ethiopia have recently been forced through thirty years of harsh military rule, drought, civil war and internal land conflict, especially in the northern and eastern border areas, with severe impacts on both the populous and state infrastructure. With 80% of the population in the small-scale agricultural sector concentrated in the highlands (above 1500m), Ethiopia is a land of dense population and intense farming practices. In 1900, 40% of the land was forest cover. Today, 3% remains, representing one of the world's fastest rates of deforestation. With a harsh topography of fertile highlands abutted by steep slopes falling to arid lowlands and the hot rift valley, installation of dams for water storage is difficult. Rivers flowing out of the highlands are so silt-laden that they require treatment even for irrigational use. With a weak drilling sector and historically weak institutions such as the Water Works Construction Authority (EWWCA) and the Water Resources Development Authority (WRDA), water resource development is difficult and limited in scope (Abate, 1994). Many of these authorities have been reorganized in the past few years to fall under the Ministry of Water.

63% of rural inhabitants get their drinking water from unimproved sources, exposing them to increased likelihood of diarrheal disease as long as they remain without treatment (RADWQ, 2007). PSI's TRaC survey in 2006 showed that among caregivers of children under age fourteen in Addis Ababa and SNNP Region, 53% stored water in narrow mouthed containers with lids yet only 3.8% had used their sodium hypochlorite solution Watergaurd (PSI, 2007). Additionally, 50% of water storage containers in the household were leaking or otherwise unsanitary, with 15% used for storing liquids other than drinking water as well (RADWQ, 2007). Much work is left to be done for HWTS in Ethiopia.

### 2.3.2 Ghana

Located on the southern coast of West Africa, Ghana is a nation of 22 million people in a climatically varied, yet flat land of 92,500 square miles, slightly smaller than the state of Oregon. In 1957, Ghana gained its independence from Britain, making it the first independent sub-Saharan country in otherwise colonial Africa. Rainfall is seasonal in Ghana, with two rainy seasons in hot and humid southern Ghana and one rain throughout the north. The author carried out interviews among organizations in the national capitol, Accra, in southern Ghana, and in Tamale, the regional capitol of Northern Region, as well as conducted household monitoring visits in their outlying communities. He also traveled to Bolgatanga in the Upper East region to witness an emergency distribution of ceramic pot filters.

The infant mortality rate during 2007 was 54 deaths per 1,000 live births (About, Inc., 2007). While the country average shows slightly better neonatal health than the surrounding countries, the Northern Region of Ghana had 154 deaths of children under five years of age for every 1,000 live births. Suffering greatly from diseases like malaria, yellow fever, schistosomiasis, and meningitis as well as high disease burdens from water-related diseases such as bacterial and protozoal diarrhea, hepatitis A, and typhoid fever, Ghanaians attain a life expectancy of 59 years (World Fact book, 2007).

### 2.3.3 Interviews

Meetings with various businesses and NGOs by Stevenson and the G-Lab Sloan business group were organized and held jointly in both countries. Meetings consisted of the G-Lab team asking a set of questions, as laid forth in their Final Report (Patel et al., 2008), followed by Stevenson gaining information on both Effective and Sustained Use by utilizing the framework developed in *Appendix A: Behavior and Sustained Use Questionnaire*. Attending these interviews provided this author with in depth knowledge of the relationships between supply chains, business operations and Effective Use. Stevenson interviewed several organizations independently in Ghana after the G-Lab team departed.

Synopses of the eight formal interviews conducted while in Ethiopia and Ghana are compiled in *Appendix B: Fieldtrip Interviews.* The synopses introduce the interviewee and provide an overview of the HWTS program investigated. Following this intro, the notes list lessons learned specifically concerning training methods, Effective and Sustained Use, and monitoring and evaluation activities. In addition, the synopses provide a list of materials collected and give reference to any associated field visits. While *Appendix C: Household Monitoring Reports* contains compiled notes on the field interviews, a few consistent concepts noted throughout the interviews are reviewed in the Discussion Chapter, under Field Interviews.

### 2.3.4 Household Visits

Where possible, Stevenson prearranged with the program managers of the interviewed organization to visit the users of the various technologies in their homes. Prior to commencing the trip and in preparation to making household visits to users of the HWTS technologies in both Ethiopia and Ghana, the author compiled an interview questionnaire for use in the house. The interview questions were drawn from the work of Peletz (2007), Baffrey (2005), and Hernandez (2008), as well as through collaboration with Clopeck. Since no formal surveying was done by the author, the interview format was informal and technology/context specific, with notes written up in shorthand in the field and formalized as field notes in *Appendix C*. Water samples were taken and analyses were undertaken by the author during these visits. The goal of the interview framework was to gain insight into appropriate questions to be posed on one-time household visits. With this in mind, the author raised questions on an informal basis without asking the same questions in every household visited. The number of households visited for any given implementation was small given the time and logistical constraints inherent in visiting rural settings on a short field study. The author visited houses outside Debre Zeyt town in Oromiya region, Ethiopia, east of Addis Ababa using the biosand filter under the guidance of the Kale Hewyet Church, seven households in total. In Northern Region Ghana, four houses in Kpanvo using the HydrAid design of the biosand filter under Osman Mumuni's implementation for International Aid were visited. Monitoring of five households was witnessed using the *Kosim* ceramic pot filter distributed by Pure Home Water for UNICEF to flood-affected victims in Upper East Region, Ghana. Six households using the ceramic pot filter as distributed by Enterprise Works were visited in a peri-urban area outside of Accra, Ghana. The results of these household visits are summarized in *Appendix C: Household Monitoring Reports* under the given implementation, and are utilized directly in the recommendations for Monitoring Observations in the Effective Use Write-ups. No households using PUR, Aquatabs or other chlorine products were visited by this author, as the organizations implementing those technologies did not monitor users of recurrent-use products and had no specific clients to contact. There were no agencies to visit who were implementing SODIS in either Ethiopia or Ghana, however, the author is familiar with KWAHO's monitoring operations of their SODIS campaign in Kibera, Nairobi as referred to in the SODIS Effective Use Write-up and received very helpful advice from SODIS experts.

A standardized formal survey of ~50 households using the ceramic pot filter, branded the *Kosim* by Pure Home Water in Northern Region, Ghana, was conducted during January 2008 by Kate Clopeck. The author accompanied Clopeck for 2 days (10 household visits) of surveying. A good deal was learnt through this process as to effectual household monitoring methodology as well as specific survey questions and observations that could yield quantifiable and/or replicable answers during single household visits. The water quality results of this survey are partially presented in *Appendix C* on pages 160-163.

# 3. Methods – Water Quality Monitoring

## *3.1 Turbidity*

Suspended sediment causes many critical interactions in the natural environment. Too much suspended sediment will kill fish and prevent photosynthesis of algae, whereas too little mud transported during the flood season can make fertile river valleys go barren. In the context of water treatment, turbidity has the potential to block the UVA light needed for disinfection by the sun, to transport adsorbed chemicals and pathogens directly to the user, to cause negative odor and aesthetics, to incur sedimentation and blockages in pipes, and even to negate the effects of chlorination.

There are a number of ways to measure particulate and dissolved matter in waters. Color makes the first aesthetic impression, and tells a great deal about processes occurring within the water. Dark brown translucent waters contain organic matter, harboring and shielding microbes from disinfection treatment. Light brown or reddish opaque waters contain mineral particles, and necessitate physical filtering or flocculation. These suspended and colloidal particles have differing physical properties, including turbidity, attenuation cross sections and average particle diameters.

Turbidity is a very simple and useful optical measurement. Nephelometric turbidity units (NTU) are measured by a device called a nephelometer which has supplanted a reagent specific method called Jackson turbidity (JTU). NTU, JTU, and optical clarity measure optical effects (refraction and attenuation, respectively) instead of mass concentration of particulates in water, which can be measured by total suspended solids (TSS). NTU and optical clarity provide a proxy to mass concentration that is suitable at the low turbidities of water that people drink.

### 3.1.1 Field Turbidity Measurement

NTU does not have a direct environmental interpretation like that of visual clarity (beam attenuation), as measured by a simple device called a turbidity tube (Davies-Colley, 2001). The turbidity tube used in the field by this author (DelAgua Ltd) is measures the depth of water where lack of clarity occurs, not unlike the familiar Sechi-disk. In the turbidity tube method, one fills a specifically designed clear plastic tube with water until the target (a cross or circle) at the bottom of the tube just disappears from sight. Proper operation necessitates holding the middle of the tube at arms length and allowing time for gas bubbles to settle out before taking a measurement. Beam attenuation is very important in evaluating techniques like SODIS, whose bacterial inactivation depends on sun-derived UVA light directly interacting with the microbes. One benefit of using the turbidity tube over nephelometry is that it takes *in situ* measurements, because turbidity is likely to change significantly within a few hours during storage and transport. For full operating procedures of the DelAgua Turbidity Tube, see *Appendix D.*

The turbidity unit (TU) of the turbidity tube, a metric designed to mimic NTU, can be read from the side of the tube, according to the depth of attenuation. Visual clarity measurement using the naked eye is accurate. However, despite an attempt made to calibrate TU on the tube to actual NTU measurements, TU and NTU are measuring different light properties (attenuation and scattering, respectively) and the calibration is not very comparable. By applying a t-Test quantitative analysis to field TU measurements with subsequent lab NTU measurements on the same sample, Losleben found that there is a significant difference between corresponding values of TU and NTU and consequently the range of values is very large, despite decent $R^2$ values as given by the regressions on Figure 3 (Losleben, 2008).

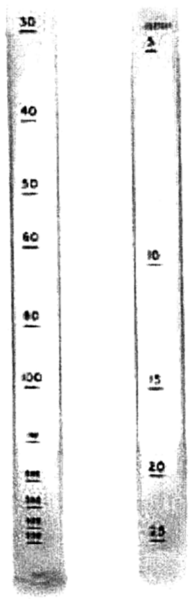

Figure 4 **DelAgua Turbidity Tube**

(Photo: Fitzpatrick, 2008)

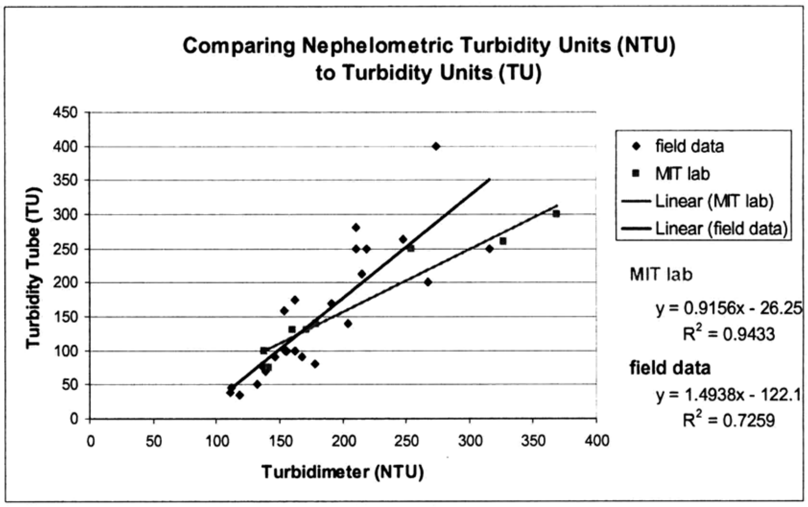


**Figure 3 Comparison of NTU and TU**

(Losleben, 2008)

The human eye can easily detect turbidity of greater than 5 NTU, and thus the WHO recommends that waters fall below 5 NTU for aesthetic acceptance (WHO, 2004). In terms of field monitoring, the recommended turbidity tube method has a lower resolution of 5 TU, which is more or less comparable to 5 NTU, and is the maximum recommended turbidity for drinking water in Ghana (GSB, 1998). Water falling below the characterization capabilities of our measurement technique is thus physically acceptable to the user and qualifies for chlorine treatment of a single dose of either Aquatabs or liquid hypochlorite. Sampling the lower turbidities often requires more treated water than is available or feasible to take from the household (about 3 cups), as using the tube contaminates treated water. Despite its limitations, the turbidity tube is well suited to operational monitoring of HWTS, with turbidity ranges <5, 30-40, and >100NTU easily discernible using the tube. As the correlation between TU and NTU is not strong and the precision of TU is limited given the turbidity tube method, this thesis refers to NTU as a more precise measure than TU.

The DelAgua turbidity tube costs about US $100 when shipping is included from England and portable electronic Nephelometers can cost hundreds of dollars. Therefore, home-made turbidity methods are well suited to low-budget monitoring campaigns, as long as the methods can be calibrated. For example, user training for the SODIS program includes the EAWAG-proposed method in which a 0.5-liter bottle is filled and stood upright atop a newspaper headline. If the large black print can still be read, the water is less than 30 NTU and suitable for treatment. If not, pretreatment through settling in a separate container or flocculation is warranted until the newspaper headline test is passed. Many SODIS users are non-literate, and may not have ready access to newspapers. In this case, place one's hand behind the bottle, and if your fingers are still visible when looking through the bottle horizontally, enough UVA will pass through and the water is suitable for treatment. These techniques can be particularly important for SODIS monitoring programs, where specific turbidities are impossible to recommend due to the variability and condition of available PET bottles. Likewise, people need measurement capabilities in the home to conduct effective treatment with SODIS and other technologies.

## *3.2 Microbial Indicators*

The standard method for measuring microbiological performance of water treatment processes involves a percent or log reduction in the concentration of a microorganism between the influent and the effluent of the process. By testing the same water sample before treatment and again after treatment for microbial counts, treatment efficiency can be deduced. Such a test typically entails an *indicator organism*, such as total coliforms. Total coliform (TC) bacteria comprise a diverse array of aerobic and facultatively non-aerobic, gram-negative, non-spore forming bacilli that readily grow at 35-37 degrees Celsius given a variety of media broths (WHO, 2006).

In terms of diseases stemming from contact with contaminated water, *index microorganisms* are used for their ability to identify likelihood of fecal contamination. Fecal contamination is directly inferred through the presence of two widely used *index organisms*, *Escherichia coliform* (*E.coli*) and thermotolerant coliforms, which are both coliforms of direct fecal origin and part of the total coliform family. Thermotolerant coliforms are culturable at higher temperatures that are lethal to other coliforms (44.5°C), whereas *E.coli* can be cultured at body temperature (35° C). Both thermotolerant coliforms and *E.coli* cannot grow outside of the body, and thus infer direct fecal contamination of the water tested.

Monitoring and evaluation programs for household water treatment technologies need to take into account not only technology performance through treatment but also the likelihood of diarrhea (water safety) at the point of use for proper program evaluation. *E.coli* and thermotolerant coliforms are usually present in too small numbers per the normal 100 ml sampling to record statistically significant reductions through treatment, and thus are not good *indicator organisms* of treatment efficiency. Likewise, certain organisms falling under the umbrella of total coliforms can grow heterotrophically on a variety of substrates outside of the human body, and thus can not serve specifically as *index organisms* for fecal contamination. Separate *index* and *indicator* organisms are thus needed to concurrently assess technology performance and absolute risk. *E.coli* comprise >99% of the target *index organism* fecal coliforms, and can be grown at 35-37 degrees from the same lactose-based media as total coliforms. *E.coli* is the recommended *index organism*, and total coliforms are the recommended *indicator organism* for monitoring HWTS systems (WHO, 2004).

### 3.2.1 Microbial Quantification Methods

Two of the most common methods for quantification of total coliforms and *E.coli* include membrane filtration and most probable number (MPN) techniques. With a dedicated lab setup and trained technician for these time-intensive methods, a small number of accurate counts are obtainable. MPN has the added advantage that it can take accurate counts with turbid waters. If more data at less resolution is desirable within a given timeframe, 3M Petrifilms provide a much simpler method without the need for extensive personnel training or even an incubation oven, eliminating expensive equipment and lab space as well. At a detection limit of 100 *E.coli* per 100 ml, however, the Petrifilm method can only detect high absolute risk from *E.coli* (see Table 2 Risk Levels from *E.coli* below) (Metcalf, 2006).

In order to surmount the inspecificity of 3M Petrifilm as well the resource intensive membrane filtration and MPN methods, IDEXX has developed the Colilert method. This method is widely used, and provides an affordable alternative that can gain resolution comparable to membrane filtration methods below 100cfu/100ml (Jacobs, 1986). This simple method requires no added lab setup than that of the 3M Petrifilm, and like the Petrifilm can be incubated on the body and run completely in the field. Colilert refers to a family of coliform testing products, yet the specific product referred to in this paper is the simplest and cheapest of the Colilert methods, called the 10 mL pre-dispensed Colilert MPN Tube. These tubes come with the growth medium already dispensed in the sampling tubes, which last 15 months at 2-25°C on the shelf. This product requires a 10mL sample and can detect presence of *E.coli* down to 10 CFU per 100ml, quantifying low absolute risk as per the 1997 WHO GDWQ. See *Appendix D* for the operating procedure for 10 mL pre-dispensed Colilert MPN Tubes. The limits of detection of *E.coli* by the combined Colilert and 3M Petrifilm method are shown below, in Table 2 Risk Levels from *E.coli*.

**Table 2 Risk Levels from *E.coli***

| Risk Level | *E.coli* in sample (CFU per 100ml) | Colilert MUG+ | # Blue Colonies on 3M Petrifilm |
|---|---|---|---|
| Conforms | <1 | - (Below detection) | 0 |
| Low | 1-10 | - | 0 |
| Intermediate | 10-100 | + | 0 |
| High | 100-1000 | + | 1-10 |
| Very High | >1000 | + | 10 |

(WHO, 1997; Metcalf, 2006)

Table 2 illustrates the WHO 1997 risk-based categories. At <1 *E.coli* CFU per 100ml, the risk to the user from drinking water is negligible. At <10 CFU per 100ml sample, WHO characterizes risk of waterborne disease as “low,” although diarrheal disease often results from drinking this type of water (Metcalf, 2008). Using the 10 mL pre-dispensed

Colilert MPN Tube, low risk would be quantified as a negative result for the 10ml undiluted sample used for the Colilert MUG test. With at least one CFU per 10ml Colilert sample, "intermediate" or higher levels of risk is assessed but cannot be quantified unless multiple Colilert tubes are used per sample (increasing cost ~US $1.40 per Colilert sample). Using 10 Colilert MPN Tubes can yield results on the order of tens of CFU per 100ml through use of a most probable number method. This specificity is lost at low counts on a 3M Petrifilm, given a one milliliter sample size. Only very high risk waters can be quantified to the hundreds of CFU per 100ml using 3M Petrifilms, and at this point the danger of contracting diarrheal disease is "high."

Dilutions are not needed to quantify WHO *E.coli* risk levels with either of these methods, negating any need for sterile lab equipment other than the sampling bags and disposable pipettes. This is beneficial not only because the 3M Petrifilm method lacks reproducibility at higher dilutions, but it also allows community members to conduct tests themselves and facilitates community education units on microbial contamination of water (Levy, 2007; Metcalf, 2008).

Measurement of the treatment efficiency achieved by an HWTS system requires multiple visits and is fraught with challenges and potential innaccuracies. One needs to sample the raw water at the time of addition to the filter, account for the volume displacement in order to know when that water will exit the tap, and then undertake a subsequent trip to the household to sample and test the treated water. Such testing is out of the scope of most operational monitoring frameworks in terms of time, money, and intrusiveness, and has only rarely been conducted academically. Using existent raw water in the home or at the source during a monitoring visit as a proxy for the water fetched and used in a given filter also incurs major uncertainties. As noted in the Safe Storage Write-up, up to 0.5 log reductions were recorded due to transport and settling, depending on source load (Levy, 2007). While percent reductions in TC cannot be quantified on one-time monitoring visits, if multiple visits to a given home are possible, better data can be gleaned from usage. Taking five inlet and five outlet samples from a single filter over the course of a week, for example, can show trends in reductions and absolute risk from *E.coli*, as well as discount outliers (Lentz, 2008).

Using the 3M Petrifilm method is useful to know if the water is of intermediate or high risk. However, if chlorine residual exists, turbidity recommendations are met for the given treatment process, and/or Effective Use is judged through monitoring observations, testing treated water with the Petrifilm method may not be warranted. As low risk (<10 *E.coli* per 100ml) is the microbial judgment of Effective Use standardized for all of the technologies in this thesis, the Colilert method is always needed in order to make this judgment for a given household's system. Simultaneous testing with the 3M Petrifilm method will more than double the overall cost of that microbial test, and has to be judged on an individual sampling basis if funds are limited (see Table 3 Bill of Quantity for 25-Household Water Testing Kit). However, when testing a system such as the biosand filter which can be sampled directly after treatment (at the spout) as well as from treated water in safe storage, the Petrifilm method's total coliform results can yield much more specificity on recontamination through storage, as numbers of TC are often more than one hundred times greater than those of *E.coli*. In this way, the Petrifilm can help determine handling efficiency through post-treatment resurgence of the *indicator* total coliforms.

These tests are specific for *E. coli*, because they contain a substrate for the Beta-glucuronidase enzyme produced by *E. coli*, but not by other coliform bacteria. The tests yield striking results within 12-18 hours, MUG + fluorescent blue in Colilert, a blue colony with a gas bubble on the Petrifilm. Petrifilms and Colilert tubes can be incubated on the body, such as in the pocket or under the belt on the small part of the back. To incubate, place up to 8-10 Petrifilms together between two cardboard pieces and wrap together with a rubber band. The cardboard protects the Petrifilm from bending, yet allows sufficient heat penetration. Similarly, a sock can be used to hold the Colilert tubes close to the body without risk of them breaking. The *E.coli* and TC cultured by these methods is non-toxic, and safe to humans. Sleep with them at night and results can be obtained by the following morning. 3M needs to be sealed for moisture after opening (masking tape), but need not be stored in a refrigerator. The Petrifilm expiration date is for food service regulations and can be extended if properly stored (Metcalf, 2008). Colilert tubes need to be kept sealed against moisture. For complete operating procedures of Colilert and Petrifilm, see *Appendix D.*

## 3.3 Chlorine Disinfection

Chlorine in water most often exists in the form hypochlorous acid ($HOCl \rightarrow H^+ + OCl^-$), just as it does in dilute bleach solution. The long-known disinfection potential of chlorine occurs from this weak acid's ability to pass through both the polar and non-polar regions of a cell membrane in its non-protonated and protonated forms, respectively. Once inside the cell, hypochlorite's acute toxicity kills the organism. After about 30 minutes of contact time with water, a certain amount of chlorine is used up through interactions with bacteria and sediment particles. This amount is known as the chlorine demand. If dosed correctly, a certain concentration of residual free available chlorine (FAC) is left after disinfection. Free available chlorine concentration is the amount of chlorine as hypochlorous acid (in the +1 oxidation state) per liter. The residual disinfection capacity that is thus left over to take care of subsequent recontamination is another advantage of chlorine disinfection.

In the absence of direct health impacts, an upper limit of 5.0 mg/L residual FAC is a conservative guideline set by the WHO to assure adequate disinfection while providing acceptable taste levels (WHO, 2004). Measuring the low end of FAC values is more important to monitoring proper use of chlorine disinfection. Under the current WHO *Guidelines on Drinking Water Quality 3rd Edition*, water vendors are required to provide 0.5 mg/L residual FAC after 30 minutes contact time (WHO, 2004). In an attempt to deal with the realities of home storage due to intermittent municipalities, the CDC developed a method that incorporates storage time into the dosing method and may be useful to the implementers of safe storage and POU treatment campaigns. In order to avoid adverse tastes in the water, the CDC recommends that a maximum of 2.0 mg/L FAC is present after 30 minutes of contact time in the water. Sodium hypochlorite solution, Aquatabs, and PUR are all meant to provide 2.0 mg/L FAC after 30 minutes of contact time. After

24 hours (the assumed average residence time in storage), the CDC stipulates that not less than 0.2 mg/L FAC remain (CDC, 2005).

### 3.3.1 Chlorine Residual Measurement

There are many products and methods that provide varying degrees of accuracy in measuring FAC. While some methods are expensive and time intensive, others are cheap, easy and durable. Four of the possible methods are reviewed here.

Free available chlorine is generally unstable in aqueous solution, sensitive to direct sunlight as well as agitation. Appropriate measurement methods must take place quickly and easily at the household during a monitoring campaign. The simplest method is that of a DPD test strip for free chlorine and total chlorine. One such product, HACH "AquaChek" is a simple strip that suffers slightly from color interpretation differences among individuals and has a lower limit of resolution of 0.5 mg/L, such that it can not accurately quantify low residual FACs (often there is <0.5 mg/L in treated water). For example, 6 of the 37 households showing FAC when tested during follow up visits in Swanton's *Kosim* and Aquatab study had FAC levels <0.2 mg/L (Swanton, 2008). While these FAC levels would lack quantification by this Hach Aquachek DPD chlorine test strip method, they would show presence or absence of chlorine nonetheless. Rob Quick of the Centers for Disease Control's Safe Water System says that measuring presence or absence of FAC is the most useful metric for looking at behavior change, so the DPD test strip method is recommended for its simplicity, cost-effectiveness, and timely results (Quick, 2008).

As for other commonly used methods, color wheels (e.g. HACH Cat. No. 21290-00) are generally imprecise among individual testers at low mg/L FAC, and titrators (see HACH Method 8210) require a good deal of lab setup and time that would be impractical for a mobile monitoring program. The most accurate, yet most expensive method is that of the digital colorimeter (Hach Cat. No. 58700-00). This unit costs around US $400 without reagents, has high accuracy at low mg/L FAC, is durable, battery powered and water proof, and only takes about 3 minutes to get an accurate reading down to low FAC levels.

The pH of natural waters has a large impact on the effectiveness of liquid hypochlorite chlorine treatment. Only one third as much of the FAC is protonated at pH 8 as at pH 7 (HOCl has a pKa of 7.46), and protonation is the key to traveling through cell walls and consequently disinfection. The special properties of sodium dichloroisocyanurate (NaDCC) in Aquatabs negate some of the pH sensitivities inherent in using dilute liquid bleach (Clasen & Edmondson, 2006). The WHO guidelines for residual FAC apply up to nearly pH 8 for liquid hypochlorite. pH considerations need to be taken into account at the outset of any chlorine disinfectant implementation. To ensure Effective Use with waters above pH 8, double dosing may need to be encouraged in trainings such that higher residual FAC levels are achieved to compensate for the accompanying disassociation. While a simple pH strip test in situ would suffice for a monitoring agent to test water at the household, users of liquid hypochlorite would not be able to test their own pH and thus they cannot be held responsible for ineffective treatment due to high pH. Although microbial testing of FAC-positive water samples is most likely to turn up negative, and is not even recommended by Rob Quick (2008) of the CDC Safe Water when FAC is present, microbial testing of FAC-positive water is recommended in this thesis in order to confirm adequate dosing to counteract the effects of high-pH and turbidity. If microbial analyses fail the WHO-categorized low-risk metric despite having residual FAC, a check of pH can be done to see if dosage needs to be adjusted. When sampling potentially chlorine-treated water for microbial analysis, it is necessary to neutralize FAC. This can be achieved by dosing the water with sodium thio-sulphate, as commonly available in powder form pre-dosed in sterile sampling bags[2].

### 3.3.2 Disinfection Potential with Turbidity

Slightly turbid waters ma be highly biologically contaminated and can have a very high chlorine demand. *The Sphere Project* set out to produce a document of minimum necessary standards for emergency response zones, which came out in 2004 under the title "Humanitarian Charter and Minimum Standards in Disaster Response." In this book, the authors stipulated that there must exist in disinfected waters not less that 0.5 mg/L residual FAC after 30 minutes of contact time with turbidity less than 5 NTU (Sphere, 2004). This is less stringent than the 0.1 NTU recommended maximum turbidity for chlorine disinfection by the WHO (WHO, 2004). Both the Sphere and WHO turbidity specifications, however, are of lower turbidity than the surface or other unimproved source waters for which HWTS chlorination products were designed to treat. In fact, if Effective Use was based on chlorination without filtration only at turbidities below 5 NTU, many useful applications of Aquatabs and liquid dilute bleach would be out of the question, especially in emergency situations. Using liquid hypochlorite with no pre-filtering, Crump found a 17% reduction in diarrheal incidence in waters averaging 55 NTU after treatment. In the same study, a 25% reduction was noted for waters treated with both a flocculant and disinfectant with an average post-treatment turbidity of 8 NTU, still above the WHO and *Sphere* specifications (Crump et. al., 2004). Despite having relatively high turbidities (30+ NTU), direct chlorine treatment can incur substantial health benefits. The usage information on these products, however, requires double dosing of visibly dirty water (>5NTU) and water from sources falling outside the UNICEF/WHO Joint Monitoring Program classification of "improved" in order to ensure the required residual FAC.

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[2] An exemplary product is 100 ml Stand-Up Whirl-Pak® Thio-Bags®, Product Number: B01402WA, US $22 per box of 100 bags).

## *3.4 Portable Water Testing Laboratory*

**Table 3 Bill of Quantity for 25-Household Water Testing Kit**

| Quantity | Product | Manufacturer | Part number | Cost per unit US$ | Cost/25 HH US$ |
|---|---|---|---|---|---|
| 25 | 10 mL pre-dispensed Colilert MPN Tubes | IDEXX, Westbrook, Maine | W200 | 1.50 | 37.50 |
| 25 | *E. coli* count Petrifilms | 3M, St. Paul, MN | 6414 | 1.20 | 30.00 |
| 25 | 4-oz Stand-Up Whirl-Pak® Thio -Bags®, | Nasco, Modesto, CA | B01402WA | 0.22 | 5.50 |
| 25 | 1ml sterile plastic pipettes | | | 0.15 | 3.75 |
| 25 | "Aquacheck" Chlorine Foil Singles | Hach, Loveland, CO | 27939-44 | 0.53 | 13.25 |
| | | | **Cost of consumables:** | **3.60** | **US $90** |
| 4 | Cardboard strips | | | 0 | 0 |
| 1 | Plastic spreader for Petrifilm | 3M, St. Paul, MN | Included with Petrifilms | 0 | 0 |
| 1 | Battery-operated, long wave UV lamp | Spectronics Corp., Westbury, NY | | 15 | 15 |
| 1 | Turbidity Tube | DelAgua | | 90 | 90 |
| | | | | **Cost of hardware:** | **US $105** |
| | | | | **Total cost for 25 full samples:** | **US $195** |

Table 3 is adapted from the portable laboratory developed by Robert Metcalf, Professor of Biological Sciences, California State University, Sacramento. This chart shows that once the hardware is purchased, the cost of consumables for a full set of all three tests is US $3.60 per sample. Most houses will not need a complete test, especially if they are not using a chlorine product. Similarly, if Effective Use is assumed through observation and knowledge of a clean source, high risk levels of *E.coli* need not be measured and use of the 3M Petrifilm is not necessary for that household. However, for systems such as the Biosand, treated water directly from the spout as well as treated water in safe storage needs to be tested, incurring greater costs for an extra Colilert sample. Other methods for measuring turbidity may be applicable that would negate the need to purchase the DelAgua turbidity tube, as explained in this chapter and the SODIS Effective Use Write-up, greatly lowering up-front costs. If ordering Petrifilms or Colilert tubes in small volumes or from overseas, shipping will become another significant proportion of the cost and must be factored in. A section for reporting water quality monitoring results is included in each of the Effective Use Checklists, as provided for each technology in *Appendix E.*

# 4. Effective Use Write-ups of Household Water Treatment and Safe Storage Technologies

"Effective Use" is defined as the proper operation of HWTS technologies in the home, as instructed by the implementing organization, resulting in the production and storage of safe water in order to limit exposure to a variety of waterborne diseases.This chapter recounts the steps needed to perform Effective Use for the eight HWTS systems selected.

Each of the Effective Use Write-ups in this chapter provides in depth information about treatment, safe storage, maintenance, and replacement period for a given technology in the form of a monitoring framework. The framework develops a set of monitoring observations and water quality tests as two independent methods of evaluating Effective Use in the home. The reduced Effective Use Briefs are intended as the core addition of this thesis to the compendium of indicators for the Network, and are appropriately referenced and researched within the body of the Effective Use Write-up. For a more explicit household monitoring survey for each technology, please refer to the Effective Use Monitoring Checklist forms compiled in *Appendix E.*

Safe storage does not have an Effective Use Monitoring Form because there is no treatment associated with it. Settling occurs pre-HWTS treatment and thus is not part of the safe storage of HWTS-treated water. As an integral part of HWTS, however, safe storage will be defined and included explicitly for each technology as one of the categories of Monitoring Observation.

Some categories overlap, especially when maintenance refers to cleaning the safe storage unit because it is built into the treatment technology. When noting hygiene, consistent use or various other aspects of the HWTS system that fall outside the four categories of treatment, safe storage, maintenance and replacement period, they will be contained in the "physical inspection" category, with direct observations to make note of included.

There are many types of observations used in these monitoring frameworks, including inspection and testing by the monitor, self-reporting by the user, prompted questions and judging hygiene traits through proxy observations, among others. These observations have been organized by content as they apply to Water Quality Monitoring and the five categories included in Monitoring Observations. Organizing the paper on the basis of content rather than type of observation is based intuitively upon how monitoring visits in the home naturally proceed.

Measuring Effective Use assumes that the system in the household monitored is operational and that water treated by this system is currently available both for consumption in the household and for testing by the monitoring agent. Without treated water available for consumption or testing, inconsistent use can be assumed, and the reasons for this should be noted before moving onto the next household. Figueroa's definition will be used throughout this text when referring to "consistent use," and will be measured in part by her proposed metrics of having treated water on hand during monitoring visits and/or showing residual chlorine when tested (Figueroa, 2005).

## *4.1 Safe Storage*

Contamination of water often occurs in the household through handling practices, such that improved sources often cannot guarantee provision of safe water (Wright, 2004). Household water treatment techniques treat water that has become contaminated both at the source as well as through domestic handling, with the goal of reducing contamination to levels of low microbial risk, as defined by the WHO (WHO, 2004). Once treated, the practice of safe storage is needed to retain safe water quality. Safe storage vessels are especially designed to eliminate sources of recontamination by keeping foreign and dirty objects (e.g., hands, ladles) out of the system. Used only for storing and dispensing treated water, they are especially effective in conjunction with proper hygiene and cleanliness.

Monitoring Effective Use of safe storage practices involves the observation of two categories: proper hardware and proper practice. Hardware refers to the vessel used to store water. With HWTS such as the CWP and SODIS, the hardware is self contained. Other treatment techniques require additional hardware to enable the practice of safe storage. Practices involve the use and maintenance of the safe storage containers, as well as other hygienic measures taken in order to limit recontamination of the water after treatment.

Three types of safe storage have been identified as pertains to this thesis:
1. Safe storage of untreated source water
2. Safe storage methods that are built into HWTS technologies
3. Separate safe storage post-HWTS treatment

In this document, safe storage will refer to specific practices related to each of the HWTS reviewed. Apart from the process of settling, the first category of pre-HWTS safe storage will not be specifically researched. Thus, when referring to safe storage, post-HWTS treatment storage (types 2+3) is inferred. As safe storage within itself is not considered adequate treatment of unsafe water, safe storage will not have an Effective Use Monitoring Form of its own, as the other HWTS technologies have as compiled in *Appendix E,* but rather safe storage will be included as a category in each HWTS Effective Use Brief and Monitoring Form. Similarly, Water Quality Monitoring will refer to the treated water contained in safe storage containers related to each HWTS process.

### 4.1.1 Safe Storage Effective Use Brief for HWTS-Treated Water

| Safe Storage Effective Use Brief | |
|---|---|
| **Monitoring Observations** | |
| ***Safe Storage*** | 1. Container is used only for treated water. |
| | 2. Lids are kept on tight, and only opened for addition or pouring of treated water. |
| | 3. Design incorporates a tap or a small sealable opening for pouring. |
| | 4. Vessel is clean, leak-free and in good condition. |
| | 5. Located indoors, out of the sun, off of the floor, in a stable position out of reach of animals and small children. |
| ***Maintenance*** | 1. Inner and outer surfaces as well as tap are cleaned and disinfected with bleach or detergent using treated water on a regular basis. |
| | 2. Soap or disinfectant used to clean storage unit can be produced by user. |
| ***Replacement Period*** | 1. None specified other than by the manufacturer. |
| **Water Quality Monitoring** | |
| ***Turbidity*** | Turbidity of <10NTU is ideal to slow settling or biofilm growth. |
| ***Microbial Testing*** | Bacteriological quality is <10 *E.coli* /100ml or no greater than that from the associated treatment process. |

### 4.1.2 Monitoring Observation

When promoting HWTS technologies that do not have residual disinfection potential after treatment (for example, SODIS, biosand and ceramic filters), safe storage practices need special attention during training and monitoring to encourage Effective Use because they provide the only protection against post-treatment contamination. In household monitoring visits by this author, safe storage and hygienic use of products often led to failing the "Effective Use" judgment as based on observational monitoring characteristics. Although safe storage is explicitly noted in brief for each technology in their Effective Use Write-up, the following set of safe storage techniques apply to all technologies in order to best ensure safe water outcomes and reduction in diarrheal disease.

#### *4.1.2.1 Safe Storage*

The most important aspect of using a safe storage container effectively is ensuring that it is used solely for safe storage. Thus, a dedicated appropriate storage container must be procured by the user separate from the container used to collect water. A proper training program will focus on separate containers for fetching and for storage, and monitoring should ensure such use. Hygienic conditions are also necessary when using storage units, and training needs to focus on limiting hand to water contact, dipping ladles into the unit, and to keep a hard cover on the unit at all times other than when adding or decanting treated water. CDC recommends that a label with usage instructions be included on every marketed safe storage device. Such a label should instruct on proper filling, disinfecting, hygienic measures to ensure safety of stored water, periodic cleaning, as well as suggested applications of treated water (drinking, hand washing, cleaning utensils, and rinsing fruit and vegetables) (CDC, 2001).

The recommended design features of safe storage units were developed by the CDC in their SWS Manual and have been included here:

1. Appropriate shape and dimensions with a volume between 10 and 30 liters so that it is not too heavy, fitted with handles to facilitate lifting and carrying, with a stable base to prevent overturning. If possible, a standard sized container should be used because then dosing can be standardized. 20 liter vessels have worked well in earlier studies. If children often carry water, the vessel will have to be smaller or the child will need to collect water in a smaller container and pour it into the safe storage container.
2. Durable material, resistant to impact and oxidation, easy to clean, lightweight, and translucent. High-density polyethylene (HDPE) is often the most appropriate material that is readily available. HDPE should be specially treated with ultraviolet absorbers, or exposure to sunlight over time will damage the plastic and vessels will crack.
3. An opening large enough to facilitate filling and cleaning but small enough that even a child cannot easily insert a hand with cup or other utensil to dip out water. The inlet should be fitted with a durable screw-on lid, preferably fastened to the container with a cord or chain. A diameter between 6 to 9 cm is optimal.
4. A durable spigot or spout for pouring that is resistant to oxidation and impact, closes easily, and can discharge approximately one liter of water in about 15 seconds.
5. Instructions for use of the container, disinfection of contents, and cleaning the interior, permanently affixed to the container on material that does not deteriorate when wet or moist.
6. A certificate that indicates the container complies with requirements of the Ministry of Health or an equivalent appropriate authority.

(CDC, 2001)

*4.1.2.2 Maintenance*

Cleaning of safe storage units on a regular basis is necessary to reduce the likelihood of contamination associated with storage. Cleaning must include the inside of the unit, the outside, the tap, lid, and associated surfaces. One method for proper cleaning of safe storage units was prepared by the CDC in their SWS Manual, as follows (CDC, 2001):

- Pour 1-2 liters of water into container
- Add double the usual dose of sodium hypochlorite (e.g., 2 capfuls instead of one)
- Add detergent
- Add hard rice grains or gravel
- Agitate vigorously
- Pour out solution
- Rinse

If bleach is not available, disregard that step and continue. A cloth or sponge can be used in place of abrasives.

When monitoring in the household, ask the interviewee the last time he or she cleaned the storage container.

- Is there a biofilm or settled solids on the inside of the container?
- Can the water caretaker produce soap and other articles used to clean the container?

*4.1.2.3 Replacement period*

Users need to replace the safe storage unit if it is cracked or leaking, or if the tap is broken. High density polyethylene (HDPE) left in the sun can deteriorate in a matter of a few years, but if cared for properly can be expected to last for 5-10 years of service. A specific replacement period is not given, as deterioration and manner of wear can vary significantly based on the design, material, and environmental conditions. A recommended replacement period can be determined by the manufacturer of a given storage unit, if applicable.

*4.1.2.4 Physical Inspection*

During household monitoring visits, inspect the storage container as noted below.
First, note the *design* of the safe storage vessel.

- If being used with a dosage-dependent disinfectant, is the vessel a standard and appropriate volume?
- Does the vessel have a tap or ability to pour for dispensing?
- Is the opening smaller than a hand (6-9cm) and covered securely with a clean hard lid?
- Does the vessel conform to the characteristics of a safe storage unit as defined in the 6 steps laid out in the CDC SWS Manual (see *4.1.2.1 Safe Storage*)?

*Location* of the vessel within the home is important to pathogen re-growth and recontamination. Is the vessel:

- Inside?
- Out of direct sunlight?
- Off of the floor?
- Stably situated?
- Out of reach of animals and small children?

*Hygienic* habits can also be teased out of direct observation of the storage conditions.

- Is the unit visibly dirty or leaking?
- Is a dedicated clean cup associated with the vessel for drinking?
- Is a bar of soap associated with the vessel for hand washing?

### 4.1.3 Water quality monitoring

Turbidity in stored water should be less than that recommended by the preceding treatment process, however turbidities of greater than 10 NTU are likely to incur biofilm and sedimentation in the container, requiring vigilant cleaning. High levels of turbidity, sedimentation and/or biofilm within the container could show that it is being used as a settling basin or for collection and should be inquired about, in order to ensure proper usage.

Effective Use is achieved if water in safe storage is of the same (or better) quality than the treated water before it enters the storage unit. While minor increases in total coliforms during post-treatment storage are normal in systems without residual disinfection, increases in *E.coli* counts denote fecal contamination and show improper handling of the stored water. Monitoring for such recontamination can be difficult as treatment and subsequent storage do not take place concurrently. Thus, stored water is often incomparable to recently treated water due to source and temporal variation. Likewise, asking the user to treat the water at the time that the monitoring staff conducts their visits is likely to induce bias into results. Whether or not reductions can be made note of between treatment and storage, absolute levels of greater than 10 *E.col*i per 100 ml of HWTS treated water in safe storage containers constitutes ineffective usage of the HWTS system, including storage.

### 4.1.4 Discussion

Safe-storage forms a key component of the Center for Disease Control's Safe Water System, which distributes the container pictured on the left in Figure 5 Various Safe Storage Containers below. To its right is the Oxfam container distributed in emergencies. Both containers feature a durable and easy to clean high density polyethylene shell, small sealable opening for daily filling, large sealable opening for periodic cleaning, and a spigot for hands-free dispensing. All of the Potters for Peace style ceramic pot filters incorporate a similar closed storage unit made of a bucket with a lid and spigot into their various designs. See the *Kosim* filter third from the left below, with a polypropylene storage unit as marketed by Pure Home Water in Northern Ghana. While often the cheapest option, with no large opening for cleaning and no tap, commonly available 20 liter plastic jerrycans are of limited value as safe storage units, failing many of the criteria in the CDC SWS Manual (CDC, 2001). Traditional clay pots as used all over the world have been modified to include a spigot, narrow opening, and a hard tap (on the right, below). These various models allow for evaporative cooling of the water, they maintain adequate levels of free available chlorine and show that safe storage containers can be produced locally and cheaply (Ogutu, 2001).

**Figure 5 Various Safe Storage Containers** (CDC, Murcott, Murcott, WHO)

Many studies have been performed using safe storage as a primary HWTS intervention. Two key studies are discussed here. In her PhD work in Northern Coastal Equador, Levy monitored users during collection and transport of water, and through storage and use, taking water samples and testing for *E.coli* at each juncture. While greater than 0.5 log reductions in *E.coli* concentration due to die-off and settling were witnessed on average during transport home from quantifiably high-risk sources, half of the samples experienced a 0.2 log increase in *E.coli* concentration during domestic use, consistently recontaminating to high-risk levels. Noting the variance in Wright's 2004 meta-analysis of post-source contamination, Levy concludes that source conditions will dictate how much reduction or contamination occurs between source and household. Similarly, in Pakistan, Jensen found that the amount of contamination at the domestic level always hovered at about 100 *E.coli* per 100ml, independent of source-level contamination (Jensen, 2002).

The work of both authors provides evidence of the benefits of narrow-necked containers. Domestic levels of contamination were on average 30% lower in the narrow-necked clay pots as compared to otherwise similar wide-necked containers in Pakistan (Jensen, 2002). Levy also showed a positive correlation between having an opening that was too small to place a dipper or hand inside and lowered *E.coli* counts (Levy, 2007).

Both authors showed that when dealing with low risk-level waters, safe storage has positive impacts. Jensen claims that protection at the domestic level (i.e., safe storage) is only important if water quality is <100 *E.coli* per 100ml. For water that is of WHO-designated low microbial risk at the source or as treated through some type of HWTS, safe-storage helps to ensure that recontamination does not occur at the domestic level and thus is a central part of HWTS (Levy, 2007).

*4.1.4.1 Settling*

Households drawing their drinking water from surface water sources are likely to be affected by high levels of turbidity, and pre-settling is an important treatment step in these instances. Settling should be performed in a separate container from the safe storage container so as to prevent a biofilm from growing in the safe storage unit.

Decanting settled water into a safe storage unit requires a cloth filter so as to prevent resuspension of dirt and microbial contamination in the safe storage container (Roberts, 2001). Settling can greatly increase runtimes between successive cleanings for ceramic as well as sand filters. Similarly, waters with lower influent loads result in lower absolute risk levels among the treated water of biosand and ceramic filtration, given existent treatment efficiencies (Brown, 2007). Settling may also be used to reduce turbidity to the required levels for solar treatment or chlorine disinfection. Settling and die-off are unlikely to consistently bring contaminated water into the low- or medium-risk WHO designations for microbial quality (Levy, 2007; Wright, 2004). Because settling is not meant to be performed in safe-storage containers and is not a dependable treatment technique, it will not be included in the general framework for Effective Use of safe storage as laid out below.

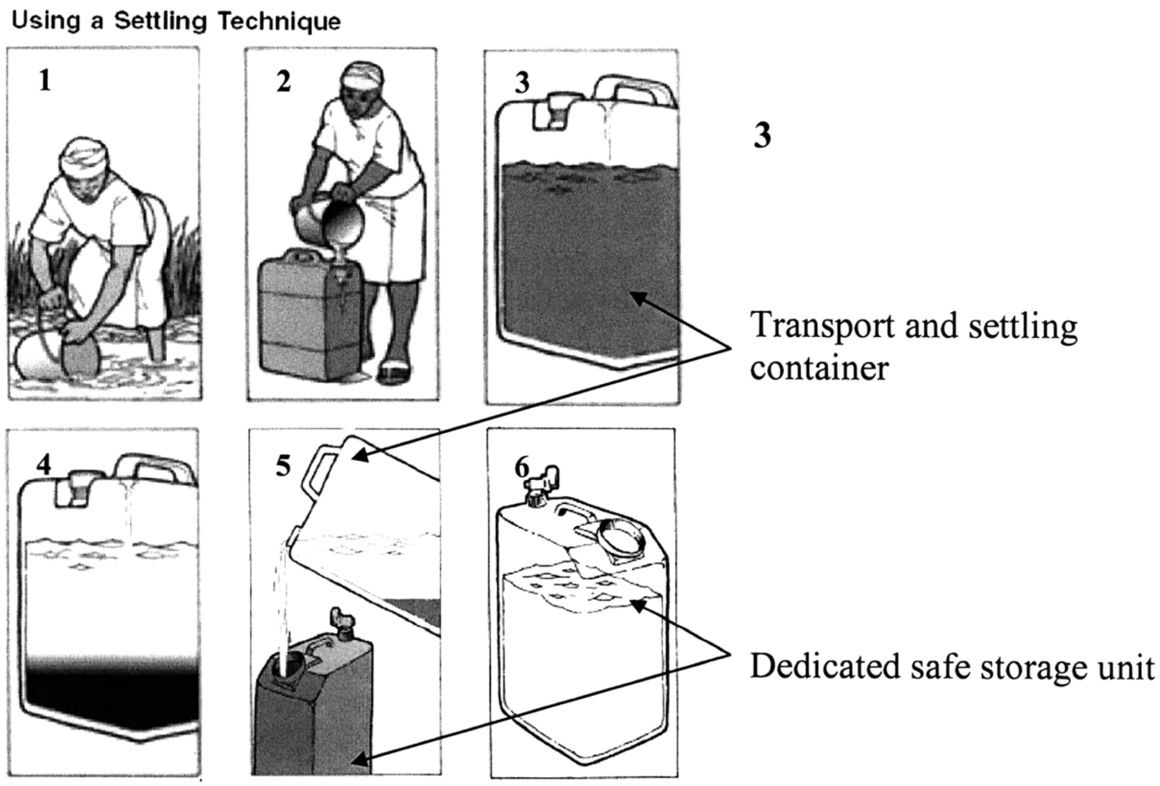



**Figure 6 CDC Settling Pictorial** (CDC, 2001)

## *4.2 Sodium Hypochlorite Solution*

Chlorine treatment of centrally treated water dates back to the early 1900s with proven health benefits. Promotion and marketing of household chlorine products by the Centers for Disease Control (CDC) and the Pan American Health Organization date back to the mid-1990s. Using a relative risk reduction of 0.49, Clasen calculated that household chlorine use costs only US $53 per DALY averted, making it the most cost effective of all the HWTS. With no infrastructure investment necessary and only US $0.66 per person treated per year, chlorine solution is also among the most affordable, easiest to produce, and most widely available forms of HWTS (Clasen, 2007).

### 4.2.1 Sodium Hypochlorite Solution Effective Use Brief

| **Monitoring Observations** | |
|---|---|
| ***Treatment*** | 1. User demonstrates knowledge of treatment and dosing as intended by manufacturer's specifications, without prompting from the monitor:<br>1.1. Add a single dose to clear water of the correct volume.<br>1.2. Double dose for water that is visibly dirty and/or from an unimproved source, following filtering through a clean folded cloth.<br>1.3. Shake thoroughly and let sit for 30 minutes prior to drinking. |
| | 2. Pretreatment is recommended for turbid waters. |
| ***Storage*** | 1. Separate containers for fetching and disinfection/storage are used, visible, clean, and have no leaks. |
| | 2. The volume for treatment as specified on the hypochlorite product is easily measurable in the safe storage container. |
| | 3. Safe storage container for treated water is located indoors, out of the sun, off of the floor, in a stable position and out of reach of animals and small children. |
| | 4. Design of safe storage unit incorporates a tap or a small sealable opening for pouring. |
| | 5. Lids are kept on tight, and only opened for addition or pouring of treated water. |
| ***Maintenance*** | 1. Regularly scheduled cleaning of the storage unit. |
| | 2. Soap or disinfectant used to clean storage unit can be produced by user. |
| ***Replacement Period*** | 1. Expiration date as specified by manufacturer or distributor on bottle. |
| ***Physical Inspection*** | 1. Water bottles for use during travel or school are clean and producible to the interviewer if consistent use is claimed outside the home. |
| | 2. Unexpired sodium hypochlorite solution sufficient for at least ten treatments is in stock and easily accessible if consistent use is claimed. |
| | 3. A dedicated clean cup is associated with the safe storage unit. |
| **Water Quality Monitoring** | |
| ***Chlorine Residual*** | Free available chlorine presence is shown if treatment is claimed. |
| ***Microbial Testing*** | Microbial testing shows <10 *E.coli* CFU/100 ml. |

### 4.2.2 Monitoring Observation

*4.2.2.1 Treatment*

As a consumable product, there is often little ability to run trainings for users at the outlet/street vendor level. Therefore, easily interpretable instructions for use of sodium hypochlorite solution need to be included on the bottle. The Society for Family Health, partner to Population Services International (PSI) in Nigeria, prints the following label for their Waterguard (1.0% sodium hypochlorite solution) product in English:

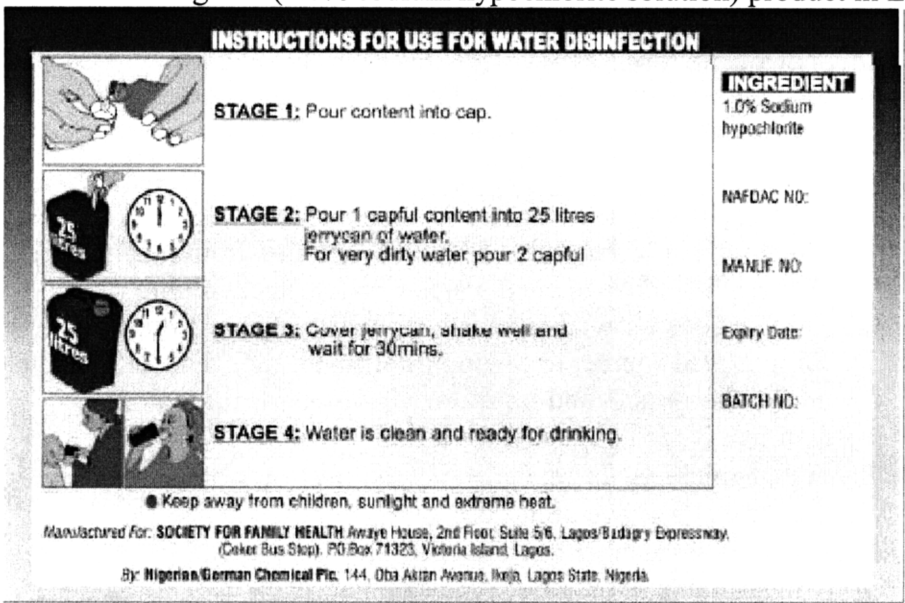



**Figure 7 PSI Nigeria Waterguard Label** (POUZN, 2007)

Each bottle is listed with a batch number and expiration date, along with the mailing address of the manufacturer and producer (see Figure 7 PSI Nigeria Waterguard Label). Aside from dosing instructions and product warnings, labels should promote uses of chlorine-treated water other than just drinking, including washing hands and dishes, rinsing fruit, and house cleaning (Lantagne & Gallo, 2008).

A single dose of chlorine solution in the suggested volume is adequate for clear water from improved sources. Double dosing is advisable if the water is visibly dirty (at least 5 NTU), providing 4.0 mg/l total chlorine for treatment and leaving at least 0.5 mg/L free available chlorine (FAC) after 0.5 hours as recommended by the World Health Organization (WHO). These use and dosage directions are easily tailorable to specific countries' literacy rates, languages and typical storage units. See *Appendix F: Sodium Hypochlorite Solution Usage Instructions* for examples of PSI labels from Kenya, Madagascar, and Ethiopia.

During a household interview, ask the user to demonstrate her/his treatment techniques, without any further prompting.

- Are they able to follow the instructions?
- If the water is visibly turbid, ask if any attempt at pretreatment is made (e.g., letting stand for sedimentation, or pre-filtering through cloth or other filter)?
- Before checking chlorine levels, ask them if and when this water was treated?
- How much water was treated at that time, and how much solution was used to treat it?
- Do the two previous claims match up with the free available chlorine results?

*4.2.2.2 Safe Storage*

Safe storage is a necessary component of the sodium hypochlorite HWTS system. While the Safe Storage Effective Use Write-up has much greater detail, the following safe storage characteristics are important to note in the home of sodium hypochlorite users. Upon entering the house for a monitoring visit, ask the user to take you to where the drinking water is stored.

- Is a dedicated safe storage container in use, separate from the container used for fetching water?
- Is the volume for treatment as specified on the hypochlorite product easily measurable in the given safe storage container?
- Does the design of the safe storage unit incorporate a tap or a small sealable opening for pouring, such as to eliminate recontamination by the introduction of dirty objects for dipping such as ladles, cups or hands?
- Is the safe storage unit kept out of direct sunlight, as the sun quickens degradation of residual chlorine and speeds re-growth of bacteria?
- Is the lid to the unit kept on tight, and only opened for addition or pouring out of treated water?
- Is the unit clean and free of leaks, situated indoors, off of the floor, in a stable position and out of reach of animals and small children?

*4.2.2.3 Maintenance*

Minimal maintenance is required with the use of sodium hypochlorite solution, as the chlorine residual is effective at sterilizing containers. CAWST recommends cleaning the storage unit at least once a week for any chlorine product (Adams, 2007). Dilute bleach solution provides an excellent cleansing agent for use in cleaning of storage units (see 4.1.2.2 Maintenance for safe storage cleaning instructions using dilute bleach). Inspection of the safe storage unit's cleanliness is necessary. When in the house, ask to see the soap or disinfectant used to clean the unit, and question the user as to when the last time it was cleaned.

*4.2.2.4 Replacement period*

NaOCL is minorly unstable in liquid solution, and PSI prints an expiration date of one year after production on its product to ensure adequate treatment. Witnessing expired Waterguard or similar product in the household is a good sign that the user is disusing the product or hoarding the product for special occasions (e.g., sick children or cholera outbreaks) instead of using the product consistently. Similarly, lack of a minimal chlorine presence shows that claims of consistent or active use are suspect. Another question to ask in this vein is whether family members carry treated water or chlorine solution while traveling. Ask the family to present water bottles, if traveling with water is claimed.

*4.2.2.5 Physical Inspection*

Liquid chlorine products are consumables, and should be used on a daily basis. PSI's market-based strategy in Ethiopia develops stable distribution networks with visible and well-positioned outlets, as needed for widespread and sustainable use of their liquid chlorine products. The volume equivalent of at least 10 treatments of hypochlorite solution must be present in the house in order to help ensure Consistent and Sustained Use of the product.

When conducting monitoring, ask the user to retrieve their hypochlorite product, if any is in stock.

- Is the product easily accessible, suggesting daily use is probable?
- Is sufficient supply of unexpired product present (at least ten doses)?
- If not in stock, how long have they gone without treatment and why?

Asking for a glass of water is often very informative, especially if you ask with the intent of drinking it.

- Did the user act hygienically while getting the water?
- Alternatively, did they wash out the glass with untreated water and then dip it into the storage unit without washing their hands? Observe behavior, as monitoring visits can induce bias among the user's habits.
- Is there a dedicated drinking cup or bar of soap near the storage container? These will show a high level of hygiene, and suggest that recontamination is less likely.

### 4.2.3 Water quality monitoring

Quick (2008) of the CDC contends that presence/absence of FAC is the most useful metric of behavior change with household chlorination using sodium hypochlorite solution. Using a DPD FAC test strip, any pinkness or other indication of FAC indicates current treatment with liquid chlorine solution and this is satisfactory to the chlorine requirement. The WHO guidelines say that FAC levels of greater >5.0mg/L can incur negative taste perceptions, as well as higher levels of carcinogenic disinfection byproducts (WHO, 2006). An FAC of >5.0 mg/l witnessed in households is most often evidence of improper dosing.

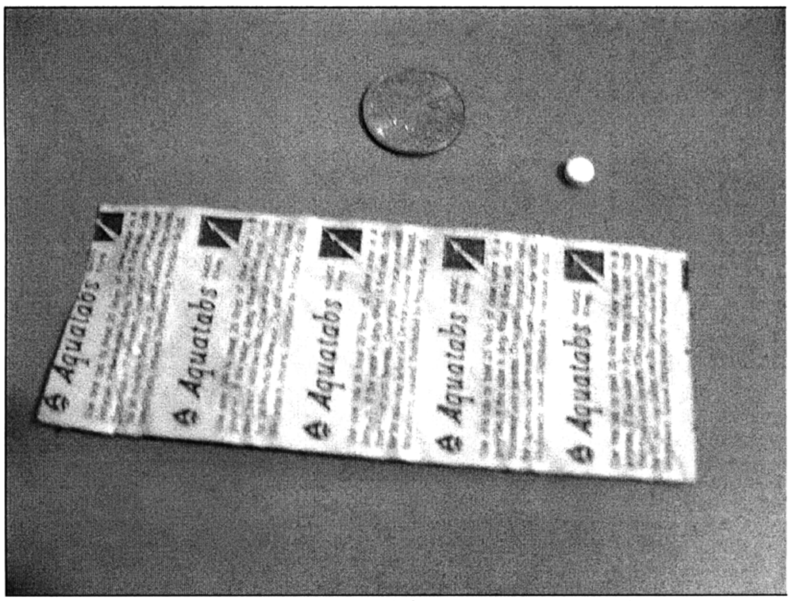
Higher FAC levels are needed if the pH of the stored water is greater than 8. However, unless the users were instructed to dose accordingly given a chlorination implementation in a place of naturally high pH, failure to have higher FAC is not perceived as ineffective use of the product on their part, but rather ineffective promotion of chlorine treatment. Thus, pH measurements are not necessary and the FAC presence/absence still holds. Effectiveness of disinfection can further be confirmed with microbial testing results.

WHO 3rd Edition Guidelines specify that waters over 5 NTU are not suited for chlorine treatment (WHO, 2004). If no other treatment option exists, chlorination of turbid water will help to disinfect the water regardless of moderate turbidity (Quick, 2008). Double dosing achieves acceptable residual FAC in waters that are visibly turbid (>5NTU) and/or from an unimproved source. If raw water is measured to be >50NTU at the household, diminishing microbial reductions from chlorination are likely and pretreatment is warranted.

Chlorine treatment has the potential to completely eliminate *E.coli* counts in treated drinking waters, and the low risk category of <10 *E.coli*/100 ml should be expected from treatment with even moderately turbid waters, as tested from household storage samples (Quick, 2008). Low *E.coli* counts have been found to correlate well with the existence of residual FAC (Arnold, 2007).

## *4.3 Aquatabs*

Aquatabs are a specifically formulated and branded solid form of sodium dichloroisocyanurate (NaDCC). This product is produced by Medentech in Ireland under strict pharmaceutical regulations and comes in many sizes for different treatment regimes. As a household water treatment and safe storage (HWTS) product, Medentech produces a 67mg NaDCC tablet which treats twenty liters of clear water. This specific 67mg product will only be referred to in this text. NaDCC produces the same active disinfection ingredient as other chlorine products, but has a few advantageous properties compared to sodium hypochlorite. NaDCC is stable in Aquatabs form as a solid, making storage, handling, shelf life, and transport much easier than with liquid bleach. In solution, NaDCC produces HOCl as a disinfectant, but withholds half of the potential free chlorine in a stored, inaccessible form until its use is demanded. This is especially useful to work around the pH sensitivities inherent in dilute liquid bleach. Aquatabs have acidic constituents that lower pH and increase effective disinfection as well. Aquatabs are hard to produce and cost a bit more than dilute bleach per health impact for all of these material benefits (Clasen, 2006).




(Photo: Swanton, 2008)

**Figure 8 Aquatabs**

### 4.3.1 Aquatabs Effective Use Brief

| Aquatabs Effective Use Brief | |
|---|---|
| **Monitoring Observations** | |
| ***Treatment*** | 1. User demonstrates knowledge of treatment and dosing as intended by Medentech, without prompting:<br>a. 1 tablet per 20 liters of clear water<br>b. 2 tablets for 20 liters visibly turbid water<br>c. Let sit 30 minutes before consumption. |
| | 2. Pretreatment is recommended for turbid waters |
| ***Safe Storage*** | 1. Two separate 20 liter containers for fetching and disinfection/storage are used, visible, clean, and have no leaks. |
| | 2. Safe storage container for treated water is located indoors, out of the sun, off of the floor, in a stable position and out of reach of animals and small children. |
| | 3. Design of safe storage unit incorporates a tap or a small sealable opening for pouring. |
| | 4. Lids are kept on tight, and only opened for addition or pouring of treated water. |
| ***Maintenance*** | 1. Regularly scheduled cleaning of the storage unit. |
| | 2. Soap or disinfectant used to clean storage unit can be produced by user. |
| ***Replacement Period*** | 1. Product expires 5 years after date of manufacture, as printed on Aquatab sleeve. |
| ***Physical Inspection*** | 1. Water bottles for use during travel or school are clean and producible to the interviewer if consistent use is claimed outside the home. |
| | 2. At least one sleeve of ten non-expired tablets is in stock and easily accessible. |
| | 3. A dedicated clean cup is associated with the safe storage unit. |
| **Water Quality Monitoring** | |
| ***Turbidity*** | If raw water is $\geq$80 NTU, pretreatment should be witnessed or emphasized. |
| ***Chlorine Residual*** | Free available chlorine presence is shown if treatment is claimed. |
| ***Microbial Testing*** | Microbial testing shows <10 *E.coli* CFU/100 ml. |

### 4.3.2 Monitoring Observation

#### *4.3.2.1 Treatment*

Instructions for treatment with Aquatabs are included on the sleeve of ten tabs as sold at the outlet. Medentech prints the following information on the ten-tab sleeves:

> "NaDCC 67mg Use one tab to treat 20 litres of clear water in a jerrycan. If the water is dirty, filter it first with cloth then treat with two tabs. Close your jerrycan and wait for 30 minutes before use. Do not swallow the tablet. Medentech, Ireland. Distributed by Precision dx Ltd."

On the reverse side, batch number and expiration date are listed. All the information is printed for every two tabs on the ten-tab sleeve. (The specific sleeve used for transcribing these instructions was manufactured by Medentech for their Ghanaian distributor, Precision dx Ltd.)

Double dosing 20 liters with two 67mg Aquatabs is advisable if the water is visibly dirty (at least 5 NTU), providing 4.0 mg/l total chlorine for treatment and leaving at least 0.5 mg/L free available chlorine (FAC) after 0.5 hours as recommended by the World Health Organization (WHO). A study conducted by the Tanzanian Ministry of Water and Livestock Department found that treatment of 47 NTU shallow well water in Tanzania with 500 *E.coli* CFU/100 ml resulted in complete reductions to zero plate counts and conformity with WHO standards from initial raw water counts of 20,000 total coliform and 500 *E.coli* (Mjengera, 2005). In their document "Emergency and HWTS use of Aquatabs," Medentech advises users to pre-treat raw waters of turbidity above 80 NTU with methods of settling, filtration, or flocculation before treating with two 67mg Aquatabs in 20 liters of water.

*4.3.2.2 Safe Storage*

Although Aquatabs provide residual disinfection throughout use, safe storage practices are a necessary component of the Aquatabs HWTS system. While the Safe Storage Effective Use Write-up has much greater detail, the following safe storage characteristics are important to note in the home of sodium hypochlorite users. One key storage observation is whether the storage unit is placed in direct sunlight. Although the half-life of free available chlorine (FAC) exposed to sunlight is increased by an order of magnitude with Aquatabs over that of sodium hypochlorite solution due to stabilization with cyanuric acid, direct sunlight on storage vessels will eventually drive out residual chlorine, eliminating residual disinfection and is to be avoided (Kuechler, 2004).

Upon entering the house for a monitoring visit, ask the user to take you to where the drinking water is stored.

- Is a dedicated safe storage container in use in which can easily be measured 20 liters, separate from the container used for fetching water?
- Does the design of the safe storage unit incorporate a tap or a small sealable opening for pouring, such as to eliminate recontamination by the introduction of dirty objects for dipping such as ladles, cups or hands?
- Is the lid to the unit kept on tight, and only opened for addition or pouring out of treated water?
- Is the unit clean and free of leaks, situated indoors, off of the floor, in a stable position and out of reach of animals and small children?

*4.3.2.3 Maintenance*

Minimal maintenance is required with the use of Aquatabs, as the chlorine residual is effective at sterilizing containers. CAWST recommends cleaning any safe storage unit prior to initial treatment and at least once a week for any chlorine product (Adams, 2007). Even without performing the added task of regular cleaning, if the vessel is covered with a hard lid and residual chlorine is maintained, then the storage unit should remain in a suitable condition (Edmondson, 2008).

*4.3.2.4 Replacement Period*

As NaDCC is stable in solid form, Aquatabs have a shelf life of 5 years, regardless of storage humidity and sensitive only to extreme heat. Household possession of expired Aquatabs is a potential sign that disuse or hoarding may be taking place. If Aquatabs are found to be expired, local distributors' supplies might need to be checked for being past their expiration dates.

*4.3.2.5 Physical Inspection*

Aquatabs are a consumable product, and are intended to be used on a daily basis. Medentech's sourcing of in-country for-profit distributors is a strategy positioned to develop stable distribution networks with visible and well positioned outlets, as needed for consistent and sustainable use of Aquatabs. At least one sleeve of ten non-expired Aquatabs must be present in the house and preferably partially used in order to help ensure Consistent and Sustained Use of the product. Checking household stocks and expiration dates is necessary in a monitoring campaign. Another useful check to ensure consistent use is the presence of any chlorine (free or total) in "treated" water. Lack of a minimal chlorine presence shows that claims of recent treatment, correct treatment, or consistent use are suspect. Another good question to ask is whether family members carry treated water or Aquatabs sleeves while traveling. Asking the family to present water bottles in order to back up their answers to consistent use while traveling can lend be informative.

Notice the level of hygiene implicit in the water handling habits of the given user. Users can be prompted to fetch a glass of water to aid in this endeavor. A dedicated clean cup associated with the safe storage unit shows a decent level of hygienic practice.

### 4.3.3 Water quality monitoring

Despite WHO regulations that waters should be under 5 NTU for regular chlorination, no upper limit to turbidity is set for Aquatabs, based upon the various studies done by Medentech. However, treating water above 80 NTU is likely to have diminished results, necessitating pretreatment. If turbidity is visible or measured as greater than 5 by the monitor, two tabs should have been used to treat the water.

Disinfection with NaDCC is the sole control measure of Aquatabs. The WHO (1993) stipulates that at least 0.5mg/L FAC remains after 30 minutes contact time. As long as 0.2 mg/L FAC exists in water 24 hours after treatment, sufficient residual disinfection potential exists (CDC, 2005). Assuming that unreasonable recontamination has not occurred (this can often be loosely confirmed through physical observation of user habits), using a DPD FAC test strip, any pinkness on the Free Chlorine test indicates treatment with Aquatabs and this is satisfactory to the chlorine requirement. Effectiveness of disinfection can further be confirmed with microbial testing results, although CAWST claims that microbiological testing is only needed if no free chlorine can be measured (Adams, 2007).

While free chlorine is very successful at inactivating bacteria in clear water (~4 log removal), *cryptosporidium* and *Mycobacterium* have shown resistance to disinfection. In water of >10 NTU, 1.8-2.8log reductions in bacteria have been noted through chlorine disinfection (Schlosser et al., 2001). Simple monitoring campaigns as described here have limited ability to accurately quantify log reductions from raw to treated water given the time delay between fetching, treating, storing and using water in the home, and thus measuring concentrations of *E.coli* in treated waters provides a potential additional water quality measurement beyond chlorine residual. Almost all of Medentech's collected literature concerning field microbial testing reports *E.coli* counts of <1 CFU/100ml. Molla reported 84% of the households surveyed out of 50 households provided with Aquatabs for a month had no shows of fecal coliform (Molla, 2005). Given such low showings of *E.coli* in the field, measurement of less than 10 *E.coli* CFU/100ml shows that total treatment worked as intended, verifying that the control measure was correctly implemented by both the user and the technology and that low risk to the user has been achieved (Moran, 2008).

### 4.3.4 Discussion

In both Ethiopia and Ghana, Medentech has paired with a single distributor, giving this company sole-rights to import and sell Aquatabs. Aquatabs are produced by Medentech under strict pharmaceutical regulation in Ireland and sold under distribution agreements to national companies with a strong track record in related consumable goods. Once imported in bulk by the distributor, the sleeves are repackaged with that company's logo and user instructions are reprinted in the given language. Medipharm is the distributor in Kenya, and their packaging is shown in *Appendix F: Aquatab Usage Instructions*, along with usage instructions from Medentech. Medentech also works with Population Services International (PSI), the not-for-profit social marketing organization, in countries throughout Sub-Saharan Africa and South Asia.

Easier to dose than liquid chlorine, only the dirtiness and volume of water needs to be judged to use Aquatabs. In a study conducted in Tanzania, 70% of FAC measurements taken at the household were within WHO limits of 0.5 to 5.0 mg/l, showing a high level of accuracy in dosing. 27% of results were reported as below 0.5 mg/l, some of which would have qualified as correctly dosed, depending on the time elapsed after treatment (Medentech, 2006). FAC levels higher than the inherent 2 mg/l dosing given the 67mg tablet have often been recorded in treated water (Swanton, 2008). Such a result is attributed to using a full tablet on less than 20 liters of water, which may be a common practice when less than 20 liters of water are available for drinking and treatment. The upper limit of 5.0 mg/l FAC in drinking water set by the WHO as a guideline value is recommended for lifetime consumption. Over-dosage is not a problem on a short-term basis (WHO, 2006). The guideline values of NaDCC that has been derived is well above the recommended maximum dosage of 8.5 mg/L (using two tabs in 20 L) (Edmondson, 2008). Aquatabs with NaDCC have been found preferable to similarly dosed sodium hypochlorite solution (HOCl) in a number of field-based taste tests (De Angelis, 1998). Potential overdosing leading to high levels of disinfection by-products such as trihalomethanes is limited with Aquatabs due not only to the ease with which it is dosed, but also the reduced production of such byproducts by NaDCC as compared with liquid bleach (Macedo, 1997).

Training is often minimal when Aquatabs are sold to the consumer at the kiosk or pharmacy, so ease of use is an important feature of this product. No mixing is needed with 67mg Aquatabs. The effervescent nature of Aquatabs allows the FAC to distribute itself homogenously throughout the storage vessel without the need for introducing foreign dirty objects for stirring or spillage from shaking. Neither in training materials or usage instructions is a time limit for use of treated water specified with Aquatabs. Given the recommended dosing, treated water meets the WHO and Center for Disease Control standards of 0.5 mg/L FAC after 30 minutes contact time and >0.2 mg/L FAC after 24 hours, respectively, as shown in field studies from multiple countries. For example, an average of 0.79 mg/L FAC was shown after 2 days in Vietnam (Chau, 1996). Joe Moran of Medentech, Ireland claims that no timeline for consumption is recommended because behaviors concerning usage of treated waters are not controllable by the distributors of the product, and people are expected to use the water as they would normally do despite recommendations to the contrary. Such a lack of stipulation is not unreasonable, as the average time to use water is daily. Upon questioning the distributors in both Ethiopia and Ghana, this lack of a stipulation was confirmed by their non-use of such a guideline in training and dissemination.

A Brazilian Government study showed a 44.5% reduction in stool parasites over the course of a one year Aquatab intervention among 618 participants (Ministério da Saude, 1996). Such reductions represent great quantitative evidence of the health benefits of using Aquatabs on a regular basis. Through monitoring as laid out in the preceding paragraphs, Effective Use of Aquatabs can be maintained and improved such that quality of treatment increases and greater individual health benefit ensues.

## *4.4 SODIS*

Solar disinfection (SODIS) is a point of use water treatment method that disinfects through a combination of direct radiative inactivation, indirect photolytic degradation, and moderate pasteurization with increased temperatures. SODIS treatment has been shown to inactivate bacteria, viruses, and protozoa including cryptosporidium and giardia (Wegelin, 1994; Mendez-Hermida, 2005). SODIS was originally investigated at the American University of Beirut during the 1970s as an efficient way to disinfect water for use with oral rehydration therapy (Acra, 1984). A serious and prolonged effort to study and promote SODIS has been undertaken by the the Swiss Federal Institute for Aquatic Science and Technology (EAWAG) since 1991. SANDEC, the Department of Water and Sanitation in Developing Countries at EAWAG has contributed a great deal of research concerning microbiological efficiency, health impact assessment, and material testing as well as international advocacy, collaboration, and training of SODIS programs (Wegelin, 1994). SODIS has also been studied by Masters of Engineering students at MIT in Nepal, Haiti, and Ghana (<http://web.mit.edu/watsan) as well as a number of other academic institutions.

### 4.4.1 SODIS Effective Use Brief

| SODIS Effective Use Brief | |
|---|---|
| **Monitoring Observations** | |
| ***Treatment*** | 1. User demonstrates correct knowledge of treatment, without prompting:<br>a. Fill clean bottles with raw water and close lid tightly.<br>b. Place the bottles on a corrugated iron sheet or on the roof, and in a place with continuous direct sunlight throughout the day.<br>c. Leave in direct sun from morning to dusk. If ≥50% overcast, leave out for 2 days. |
| | 2. Use of clean and clear PET bottles that are ≤5 liters in volume and not heavily scratched. |
| ***Safe Storage*** | 1. SODIS treatment bottles provide post-HWTS treatment safe storage, and thus need to have no leaks and be kept clean, stored in a safe location out of reach of animals and small children, with lids kept on tight. |
| ***Maintenance*** | 1. Clean the bottles with soap and a bottle brush if available if you observe the formation of algae on the inner side of the bottle. |
| | 2. Soap or disinfectant used to clean the bottles can be produced by user. |
| ***Replacement Period*** | 1. Replace bottles when heavily scratched, opaque, or leaking. |
| ***Physical Inspection*** | 2. Treated water is available, and if weather conditions permit, water is currently being treated. |
| | 3. A dedicated clean cup is associated with the safe storage unit. |
| **Water Quality Monitoring** | |
| ***Turbidity*** | If when one's hand is placed behind a full bottle laying horizontally and the fingers are still visible, then the turbidity requirement is satisfied and water can be adequately treated. Pretreatment to reduce turbidity is needed if fingers cannot be seen. |
| ***Microbial Testing*** | Microbial testing shows <10 *E.coli* CFU/100 ml. |

### 4.4.2 Monitoring Observation

*4.4.2.1 Treatment*

Treating water with SODIS is straight forward, although there are a few key aspects to keep in mind. Below is the schematic developed by SANDEC and published in their SODIS Manual.


(Meierhofer, 2002)

**Figure 9 SODIS Usage Pictorial**

These directions are clear and simple. After making sure that the bottle is clean, fill the bottle ¾ full with water, close, and shake it for 20 seconds to enhance aeration. Completely fill the bottle, and seal tightly. During the morning, place the bottles on a firm darkened or reflective surface, preferably a clean corrugated iron roofing sheet that is raised off of the ground. When placing the bottles, ensure that they will be exposed directly to sunlight for the entire day. If over 50% cloud cover persists, leave the bottles out a second day (http://www.sodis.ch/Text2002/T-Howdoesitwork.htm). Retrieve the bottles at dusk and the water is ready for consumption. SODIS is not recommended for rainy days.

Leaving a few inches of airspace and shaking the bottles vigorously prior to sun exposure has been recommended by a number of agencies, including the Global Research Institute as in the attached instructions (See *Appendix F: SODIS Usage Instructions*). SODIS deactivates microbial contaminants partially through the creation of reactive oxygen species by indirect photolysis. Matthias Saladin of the Fundación SODIS in Bolivia no longer recommends shaking the bottles, as natural waters have the requisite 3 mg/L of dissolved oxygen and adequate agitation occurs through pouring into the bottle (Saladin, 2008). He also recommends putting the bottles out for the whole day, as most SODIS users do not possess clocks. Accordingly, he proposes a simpler five-step usage framework that can be viewed at www.fundacionsodis.org/en.

#### *4.4.2.2 Safe Storage*

Ensure safe storage practices by using the SODIS treatment bottles themselves as safe storage containers. SODIS treatment bottles provide post-HWTS treatment safe storage, and thus need to have no leaks and be kept clean, stored in a safe location out of reach of animals and small children, with lids kept on tight. Secondary safe storage containers are not recommended because SODIS treatment does not provide any residual post-treatment disinfection potential, unlike the various chlorine products.

#### *4.4.2.3 Maintenance*

Proper maintenance requires regular cleaning of the bottles. KWAHO explicitly recommends cleaning of the bottles prior to the first usage. Although the bottles are subject to the daily disinfection process, cleaning bottles with brushes and soap is necessary from time to time to remove algae that may grow on the inner surface, as the film formed impedes UV-A transmittance. The extent of algae growth is partially dependent on the quality of the local source water.

#### *4.4.2.4 Replacement period*

Usage and exposure to the environment tends to incur scratches that can block a large percentage of the UV-A disinfection potential, and heavily scratched or opaque bottles need replacement. Non-sealable or leaking bottles need to be replaced for sanitary reasons, as well. No firm timeline is recommended for bottle replacement, as it will be situation dependent.

#### *4.4.2.5 Physical Inspection*

Household monitoring of SODIS needs to be conducted on days without rain in order to directly witness use. When visiting a home, ask to see bottles undergoing treatment:

- Are an adequate number of bottles (2 per person) currently being treated (Meierhofer, 2002)? Current treatment can help ensure claims of consistent use, an important component of reducing the likelihood of diarrheal disease.

- Are bottles undergoing treatment lying on their side, positioned in direct sunlight throughout the day, and on a clean surface off of the ground? Some regular users do not place bottles outside for treatment everyday, although they should have treated water on hand (Saladin, 2008).

Within the house, ask the person in charge of water treatment (if available) to explain how they treat the water, making sure to note the directions listed in the *Treatment section*. While in the house, inspect the storage and hygiene conditions.

- Are the bottles made of PET, less than 5 liters in volume, clean and not heavily scratched with all labels removed? Leaks can also be assessed.
- Are bottles clean on both the inner and outer surfaces?
- Does the user have a suitable system of bottle rotation that can allow for bottles to be exposed for two days depending on the weather while providing sufficient drinking water for the household?
- Is treated water available for consumption in the house?
- Do users carry the treated bottles to work or school, incurring consistent use?
- Is a clean cup present for individual drinking use?

### 4.4.3 Water Quality Monitoring

Turbidity reduces the transmittance of UV-A radiation, and therefore it is recommended to pretreat water of turbidity greater than 30 NTU. Testing of turbidity can be achieved with a Turbidity-tube by the monitor. Pre-settling before addition to the SODIS bottle can be encouraged, but results will vary. User training for the SODIS program should include the EAWAG-proposed method in which a 0.5-liter bottle is filled and stood upright atop a newspaper headline. If the large black print can still be read, the water is less than 30 NTU and suitable for treatment. If not, pretreatment through settling in a separate container or flocculation is warranted until the newspaper headline test is passed. Many SODIS users are non-literate, and may not have ready access to newspapers. In this case, instruct users to place one's hand behind the bottle, and if your fingers are still visible when looking through the bottle horizontally, the water is suitable for treatment. This technique needs confirmation, yet has the added advantage of confirming light transmittance through both the water and bottle width (Saladin, 2008). These techniques can be particularly important for monitoring programs, avoiding the wastage of water necessary to fill the Turbidity Tube. Measurements of turbidity in a household's SODIS bottles need to be taken throughout varying climatic seasons in order to fully judge effective pretreatment and applicability.

Exposing natural waters that contain nutrients to sunlight and enhanced temperatures creates conditions under which many bacteria can multiply. While not producing a sterile water, SODIS treatment has been shown to achieve the intended die-off of pathogenic microorganisms, as shown through SANDEC's multiple results of zero fecal coliforms after treatment (EAWAG/SANDEC, undated). Accordingly, reductions in total coliforms need not be monitored with the use of SODIS. Simple monitoring programs as laid out here have very little ability to accurately quantify log reductions from raw to treated water given the time delay between fetching, treating, storing and using water in the home, and thus absolute numbers of *E.coli* in treated waters will be measured. The goal of SODIS is to incur low microbial risk as defined by the WHO, and thus waters treated effectively should result in <10 *E.coli* per 100 ml of sample when tested.

### 4.4.4 Discussion

With minimal hardware cost both to the user and the implementing agency, SODIS is a very cheap method with the potential for great health impact. Randomized controlled studies have been conducted that show reductions in diarrheal disease comparable to many of the other HWTS. In one such study, Rose reported a reduction of 40% among 100 users and a high acceptance rate among female users (Rose, 2006). Clasen reports a cost of US $61 per DALY averted, putting SODIS on par with the most cost effective HWTS intervention, dilute bleach solution (Clasen, 2007). SODIS has the added advantage of being a self-contained safe storage unit that is available worldwide. Reusing a large number of water bottles can reduce the burden of rubbish accumulation, keeping scarce land free from debris in crowded urban dwellings.

SODIS treatment requires sustained incident solar radiation of 500 $W/m^2$ for 5 hours for adequate microbial inactivation (EAWAG, 1997). While semi-arid regions between latitudes 15°N and 35°N have ideal solar activity throughout the year, the majority of developing countries lie between 35N and 35S and often have adequate sunshine for SODIS treatment as well (Tech Note 5).

The effects of turbidity and bottle type on UV-A transmittance within the bottle have been well studied. As to be expected, UV-A radiation is reduced through absorbance and dispersion as it travels through water. Only 50% of incident UV-A makes it to a depth of 10 cm in water of 26 NTU, prompting SANDEC to recommend a 30NTU upper limit of turbidity for SODIS treatment, as well as containers that are at most 10 cm in depth (Tech Note 7). In terms of material recommendations, translucent polyethylene (PE) bags have been shown to inhibit UV-A transmittance less than bottles made of glass or polyethylene terephthalate (PET), a polyester. However, PET bottles can transmit an acceptable 70% or more of incident UV-A light and are much more available. Chemically, both PET and polyvinyl chloride (PVC) contain additives such as UV-stabilizers. While these stabilizers are largely immobile and pose minimal health danger, PET contains much less stabilizers than PVC and is thus preferable (Tech Note 2). The plasticizers used in PET, di(2-ethylhexyl)adipate (DEHA) and di(2-ethylhexyl)phthalate (DEHP) are also of possible concern. SANDEC has shown that SODIS treated water contains concentrations of these plasticizers on the order of 1 to 3 logs below the WHO guideline values. Similarly, acetaldehyde and formaldehyde concentrations posed little health risk (http://www.sodis.ch/Text2002/T-PETBottles.htm). Based on their greater durability, availability and suitable chemical properties, only clear PET bottles of less than 5 liters in volume have been recommended for use in SODIS applications (Saladin, 2008).

Temperatures above 50°C are lethal to many organisms, including cholera, giardia cysts, and schistosomas eggs over the course of an hour (EAWAG/SANDEC, undated). In combination with UV-A radiation, synergistic treatment effects occur at temperatures above 50°C, resulting in increased treatment potential. SANDEC has developed a reusable paraffin-based sensor that is placed inside the bottle and melts at 50°C, indicating that a water temperature of 50°C has been reached. However, SODIS is effective also at water temperatures below 45°C due to the effect of UV-A radiation only (bacteria, viruses and cysts of Giardia and Cryptosporidium are disinfected). Due to ongoing research on synergistic effects of UVA radiation and heat inactivation, Meierhofer's and Metcalf's recommendations, and increased burden on the user, the use of a temperature indicator is not necessary. Decreasing treatment times based on synergistic effects is not recommended. Similarly, SODIS proponents no longer recommend painting one side of the bottle black, but rather recommend placing the bottles on corrugated zinc-plated iron roofing in order to increase reflection, heat, and sanitary conditions (Baffrey, 2005).

## *4.4 Cloth Filter*

Cloth filtration is an ancient water treatment technique, dating back to at least 500 BCE in India, yet in recent decades has been found to be particularly effective against specific pathogens with large carrier hosts.

### 4.5.1 Cloth Filter Effective Use Brief

| Cloth Effective Use Brief | |
|---|---|
| **Monitoring Observations** | |
| ***Treatment*** | 1. Fasten cloth to water storage vessel and tighten string, using same side up each time (for Guinea Worm Cloth). |
| | 2. Fold sari cloth at least 4 times and wrap tightly around rim of storage vessel inlet. |
| | 3. Filter all water that is fetched immediately at source or upon returning home from the source. |
| | 4. Use filtered water for all domestic water uses. |
| | 5. Always use manufactured cloth filters with the same side up. |
| ***Safe Storage*** | 1. Maintain separation of filtered water from non-filtered water. |
| ***Maintenance*** | 2. Rinse off filter after each use, with a final rinse of cloth filtered water and then leave cloth in the sun for decontamination. |
| | 3. Clean cloth filter with soap regularly. |
| | 4. Soap or detergent used to clean cloth filter can be produced by user (if applicable). |
| ***Replacement Period*** | 1. Replace filters when visible tearing or holes occur. |
| ***Physical Inspection*** | 1. User stores cloth filter in a safe and accessible place. |
| | 2. Cloth filter is clean and without tears or holes. |
| | 3. User correctly describes or enacts use and cleaning. |
| | 4. User knows where to get a new cloth filter (if bought or distributed). |

Two current cloth filter applications include use of the sari cloth in Bangladesh to combat cholera and the use of cloth filters in the Guinea Worm Eradication Program (GWEP) in Africa. In the mid 1990s, Huq showed that 99% of cholera parasites (those bound to planktonic copepods) were removed by quadruple-folded sari cloth in Bangladesh (Huq, 1996). Since then, there has been considerable press coverage of this seemingly simple intervention, with Dr Claire-Lise Chaignat, coordinator of the World Health Organization's global taskforce on cholera control claiming "The method can save thousands of lives during massive epidemics, particularly those of children under the age of five" (BBC, 2003). In a 133,000 person study conducted over three years in Bangladesh, Colwell found a 48% reduction in cholera incidence accompanied with a reduction in severity of the cases. She also claimed high cultural acceptability and 90% correct usage among the intervention group. Mothers in the study often self-reported lower disease burden within their own households, which has positive implications for effective and sustained use of cloth filtration (Colwell, 2003).

Similar to that of cholera, the vector of dracunculiasis (guinea worm) is a water-borne cyclops that can be filtered by cloth. The Carter Center distributed 1.4 million filters from Jan. 2003 to June 2007 in Ghana alone, and in combination with vigilant rural monitoring and chemical treatment of affected water sources with Abate®, the cloth filter intervention has helped to incur a 91% reduction during the peak transmission season in the first quarter of 2008 as compared to 2007 (GW Wrap-up, 2008). The reduction in guinea worm incidence is so pronounced that the GWEP expects world-wide eradication within the next few years. Cotton cloth filtration is also a component of the PUR flocculation/disinfection system, as described in the *PUR Effective Use Write-up*.

### 4.5.2 Monitoring Observation

*4.5.2.1 Treatment*

Household use of the cloth filter requires simple training, as demonstrated in the following schematic for sari cloth or similar homemade cloth filters. This pictorial illustration was developed by the Centers for Disease Control (CDC) and published in their Safe Water System Handbook.[3] Older sari cloths had an effective pore size of 20μm when folded 4 to 8 times, as recommended by Colwell and shown in the diagram below (Colwell, 2003). In Bangladesh, where Colwell's study took place, women fetch water by dipping their *kalash* water containers into streams and standing water, such that tightly covering the inlet is very important to ensure that targeted contamination does not bypass filtration, also shown in the diagram below.

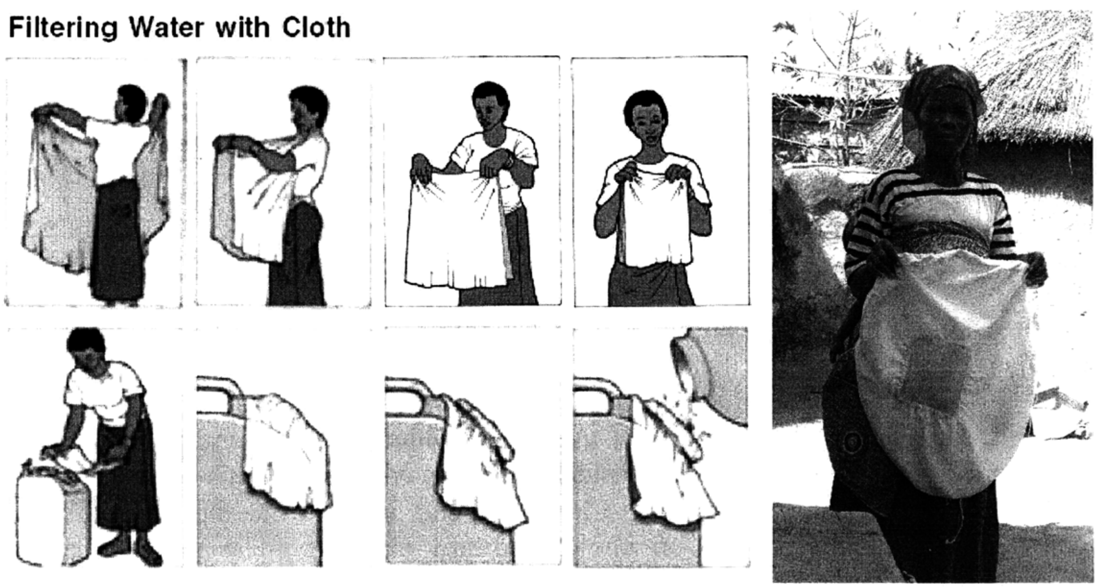



**Figure 10 (a) CDC Cloth Filter Usage Schematic; (b) GWEP Filter in Ghana**

(CDC SWS Handbook; Murcott, 2007)

[3] http://www.cdc.gov/safewater/manual/sws_manual.pdf

The following instructions are specific to use of the Vestegaard Frandsen S.A. 30 inch, 120 micron pore size nylon and cloth filter unit as employed by GWEP, Ghana (Murcott, 2007):

- Fasten cloth to wide-mouth storage vessel and tighten string.
- Pour source water into the center of the cloth
- Allow the poured water to pass through the cloth before adding more.
- Do not exceed the capacity of the cloth to strain the water.

Important to the use of the Vestegaard guinea worm cloth filter, pictured on the right above, is that it is used with the same side-up every time so as to prevent contamination from previous uses.

While training on appropriate usage of cloth filters is straightforward, vigilant monitoring is often needed to promote the sustained and consistent use of the filter every time water is fetched, and to ensure that filtered water is used for all domestic water uses, not just cooking and drinking (Aikhomu, 2000).

*4.5.2.2 Safe Storage*

Filtering all of the water brought to the house and/or maintaining separation of filtered and unfiltered water will ensure adequate safe storage of cloth-filtered water. If all water is immediately filtered at the source or following transport to the home, the difficulty of maintaining separation of filtered and non-filtered water through safe storage is greatly diminished. As other microbial contamination from waterborne bacteria, viruses or protozoa is not removed by cloth filtration, safe storage does not ensure the quality of cloth filtered water. Secondary treatment is often required to reduce the likelihood of diarrheal disease.

*4.5.2.3 Maintenance*

Maintaining a filter has two goals, to prevent both tears and re-contamination. To prevent cloth filters from tearing, it is important that they are kept in a safe and clean location that is easily accessible for daily use. Vigilant user-inspection for small holes goes hand-in-hand with awareness of tearing. Keeping the filters off of the ground is a key training lesson in the prevention of recontamination. The user should also be informed of where to find a replacement cloth filter, if the current one tears or is spoiled.

While cleaning techniques are tailorable to the material and make of the cloth filter, it is important to rinse them off after each use, with a final rinse of cloth filtered water and then leave them in the sun for decontamination (Colwell, 2003). Occasional cleaning with soap/laundering of sari cloths is recommended. Cloth filters do not clean the water of bacterial contamination, and thus regular cleaning of storage units is useful to keep biofilm from accumulating as a result of nutrient-rich treated waters. As previously mentioned, additional treatment for other microbial contamination may be needed as well

*4.5.2.4 Replacement Period*

Aikhomu et al. (2003) found that distributed cloth filters often do not last a full transmission season. The Carter Center Guinea Worm Eradication Project's community volunteers' vigilant monitoring campaign (which visits each household at least once per week) advises that it is important not only to quickly report and treat individual cases of guinea worm, but also to inspect and replace faulty cloth filters, providing a visible contact for whom community members can turn to when their filters are spoiled. Such a large network of constant monitoring resulted in 100%-witnessed Effective Use of the cloth filter in the 50 or so households visited by this author near Tamale, Ghana in January, 2008. Multiply-folded sari cloths, while harder to inspect than Vestegaard's guinea worm cloth filter, adds multiple layers of protection and is easily replaceable in Bangladesh when worn out or torn. In fact, older sari cloths are recommended as their effective pore size is smaller due to moderate wear.

#### *4.5.2.5 Physical Inspection*

When monitoring at the household or water source, ask the person who fetches and/or treats water to see their cloth filter. Where do they store the filter? Does the storage area provide adequate protection from tearing? If the filter is readily accessible and clean, this suggests possible consistent use. Personally inspect the filter. Pin prick holes in manufactured filters may not be perceived as problematic, yet they represent highly increased likelihood of disease transmission. Ask the user to show you how they operate the cloth filter, if possible. Do they effectively cover the inflow of the water storage container? Ask them the last time the cloth was cleaned and the method of cleaning to make sure that previous training and common knowledge match up (Hernandez, 2008).

### 4.5.3 Water Quality

Other than the specific pathogens targeted by the cloth filter intervention (e.g., cholera and guinea worm vectors), which are very difficult to measure, no noticeable changes in water quality are likely to occur. While subsequent treatment will most likely be needed to make cloth-filtered water microbiologically safe to drink, straining through a cloth is often very important to other treatment methods such as PUR. Turbidity reduction is typically unnoticeable, and thus no turbidity measurement is needed. Cloth filters will not affect *E.coli* concentrations, so indicator bacteria testing as called for in other interventions is irrelevant here. Visually, the water should be free from large suspended debris if filtration is claimed by the user, although the naked eye cannot see particulates on the order of 100μm or less.

## *4.6 Ceramic Pot Filter*

The ceramic filter is a porous flower pot-shaped device that holds 8 liters of water when filled. The ceramic pot filter element sits in a self-contained safe storage unit of 20-45 liters with a lid to form an enclosed single unit, referred to here at the ceramic water purifier (CWP). While working with the Central American Research Institute for Industry (ICAITI) in the early 1980s, Dr. Fernando Mazariegos developed the original design for a colloidal silver impregnated ceramic pot-shaped filter. Many organizations have embraced the filter since then, including Ron Rivera's Potters for Peace, which has helped greatly to disseminate the filter to over 1.5 million people in 21 countries (Rivera, 2008).

With effective pore sizes that range from 0.6-3 μm as necessary for sufficient flowrate, typical ceramic filters from Nicaragua allow small numbers of *E.coli* (2 μm long by 0.5 μm wide) and other bacteria to pass through (Lantagne, 2001). To help solve this problem, Mazariegos painted the underside of the ceramic pot with colloidal silver in order to inactivate these bacteria. Brown witnessed 99.5% *E.coli* reductions in his lab tests using filters with and without the addition of colloidal silver (Brown, 2007). These findings compared quite well with results from field testing in Cambodia, in which 80 households with ceramic water purifiers CWPs from an International Development Enterprises (IDE) distribution the previous year were monitored thrice over a four year period, resulting in 98% average reduction in *E.coli* counts. This study recorded a 46% reduction in diarrhea prevalence among 203 users and thus showed the ability of users to effectively manage their drinking water through use of the CWP (Brown, 2007). While viruses are smaller than 0.2 microns, and thus are not targeted by the ceramic pot filter, Brown found 1-2 log removal of the indicator MS2 bacteriophage in laboratory trials (Brown, 2007). With a cost of US $6-25 worldwide and health impacts similar to other treatment options, the health-based cost effectiveness of ceramic filters compares well with other HWTS.

### 4.6.1 Ceramic Pot Filter Effective Use Brief

| Ceramic Pot Filter Effective Use Brief | |
|---|---|
| **Monitoring Observations** | |
| ***Treatment*** | 1. Water is added to the CWP every day. |
| | 2. Ceramic pot is frequently topped off in order to achieve faster flow rate. |
| | 3. Ceramic pot is not overfilled. 3-5cm below the brim is the maximum recommended fill level to prevent spillage over the lip and into storage. |
| | 4. Storage unit is not filled above the bottom of the ceramic pot. |
| | 5. Lid for the CWP is kept in place except when being filled. |
| | 6. Proper installation is witnessed, including:<br>6.1. Raised above the ground to about table height<br>6.2. Sits level on a stable base that is large enough to accommodate it<br>6.3. Located out of direct sunlight and out of reach from young children and animals.<br>6.4. Tap is not resting on any nearby object and does not leak. |

| | |
|---|---|
| | 7. Turbid waters undergo settling for at least one hour before ceramic filtration |
| ***Safe Storage*** | 1. The CWP includes a closed safe storage unit with a tap that should keep treated water safe if the ceramic pot remains in place throughout use as directed and the storage unit is regularly cleaned. |
| | 2. If possible, check to see if clay particles have settled in the storage unit. These are likely to be from the ceramic pot itself, yet infer infrequent cleaning (i.e., improper maintenance) of the storage unit. If found, the monitor should ask when the last time the storage unit was cleaned. |
| | 3. Secondary storage is not recommended without chlorine disinfection to retain microbiological quality of treated water. Safe storage characteristics and effective use of the chlorine product should be noted if secondary storage is used. |
| ***Maintenance*** | 1. Cleaning of the ceramic pot is needed when a significant reduction in flowrate occurs. Conversely, cleaning can be regularly scheduled with a frequency determined by source water quality. |
| | 2. To clean the ceramic pot, scrub the inside with a hygienic brush and rinse with filtered or boiled, cooled water. Never use soap or disinfectant with the ceramic pot itself. |
| | 3. Regular cleaning of the safe storage unit, tap and lid with filtered or boiled water and soap or chlorine disinfectant is necessary. |
| | 4. Ask the user when the last time the CWP was cleaned, and make sure she/he has a sound scheduling mechanism for cleaning. |
| | 5. Ceramic pot, storage unit and tap are clean with no visible leaks or cracks. |
| ***Replacement Period*** | 1. No expiration period suggested. Replace filter when cracked or broken. |
| ***Physical Inspection*** | 1. There is water in the storage unit and the ceramic pot is partially full or at least damp infers active use. |
| | 2. A clean cup that is used only for drinking is associated with the CWP. |
| | 3. Water bottles for use during travel or school are clean and producible to the interviewer if consistent use is claimed. |
| | 4. User demonstrates hygienic method when asked to add or fetch water to the CWP. |
| | 5. Instructional material is displayed with the CWP, if provided during purchase or installation. |
| **Water Quality Monitoring** | |
| ***Turbidity*** | Treated water is expected to be clear (<5NTU) unless influent is >100NTU from source, which requires settling before treatment. |
| ***Chlorine Residual*** | Free available chlorine presence in secondary safe storage if chlorine treatment is claimed. |
| ***Microbial Testing*** | Microbial testing shows <10 *E.coli* CFU/100 ml of treated water from storage unit(s). |

### 4.6.2 Monitoring Observation

*4.6.2.1 Treatment*

*Installation*
Effective use of the filter starts with proper installation. As opposed to the biosand filter, where the user takes part in construction and installation with careful oversight by technicians, the CWP is often left to the user to install after instruction. Important installation instructions are as follows, and can be taught through group trainings or by having a salesperson deliver the filter directly to the home. Prior to assembly, wash all pieces of the system using boiled water, and disinfectant or soap for the non-ceramic parts, taking note of the techniques described in the *Maintenance* section below. A single Aquatab is provided by Pure Home Water (PHW) for an initial disinfection during installation. Assemble the unit in proper fashion, as demonstrated on stickers, posters or through training sessions, making sure the tap does not leak. Place the unit on a stable, flat base, raised to table height above the ground (~75 cm) in a safe yet convenient location indoors, out of the sun where animals and young children can not access it. Once in place, run enough water through the new filter to decrease the taste of clay in the water to acceptable levels if necessary, but otherwise the filter is ready for use. All of these aspects of setup can lead to longer and safer use of the CWP, and may be observed directly through operational monitoring at the home. Following installation, day to day operation of the filter is straightforward, with only a few key points to mention.

*Turbidity*
Rivera recommends straining turbid waters through a cloth tied around the edge of the unit while adding water for filtration (See *Appendix F: Ceramic Pot Filter Usage Instructions* for the pictorial schematic from Potters for Peace). Pure Home Water's training materials specifically instructs users to let turbid water settle in their primary storage units for at least one hour prior to adding to the CWP (See *Appendix F: Ceramic Pot Filter Usage Instructions* for the pictorial schematic from PHW). Despite achieving better efficiency or larger log reductions with high influent turbidities, higher resultant turbidities and contamination levels have been noticed in filtered waters coming from more turbid sources (i.e., a 98% reduction of 1000 *E.coli* per 100ml represents intermediate risk water) (Peletz, 2008). Elevated source waters turbidities reduced ~50% before treatment through settling in large clay urns in Northern Region, Ghana with residence time on the order of a few days before undergoing ceramic filter treatment (Johnson, 2007). Without this pretreatment, turbidity was higher than 10 TU from a number of filters in Swanton's study despite otherwise effective use (Swanton, 2008). High turbidities require more cleaning, and thus greater wear on the filter, more burden on the user, more chance for breakage during cleaning, and consequently more chance for recontamination in the storage unit through ineffective cleaning. While CWP's are suited to a variety of source waters, pre-treatment settling of highly turbid waters is needed for improved performance of this technology. Measuring of turbidity to aid in discerning whether the filters are being used effectively will be covered later in the *Water quality monitoring* section.

*Flowrate*

Pressure from elevation head is the mechanism that drives filtration in this system. If users understand this, then they will know to keep the filter filled for faster filtration. This author witnessed users in Ghana waiting until the filtration had finished before adding more water, and these same users complained of the filter not providing enough water for the family. In the effort to improve flowrate by keeping the filter full, it is important that the user not overfill the pot, as overflowing water can make its way around the narrow lip of the ceramic pot and into the safe storage unit without filtration, reducing filtration effectiveness by half. Baumgartner et al. recommend not adding water to the above 3-5 cm from the top of the ceramic pot (Baumgartner, 2007). When adding water, use a clean cup or *calabash* to add small amounts of water at a time. To avoid contamination from overfilling, and possibly cracking or knocking over the filter, never add water from a large bucket or from any height to the filter. These are fragile units, and breakage is a major reason for discontinued use. Other than for filling and cleaning the filter, the lid to the unit must stay on at all times. A missing lid signifies poor hygiene and improper use.

*Water Level*

Regarding water level, on of the CWP sold by Pure Home Water in Northern Region, Ghana, a usage sticker is placed on the safe storage unit with clear line drawn at the level of the bottom of the ceramic pot in order to discourage users from filling the storage above that line (Pure Home Water, 2008). For a visual representation of this sticker, see *Appendix F: Ceramic Pot Filter Usage Instructions.* Allowing the storage unit to fill above the bottom of the pot can negate the head gradient within the filter unit, leaving water inside the filter walls for unnecessarily long times. With a flowrate of 1-2.5 liters per hour when new, these filters do not produce a lot of water in short amounts of time. Witnessing excess water in storage during a household visit may be a sign that the household tends not to drink the water from the filter.

*4.6.2.2 Safe Storage*

The CWP includes a closed safe storage unit with a tap that is a well regarded feature of the unit, and if the ceramic pot remains in place throughout use as directed and the storage unit is regularly cleaned, the self-contained storage unit should keep treated water safe. However, the storage units have been noted to be prone to recontamination through improper use, and careful attention to them must be given during household visits (Brown, 2007).

If there is not much water in the ceramic pot, lift the pot and check to see if the inner surface of the storage unit (typically a 20 liter bucket) is clean. Clay particles settled in the storage unit are likely from the ceramic pot itself, and infer infrequent cleaning (i.e., improper maintenance) of the storage unit. If settled clay particles are found, the monitor should ask when the last time the storage unit was cleaned. The recommended regular interval is one to two weeks, and should coincide with cleaning and disinfection of the tap, lid, and associated outer surfaces of the CWP.

Secondary storage is not recommended without chlorine disinfection to retain microbiological quality of treated water. If secondary containers are used for storage, safe storage characteristics of the container and effective use of the chlorine product should be noted.

*4.6.2.3 Maintenance*

The following maintenance protocol was developed by Potters for Peace, and is in use throughout the world among production facilities that were initiated by Ron Rivera's trainings (PFP website, 2007):

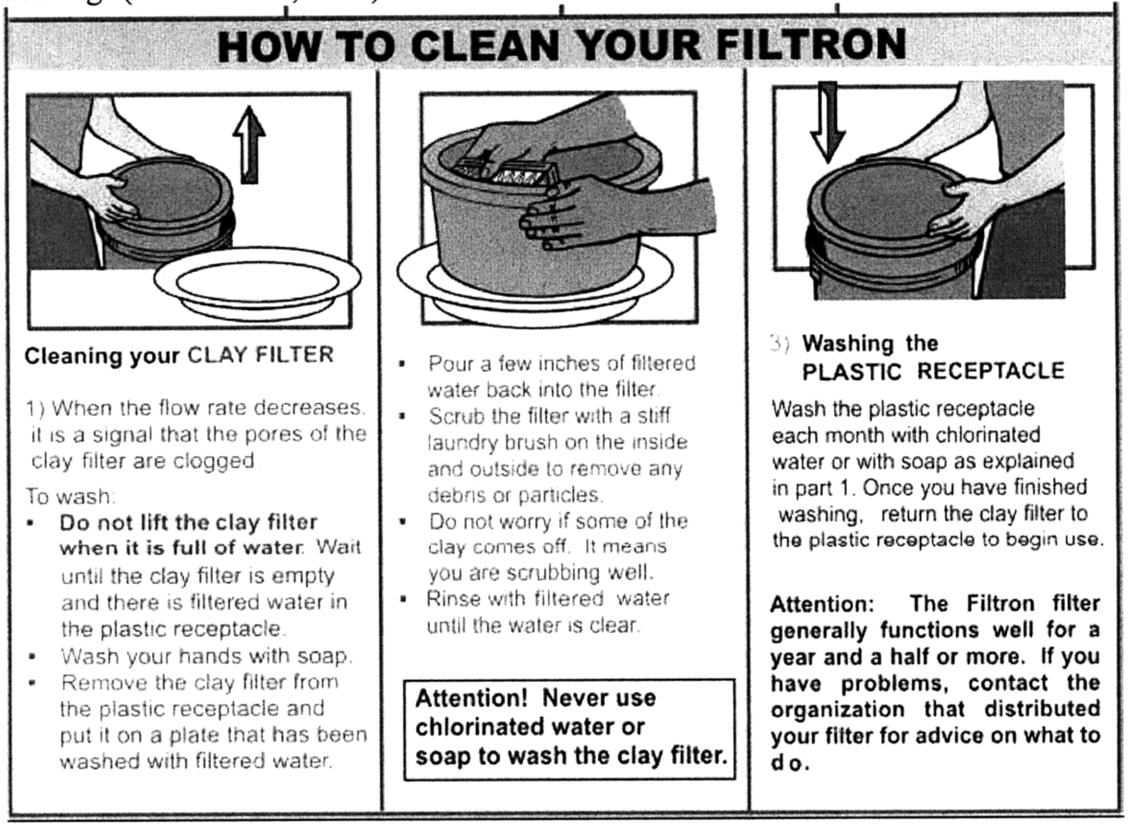



**Figure 11 Potters for Peace CWP Maintenance Poster**

In Brown's study area in Cambodia, where source water averaged under 10NTU, average cleaning rate was 2.3 times per week (Brown, 2007). Similar high rates of cleaning were claimed in Northern Region Ghana during surveying in January, with much greater turbidities (averaging >100NTU). Unlike with the biosand filter, cleaning the CWP does not disrupt treatment and high rates of cleaning are admissible. The system should be cleaned when the flow-rate is reduced or stops, or when any plastic part becomes visibly dirty (Pure Home Water, 2008).

Basing cleaning frequencies as needed on reduced flow rates seems impractical, given the average 0.5 liter per hour flowrates for old, clean filters as measured by Swanton (Swanton, 2008). With the biosand, the flowrate is quick (recommended 36 liters per hour (CAWST, 2007)) and visibly drops in flow when cleaning is needed. In contrast with the CWP, there is no visible flowrate as the unit is self contained. However, flowrates can be discerned from the dripping rate emanating from a filtering CWP. Regular cleaning of the ceramic pot may be easier than making observations based on flowrates. Nevertheless, multiple cleanings per week were claimed and correspondingly clean units were witnessed in surveying visits in Ghana, showing that users can effectively clean their units without following a prescribed schedule. While disinfection of the storage unit and especially the tap on a regular basis is warranted as well, little information exists that looks at storage practices in conjunction with survival of fecal bacteria on the timescale of a week (a typically recommended maintenance interval). Thus, we can recommend weekly disinfection of the storage unit and tap as a seemingly conservative yet unfounded recommendation. A full cleaning every week might be too much to ask of women in the household, especially without more evidence from the field. Further research into rates of contamination and regrowth in storage units of ceramic-filtered water is needed

When cleaning the CWP, the user must use two hands and lift the empty ceramic pot filter by the rim without touching the outside of the ceramic element. The plastic lid to most of these systems can also provide a suitable surface on which to place the ceramic pot, both lying upside down, given that it has been cleaned with sterilized water. Never placing the filter on the ground or touching the under-surface of the ceramic pot are key training points to prevent post-treatment contamination! Many people witnessed in northern Ghana used dirty water to rinse of drinking cups as well as to clean their storage units. In this vein, PHW specifically highlights that a dirty cup negates the benefits of using the filter in their training materials. While using filtered water to clean the cup is a clear lesson, coordinating the use of filtered water with soap in the cleaning and then rinsing of all parts of the system during maintenance can be tricky. Having salespeople demonstrating these cleaning techniques directly during house-to-house follow-up monitoring to a distribution of filters to flood affected victims in the Upper-East region of Ghana was much appreciated by the residents, with a complete reinstallation often necessary to fix the leaky and fragile taps. Using only treated water (filtered, boiled and/or chlorine disinfected) during cleaning processes is imperative, and cannot be overstressed.

When conducting monitoring visit, the monitor can ask the user to describe or demonstrate their techniques:

- When was the last time they cleaned their filter?
- Do they only brush the inside of the ceramic pot? Can they show the brush or cloth used to clean the ceramic pot? Is it appropriate and hygienic?
- Is treated or boiled water and soap or chlorine solution used to clean the storage unit and tap and available upon request? Using dirty water for cleaning is a common faulty practice witnessed among users, and should be checked.
- Is the basis of the ceramic cleaning schedule logical (either due to flow rate stoppage or on a frequent time basis) and the filter clean inside (visibly bright ceramic)?
- Are the storage unit and tap cleaned on a regular basis with treated or boiled water and soap or bleach disinfectant?

*4.6.2.4 Replacement period*

As noted in the bottom right column of Figure 11 above, a lifespan of one and a half years is expected of the filter by Potters for Peace. Similarly, Brown found that filters had an average lifetime of two years (2% per month reduction in original number of filters over 44 month study). However, Brown found that filters perform adequately up to four years, with breakage of almost all filters by 48 months limiting his observation (Brown, 2007). Lantagne measured effective treatment after 5+ years of use (Lantagne, 2001a). Microbial removal efficiency does not degrade over time, thus recommendations on a one or two year replacement are unwarranted if the filter remains unbroken (Brown, 2007). Due to the instruction at the outset of the Cambodia program to discontinue use after one or two year lifetime, 5% of people stopped using the filter after a few years of operation despite proper functioning of the filter, incurring greater cost and/or greater likelihood of disease to those users. With high breakage rates, a sustainable program will need pay close attention to the supply chain so that when filters break, the users know where to quickly and cheaply get a new filter. Given an average two year lifetime for the ceramic element, the plastic safe storage unit should last through many replacement ceramic pots.

*4.6.2.5 Physical Inspection*

Many implementing organizations hand out training materials such as those shown in *Appendix F: Biosand Filter Usage Instructions*. If these are included in the distribution of filters, it is important to witness them positioned along with the filter, especially if multiple users are involved with the filter.

When in the home conducting an interview, be sure to ask the user if they always drink filtered water. Do they carry treated water to work or school, incurring consistent use? If so, can they produce the bottles used? Consistent use of the filter implies current use, which means maintaining the system in good working order and having the storage unit at least partially full and the filter at least damp. Depending on local climatic conditions, filters take about 3 days to dry out completely, such that dry filters are not currently in use. A clean drinking cup associated with the BSF is recommended to limit recontamination. Noting hygiene practices when asking the user for a glass of water can be informative as well.

To recapitulate the main things to inspect during a household monitoring visit, take note that the CWP unit israised off of the ground and situated on a stable base, installed out of the sun and rain, and inaccessible to animals and small children. Make sure that the spigot is visibly clean, does not leak, and has nothing exerting pressure on it, as it will tend to break. These measures will provide a decent level of hygienic practice as well as make breakage less likely. These measures will provide a decent level of hygienic practice as well as make breakage less likely.

### 4.6.3 Water quality monitoring

Johnson found 99.7% reductions in *E.coli* among rural households with highly turbid source water in Northern Region, Ghana (Johnson, 2008). While Brown measured 98% average reductions in his field trial in Cambodia, the range of reductions was very large. Using a method of sampling from untreated water and comparing the microbial results to the treated water from the safe storage unit, Brown recorded 99.9+% reductions from many filters, yet 17% of filters tested yielded increases in contamination (Brown, 2007). While many samples underwent large amounts of recontamination through improper handling and cleaning of the storage units, the method of sampling was also faulty, unable to take into account temporal differences between the treated water and the source water. As noted in the *Safe Storage* section, up to 0.5 log reductions were recorded due to transport and settling of source water, and given the slow flow rate of a ceramic filter, it is unlikely that untreated water in the household closely resembles the source water actually used for the treated water in the safe storage unit (Levy, 2007). Without a controlled monitoring campaign using multiple visits over the course of a few days, accurately recording reduction efficiency is challenging. Thankfully, this work has already been done in the laboratory and in multiple field studies, and is not necessary in operational monitoring campaigns as described here. Microbial testing is useful as a proxy indicator for risk of diarrheal disease to the user, however.

Median *E.coli* per 100 ml for treated water from n=203 in Cambodia over 3 sampling rounds was <10 CFU/100ml, showing that household use of ceramic filters can achieve the proposed microbial target of Effective Use. With 66% of samples containing less than 10 *E.coli* per 100 ml, our metric is a stringent measure of microbial water quality. It may be too stringent in the case of highly contaminated influent waters, despite Effective Use practices. While measuring *E.coli* counts of an untreated sample from storage or from water that is currently undergoing treatment (in the top of the filter at the time of the visit) will not yield reproducible information on reduction efficiency, knowledge of influent contamination levels can often yield information on whether treated water quality of <10 or <100 *E.coli* per 100 ml represents Effective Use (in either case, *E.coli* should not show up on Petrifilms). Improperly treated water carried very high *E.coli* loads, lying far outside the normal or acceptable limits in Brown's study. Likely due to post-contamination or faulty filters, 14% of users had >100 *E.coli* per 100 ml. Brown claims that recontamination through cleaning and handling is a large threat to the effectiveness of the CWP (Brown, 2007).

The ceramic pot filter has been applied to waters of all turbidity levels, attaining significant reductions in turbidity. More than 75% of treated water samples taken in Brown's study had less than 2NTU after treatment from an average of 10NTU in source water. In Ghana, where turbidities often are in the 100-1000 NTU range, the ceramic pot filter brought turbidities down to non-detectable levels (<5NTU) in 22 out of 24 samples taken (Swanton, 2008). When these same filters were sampled a week later, the two households with higher turbidities in their treated water during the first round had non-visible amounts of turbidity in their treated water yet other users had visible amounts of turbidity, ruling out cracks in the filter, yet exemplifying inconsistent Effective Use through lack of pretreatment settling of the highly turbid water (Swanton, 2008). During the rainy season in Northern Ghana in 2007, the average turbidity value of the dams tested was 690 TU, with a median of 300 TU (Foran, 2007). With settling in large clay urns prior to filtration, Johnson consistently found >50% decreases in turbidity. After pre-settling, the average 190NTU waters (n=33) were brought down 92% to 11NTU (n=19) post treatment, showing Effective Use despite treated water having visible turbidity (Johnson, 2007).

Visible turbidity in treated waters (>5NTU) can result from treatment of very high turbidity waters (>100NTU) without constituting ineffective use. Letting water from high turbidity sources settle before filtration is recommended for Effective Use. If source water is found to be >100NTU when tested, storage of water for settling should be enquired about and directly observed in the home to ensure effective treatment. However, source water of moderate turbidity that still has visible turbidity following treatment could signify a cracked or faulty filter. Enquire of the user how fast the flowrate is, and if they say it is high (>3 liters/hour), check for cracks and/or replace the filter. Measuring 5-10NTU water in the turbidity tube can require up to 3 glasses of water, and this water should not subsequently be used for drinking or bacterial indicator testing. Under scarce water conditions, a visual check of turbidity can suffice while at the same time allowing the monitor to check hygienic practices as the user fetches a glass of water.

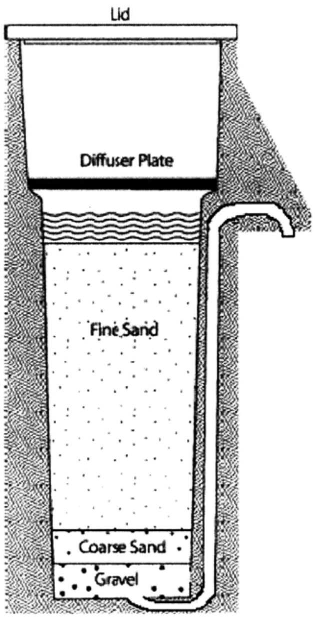
Chlorine should not be noticed within the ceramic filter or storage unit, but can provide added treatment and necessary protection from recontamination in secondary storage units. In fact, unless chlorination is involved, secondary storage of ceramic pot-filtered water is not recommended. Due to the slow flow rate of the filters, obtaining sufficient volume of water for standard treatment of chlorine (10 or 20 liters) is difficult, given demands on drinking water (Swanton, 2008). If chlorine treatment for secondary storage is claimed, checking presence/absence of free available chlorine will indicate effective treatment.

*4.6.3.1 Sampling Procedure*

1. When sampling treated water from the tap of the ceramic water purifier (CWP) system's storage unit, make a visual check of the turbidity level of the treated water. If turbidity is very visible in the sample bag, first take a turbidity measurement if sufficient volume of treated water exists. Second, check the condition of the ceramic pot. Are there any cracks or problems? Third, check the quality of the influent source. If the source turbidity is >100NTU, turbidities >5TU in treated water are expected. Ask the user if they practice settling of the water? Does this check out with what you can see?
2. If source water is of visibly poor quality, it is best to test its bacteriological quality using Petrifilms, if possible. Water samples can be drawn from primary storage units or directly from water currently undergoing filtration within the pot. These results can aid in the judgment of effective turbidity and bacterial treatment of the water using the CWP.
3. If safe storage of treated water exists outside of the CWP safe storage unit, take a sample for microbial testing. If chlorination is claimed by the user, take a

presence/absence measurement of free residual chlorine of this stored sample and ensure that the sampling bag contains sodium thiosulphate or an equivalent compound to neutralize the effects of free chlorine. In any case, effective safe storage would dictate that the quality of the stored water is better or the same as the water from treatment.

## *4.7 Biosand Filter*




Originally developed by David Manz at the University of Calgary during the mid 1990s, the biosand filter is a household version of the slow sand filters that have been used at the municipal level throughout the world since their invention by a London architect, James Peacock, in 1791. The continuing use of slow sand filters in the London water works has helped to control cholera and other waterborne diseases since the mid 1800s to the present.

**Figure 12 Typical square concrete household biosand filter unit.** (CAWST, 2007)

### 4.7.1 Biosand Filter Effective Use Brief

| **Biosand Filter Effective Use Brief** | |
|---|---|
| **Monitoring Observations** | |
| ***Treatment*** | 1. Water is added daily to the filter. |
| | 2. Uses separate containers to pour dirty water and store filtered water. |
| | 3. Adds water slowly and with the diffuser plate in place. |
| | 4. Never adds bleach into the intake of the filter. |
| | 5. No one touches the spout of the filter with anything unless cleaning it. |
| | 6. Uses the filtered water for as many tasks as possible. |
| | 7. The lid to the filter is in place, diffuser plate intact, unobstructed clean spout and smooth sand bed at water depth of 4-6 cm. |
| | 8. Flow rate < 0.6 L/min when full of water. |
| | 9. Proper installation of biosand filter is witnessed, including:<br>a. Sitting flat on firm ground.<br>b. Out of direct sunlight.<br>c. Out of reach of animals<br>d. No visible leaks or cracks. |
| | 10. Pretreatment is recommended for turbid waters (>100 NTU) |
| ***Safe Storage*** | 1. A dedicated safe storage container is used to catch and store the treated water from the spout of the BSF. |
| | 2. Safe storage container is located with the BSF indoors, out of the sun, off of the floor, in a stable position and out of reach of animals and small children. |

| | |
|---|---|
| | 3. Design of safe storage unit incorporates a tap or a small sealable opening for pouring. |
| | 4. The safe storage container has a lid that is kept on tight, and only opened for addition or pouring of treated water. |
| ***Maintenance*** | 1. Cleaning schedule is not prescribed but is determined by significant reduction in flowrate. Less than one cleaning per week helps to ensure proper biological treatment. |
| | 2. User demonstrates "swirl and dump" method successfully:<br>a. Harrow with a wooden stick or spoon<br>b. Decant muddy water<br>c. Refill water (after replacement of diffuser plate)<br>d. Check flowrate and repeat if necessary. |
| | 3. User cleans the spout and storage unit with treated water and soap or chlorine solution each week. |
| | 4. Soap or disinfectant used to clean storage unit can be produced by user |
| ***Replacement Period*** | 1. No replacement period suggested. |
| ***Physical Inspection*** | 1. Water bottles for use during travel or school are clean and producible to the interviewer if consistent use is claimed outside the home. |
| | 2. User demonstrates hygienic method when asked to add water to filter and fetch a glass of water. |
| | 3. A dedicated clean drinking cup is associated with the safe storage unit. |
| | 4. Instructional material is displayed, if provided during purchase or installation. |
| **Water Quality Monitoring** | |
| ***Turbidity*** | Treated water is clear (Turbidity of <5 NTU). |
| ***Chlorine Residual*** | Free available chlorine presence in storage if chlorine treatment is claimed. |
| ***Microbial Testing*** | Microbial testing shows <10 *E.coli* CFU/100 ml in water from both running spout and storage unit. |

### 4.7.2 Monitoring Observation

*4.7.2.1 Treatment*

Shown below is the Samaritan's Purse version of standard operating procedures for the biosand filter, which covers the main points relating to Effective Use[4].

1. ONLY pour water in the filter with the diffuser basin in place - failing to do this will damage the filter.
2. ALWAYS use two buckets: one to pour in dirty water and one to collect filtered water. If only one bucket is used, the dirty bucket will contaminate the filtered water.

[4] For greater detail, see Appendices H and J of the CAWST document "Installation Operation & Maintenance Manual: Biosand Water Filter," Version 2007-01, as included in this document's *Appendix B: Biosand Filter Usage Instructions*. As presented here are revised with the aid of Ron Lentz of CAWST, August, 2008.

3. NEVER attach anything to the spout, such as a longer pipe, a hose or a valve.
4. ALWAYS use filtered water for as many tasks as possible: drinking, cooking, cleaning food, cleaning clothes, washing children, and feeding animals. Using the filter for all your water needs will contribute to better health.
5. NEVER put bleach in the water before pouring it into the filter and NEVER pour bleach directly into the filter - this will damage the filter.
6. ALWAYS pour the water into your filter SLOWLY.
7. NEVER move the filter once it has been installed - unless it is an emergency. Moving the filter will cause water to come out more slowly. If moved, the filter must be placed in a level position before using.
8. ALWAYS keep the lid on the filter when not in use.
9. DO NOT touch the spout of the filter unless cleaning it - keep animals and children away.

(Earwaker, 2006)

The following is a list of specific physical attributes which the monitoring agent should check at households with mature filters (in use for more than one month since start-up) to ensure effective treatment procedures, as adapted from "HWTS Technologies: Key Operating Parameters" (CAWST, 2007):

- The filter housing does not leak
- No tap or hose is attached to the spout
- The diffuser plate is in place, clean, and effectively preventing sand disturbance
- The filter is installed out of the sun and rain, near the kitchen, and away from animals
- The spout is clean
- Flow rate is not more than 0.6 liters per minute when the filter is full of water
- Sand is level and sits 5cm below standing water level

While examining the filter, ask the user how often the filter is filled. For effective treatment, the filter needs addition of water every day so that anoxic conditions are avoided in the lower sand layers. The filter is intended to be used intermittently such that residence time within the filter is sufficient for effective treatment. This is distinctly different from the ceramic filters, which operate most efficiently when kept filled.

*4.7.2.2 Safe Storage*

Utilization of a clean storage unit that is covered when treatment is not occurring is very important to the BSF system, yet is often overlooked during implementation. Current designs of the BSF often do not allow for the addition of a permanent, closed safe storage unit with a tap at sufficient levels above the floor. A dedicated, closed and hygienically handled safe storage unit is imperative for Effective Use. Chlorine treatment is recommended by CAWST within safe storage units of BSF treated water in order to maintain a residual protection against recontamination through use (CAWST, 2007). See the 4.7.4 Discussion section for more in depth information on safe storage with the BSF.

While the Safe Storage Effective Use Write-up has much greater detail on safe storage within the home, the following safe storage characteristics are important to note along with a biosand filter.

- Is a dedicated safe storage container in use, separate from the container used for fetching water?
- Does the design of the safe storage unit incorporate a tap or a small sealable opening for pouring, such as to eliminate recontamination by the introduction of dirty objects for dipping such as ladles, cups or hands?
- Is the safe storage unit kept out of direct sunlight, as the sun speeds re-growth of bacteria?
- Is the lid to the unit kept on tight, and only opened for addition or pouring out of treated water?
- Is the unit clean and free of leaks, situated indoors, off of the floor, in a stable position and out of reach of animals and small children?

*4.7.2.3 Maintenance*

While the use of biosand filters is straightforward, maintenance requires proper training and execution commensurate with increased user responsibilities. The following cleaning steps are recommended[2] (CAWST, 2007; Lentz, 2008):

Swirl and Dump

- Remove the lid to the filter;
- Add 4 liters of water to the top of the filter
- Remove the diffuser plate
- "Swirl" an appropriate tool such as a wooden stick or spoon around in the top layer of sand at least 5 times. You will disturb the surface of the sand but do not mix the surface layer below the top 5 cm of sand. The water above the sand will become dirty.
- Scoop out dirty water with small container (i.e. cup or cut open plastic bottle) Avoid scooping out sand.
- Discard the contaminated water outside the house in an appropriate location such as a soak pit or garden
- Repeat this until all the water has been removed from the filter
- Smooth and level the sand surface
- Replace diffuser
- Add 20 liters or 5 gallons of water and replace lid
- Check flow rate
- Repeat if flow rate is still low (less than 0.6 liters per minute)
- Wash your hands with soap and clean water

Cleaning of the top sand layer in this way is only needed when the flowrate is reduced to an unacceptable minimum. Slower flow means cleaner water, and cleaning the unit on a schedule or too frequently disrupts effective treatment, (see *4.7.3 Water Quality Monitoring* section below). Cleaning as needed based on flowrate is an essential maintenance lesson. On the other hand, regular cleaning and disinfection of the outlet spout and the safe storage unit is necessary to limit likelihood of diarrheal disease, using either chlorine solution or soap. Earwaker noted that 60% of users in his study of Kale Hewyet Church's biosand implementation in Ethiopia clean the spout without soap or not at all, representing significant likelihood of post-treatment contamination (Earwaker, 2006).

Wet harrowing, as described above can alternatively be done with the palm of the hand and gentle kneading of the fingers, incurring less damage to the *schmutzdecke* while achieving similar results. Cleaning techniques that require the removal of sand, however, are strongly discouraged and outdated. Removing sand is unnecessary because most of the physical particles that cause the reduction in flowrate are trapped in the top few centimeters of sand. The process of removing and replacing the sand creates air pockets and cracks in the filter bed, as well as unnecessarily disturbs the *schmutzdecke* (Fewster, 2004). Removal and replacement of sand was taught during the pilot scale distribution of biosand filter in Ethiopia by Kale Hewyet Church in the late 1990s and resulted in recurring losses of sand among users. Before addition to the filter during installation, sand is sifted to the appropriate grain size and thoroughly washed. Often sourced from outside the communities, replacing lost sand was impossible for many users and Kale Hewyet Church spent a good deal of money and time replenishing sand and eventually retraining all of the users. Losing sand changes the pause depth (the resting height of water above the top of the sand layer), which is designed to be between 4cm and 6cm in order to facilitate optimal oxygenation to the *schmutzdecke*, one of the key innovations to allow intermittent flow. With similar effects to the loss of sand, placing pipes, hoses or valves on the outlet of the filter can change the pause depth and kill the *schmutzdecke*, compromising the microbial treatment properties and placing the user in danger.

There are currently two schools of thought as to how to clear the turbidity entrained in the upper layers of a biosand filter: stirring gently using a clean tool such as a spoon or stick down to at most 5cms, or using the flat palm of ones hand to gently stir up the trapped dirt[5]. While the tool stirring technique is likely to suspend more solids into the water, causing greater lengths of time between cleanings, the flat palm method disturbs the *schmutzdecke* much less and thus biological treatment is likely to stay more constant. Though both are used widely throughout the world as maintenance techniques for the biosand filters, there has yet to be any study as to which method actually causes more degradation to the treatment efficiency. Doing such a study could also yield information on the max frequency of cleaning possible to maintain sufficient treatment, and from this could be back-calculated a maximum suitable turbidity for treatment by the BSF. Before recommendation of the more apt technique is made, research must be conducted. Until that point, available data seems to say that both methods are suitable for cleaning the BSF.

[5] Using the index finger down to the second knuckle, as previously proposed by CAWST and Samaritan's Purse, among others, places users in contact with untreated water and biologically active media. Placing the finger into the sand is to be avoided in order to limit possible infections in open sores on the hands (Lentz, 2008).

When conducting monitoring at a household, ask the user to describe their maintenance techniques to you:

- When was the last time they cleaned their filter? This should not be within the last week, in order to achieve maximum filter performance. Cleaning should be performed when filter rate is too slow.
- Are the storage unit and spout cleaned on a regular basis with BSF treated or boiled water and soap or bleach disinfectant?

*4.7.2.4 Replacement Period*

Unlike consumable HWTS products, biosand filters have no expiration date. With proper operation and maintenance, the sand should not have to be replaced during the lifetime of the concrete (20 – 40 years) or plastic filter housing (2-5 yrs) (Lentz, 2008). Sand may occasionally need to be added to maintain the standing water level at 5 cm or less. Biosand filters typically outlast other HWTS hardware installments and achieve higher rates of Sustained Use as well (Sobsey, 2007). For example, the rate of Sustained Use was 85% after five years for Kale Hewyet Church distribution in Ethiopia, a number they continue to claim even after almost ten years of use (Earwaker, 2006). Despite a few leaks due to construction and breakages during transport, concrete biosand filters have been effectively used for nine years in some households in Ethiopia. The sand in these filters has never been replaced, although sand has been added to many units due to the aforementioned outdated cleaning method. Consequently, there is no set date for the replacement of biosand filters.

Depending on their construction, the various plastic models may fatigue or degrade after many years. Some agencies suggest a product life of five years for plastic biosand filters, but this is dependent on the type of plastic used (HDPE, PP, other), mode of manufacture, and other variables. Keeping biosand filters out of the sun is very important to preventing degradation as well as for Effective Use, preventing algae from forming in the standing water layer.

*4.7.2.5 Physical Inspection*

Many implementing organizations hand out training materials such as those shown in *Appendix F: Biosand Filter Usage Instructions*. If these are included in the distribution of filters, it is important to witness them positioned along with the filter, especially if multiple users are involved with the filter.

Ask the user if they always drink filtered water. Do they carry treated water to work or school, incurring consistent use? If so, can they produce the bottles used? A clean drinking cup associated with the BSF is recommended to limit recontamination. Noting hygiene practices when asking the user for a glass of water can be informative as well.

### 4.7.3 Water quality monitoring

The main barrier that the biosand provides against diarrheal disease is its ability to reduce fecal bacterial contamination. Measuring reductions in indicator organisms is a common metric of treatment efficiency. Samaritan's Purse set a target reduction of 95-97% in total coliform count between raw and treated waters for their co-implementation with the

Kale Hewyet Church in 2001 (Earwaker, 2006). For accurate measurements of treatment efficiency, one must sample the raw water at the time of addition to the filter, perform an accounting for the volume displacement in order to know when that water will exit the tap, and then undertake a subsequent trip to the household to sample and test the treated water. Such testing is out of the scope of a simple monitoring program in terms of time, money, and intrusiveness. Using existent raw water in the home or at the source during a monitoring visit as a proxy for the water fetched and used in the treatment of water to be collected from the biosand filter also incurs major uncertainties. Jenkins notes up to 0.4 log differences in treated water quality as a result of the length of residence time within the filter (maximum 12 hours), and similarly 0.3 log discrepancies for the amount of water added at one time (Jenkins, 2008). As noted in the *Safe Storage Effective Use Write-up*, up to 0.5 log reductions were recorded due to transport and settling, depending on source load (Levy, 2007). These results render percent reductions from one time monitoring visits with error bars on the scale of the anticipated treatment efficiencies! If multiple visits to a given home are possible, better data can be gleaned from usage. Taking five inlet and five outlet samples from a single filter over the course of a week, for example, can show trends in reductions and absolute risk from *E.coli*, as well as discount outliers.

The most useful measurement in terms of effective treatment is to get a proxy of general treatment through measurement of absolute *E.coli* levels from the outflow of the unit, and if water is stored, to get a representative sample from the storage unit. Noting the level of recontamination from storage can show the effectiveness of safe storage techniques, and whether training and usage is appropriate. With average *E.coli* reductions of 93%, *E.coli*-quantifiably low risk as per WHO Guidelines was found by Stauber among 55% of treated waters by the 55 biosand filters in use in Bonao, Dominican Republic, with an average of <5 *E.coli*/100ml among all samples (Stauber, 2006). Similarly, in the WEDC Monitoring paper from Machakos Kenya, Fewster reports that 70% of households had less than 10 *E.coli*/100ml (Fewster, 2004). Effective Use is thus measured by these authors as <10 *E.coli* per 100 ml sample, and such a level should be measured in both the treated water from the tap of the unit as well as any water in the associated storage unit.

Turbidity is an important variable in the use of biosand filters. As filters clog with debris and slower flow rates occur, better treatment takes place through finer straining, increased residence time, and less system pressure exerted through greater head loss. Likewise, less frequent cleaning has been associated with significant improvement in turbidity and microbial reductions (Jenkins, 2008). With high influent turbidity, filter run-times are reduced and maintenance is more frequent, incurring greater exposure to microbial contamination following each cleaning as the *schmutzdecke* reestablishes itself. Pre-implementation, raw waters used in treatment need to be analyzed for turbidity levels during all climatic seasons, and CAWST recommends the use of biosand filters in areas with a maximum raw water turbidity of less than 50–100 NTU (CAWST, 2007). Seasonality of raw water quality and pre-treatment methods need to be directly measured and/or questioned of the user, as both can have significant effects on turbidity. Maintenance schedules should be based on the time at which flowrate reduces to unacceptable levels, as determined by the user. Higher influent turbidities require more frequent maintenance. There is no maximum time between cleanings.

Biosand units are very effective at reducing turbidity. Despite ineffective use and influent turbidities commonly over 300 NTU, samples of treated water tested by the author in both Ethiopia and Ghana in January, 2008 almost never had visible turbidity. The technicians trained by Fewster and MEDAIR of both Machakos, Kenya and Maintirano, Madagascar, take <5NTU to be Effective Use (Wiesent-Brandsma, 2004; Fewster, 2008). In the 2000 Machakos survey, <5NTU was as stringent a measure of Effective Use as the microbial testing, with similar percentage of households passing the <10 E.coli per 100ml Effective Use metric as shown in the Table 4 Biosand filter Effective Use metrics derived from the monitoring data of the MEDAIR Machakos filters in 1999 and 2000 (Mol, 2000).

**Table 4 Biosand filter Effective Use metrics**

| Effective Use metric | <10 *E.coli* per 100 ml | <5NTU | <10NTU | Both <5 NTU and <10 *E.coli*/100 ml |
|---|---|---|---|---|
| n | 153 | 124 | 124 | 124 |
| Number failing effective use | 37 | 32 | 12 | 9 |
| % practicing effective use | **76** | **74** | **90** | **93** |

Although higher turbidities are associated with 50% higher *E.coli* results, turbidity measurement is not a good indicator of microbial water quality on an individual basis, with only 1 in 4 results of >5NTU correlating with samples of >10 E.coli/100ml. Similarly, despite the uniformity of measurements of <5NTU treated water from the filters in Maintirano, Madagascar, microbial results were outside of the low risk category (see Table 2 Risk Levels from *E.coli*), with high influent turbidity and *E.coli* loads (Wiesent-Brandsma, 2004). While turbidity measurement cannot suffice as a cheap substitute for microbial testing, <5NTU is recommended as an independent measurement of effectively treated water by the BSF.

Chlorine treatment is recommended by CAWST within storage units of treated water in order to maintain a residual protection against dirty storage units and recontamination through use (CAWST, 2007). In such cases, measuring free chlorine levels is applicable. Chlorine should never be added to water before biosand treatment, as chlorine can deactivate the biologically active sand layers.

During the first few weeks of operation following installation, the biologically active *schmutzdecke* has not fully formed and microbiological treatment is only expected to have 30-70% removal efficiency through physical straining (CAWST, 2007). However, the level of treatment through a BSF in the process of ripening is still better than the raw water, and users can thus be instructed to use the treated water immediately after installation. As for secondary barriers to help protect users during this initial period, Eric Fewster recommends that boiling biosand-treated water should be recommended if boiling is already a common practice within the community (Fewster, 2008). The same can be said of chlorine treatment. While monitoring for proper use and retraining in the home can be very important within the first few weeks, microbial testing for Effective

Use of the filter is not warranted during this period and would be recommended a month or more after installation. A recommended procedure for taking all of the water quality measurements is as follows:

*4.7.3.1 Sampling Procedure*

1. Before taking a sample from the filter, grab a sample from the storage unit (if water remains in it). If chlorination is claimed by the user, take a presence/absence measurement of free residual chlorine of this stored sample.
2. In preparation to taking a sample of treated water, fill the filter to a consistent level that can yield an appreciable flow rate. This level can be a specified volume added to a filter that is not currently filtering water (at rest), or a known depth of water above the *schmutzdecke*, such as using the diffuser plate as a reference depth. Filling the filter to the top will not be possible at all households due to water availability and is not recommended for normal use to achieve maximum efficiency (Baumgartner, 2007).
3. Once you have added water, take a flow rate measurement using a container with known volume. The flow rate should not exceed 0.6 liters/minute when the top reservoir is full of water. Remaining under the 0.6 liters/minute will help to ensure that adequate treatment is taking place. Use the water collected in the flow rate test to take a turbidity measurement, if sufficient volume exists.
4. Before taking a microbial sample, evaluate operating conditions as the primary indicators. If the diffuser plate is broken, the filter body is leaking, or the sand is too shallow, then the filter is not working properly and microbial testing is useless (Lentz, 2008). If operating conditions are adequate and taking a sample for microbial analysis is warranted, take a sample from both the filtering spout as well as from any treated water in storage in order to analyze user contamination during storage.

**4.7.4 Discussion**

The BSF has shown impressive treatment results in laboratory testing. Palmateer undertook an extensive study of the effects of the intermittent slow sand filter on a variety of chemical and biological contaminants, using Manz's original square concrete intermittent slow sand filter design (MISSF). Palmateer reports that 100% of Giardia cysts and 99.98% of Cryptosporidium oocysts were removed when spiked with 10-100 times normal environmental pollution levels (Palmateer, 1999). Elliott found that Echovirus reductions were within a range of 1 to 4.3 log and with mean reductions of 2.1 log after 30 days. Bacteriophage (viruses that infect bacteria) reductions were much lower, ranging from zero to 1.3 log10 (95%) with mean reductions of 0.5 log (70%). Viral reductions by the BSF are thus expected to differ substantially depending upon the virus encountered (Elliott, 2008). The first rigorous health impact field study of the biosand filter, as conducted in the Dominican Republic by Stauber showed 47% reduction in diarrhea among the intervention group, placing the biosand on par with the other household water treatment and safe storage (HWTS) interventions studied herein, with better potential for Sustained Use through increasing efficiency over time and robust design (Stauber, 2007).

*4.7.4.1 Recontamination in storage units*

Storage of filter-treated water has a large potential to become recontaminated. The storage unit of the ceramic water purifier (CWP) greatly prohibits recontamination by creating a closed system. With current designs of the biosand filter, however, the storage unit is most often left open and without a spout or narrow mouth as is recommended for safe storage. In training materials and household usage, safe storage practices were largely overlooked in the implementations of the BSF, as witnessed by this author in Ethiopia and Ghana. While a limited number of accurate membrane filtration samples of the BSFs in Kpanvo village, Ghana, did not find recontamination in storage, the results are statistically insignificant. The results presented in Stauber's PhD thesis in 2007 provide convincing statistical evidence of fecal recontamination occurring during storage, as found in the following table.

| Type of Sample | Number (%) of Samples Total n = 2060 | Geometric Mean *E. coli* MPN/100mL (SD) | % Reduction (from untreated water) |
|---|---|---|---|
| Untreated | 718 (35) | 21 (11.7) | - |
| Treated – direct from BSF outlet | 682 (33) | 4.6 (6.5) | 79 |
| Treated – stored BSF treated | 506 (25) | 10 (8.3) | 53 |

**Table 5 Water quality in BSF households after BSF intervention (Stauber, 2007)**

Storage brought a 79% reduction with an average low risk (<10 *E.coli* per 100ml) of treated water at the BSF outlet down to a 53% reduction for overall treatment, resulting in intermediate risk for the majority of the 500+ users sampled. Likewise, Sobsey's study from Cambodia on the BSF shows consistent recontamination in storage over the course of five monitoring visits on a large number of filters (a subset of n=1365), per month for 5 months longitudinal study, as shown in Figure 13 below.

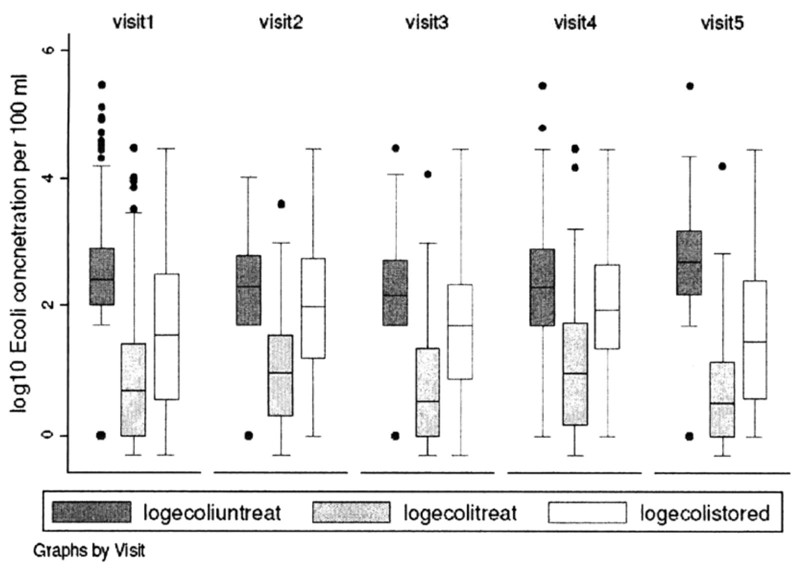



**Figure 13 Log10 concentrations of *E.coli* throughout BSF treatment and use (Sobsey, 2006)**

A redesign of existing BSF units may be necessary to accommodate the safe storage unit needed. One such design has been produced and implemented through the efforts of Bushproof in Machakos, Kenya. Using the original square concrete BSF design, it includes a closed safe storage unit with a tap. However, it will be impossible to elevate BSFs in this fashion in many circumstances because of the weight of the unit as well as the height needed to lift the water. Despite an appropriate design, the storage is visibly dirty and the top is loose, failing two key monitoring observations in this instance.

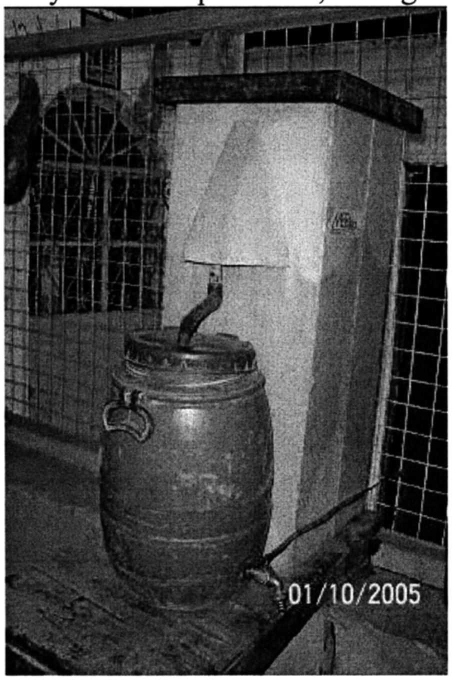



**Figure 14 BSF with Safe Storage from Machakos, Kenya** (Baffrey, 2005)

Storage units need to be covered at all times, necessitating a downspout from the filter outlet that connects directly into the storage unit. Safely elevating the heavy units currently in use will present a challenge. Thus, if no tap can be installed on the storage unit, then the unit should have a narrow mouth and be able to pour, so as not to incur direct handling of water within the unit. Unless the storage unit is elevated to practically engulf the spout of the BSF, chancing contact with the spout and contamination, however, narrow mouthed storage units can be ineffective due to the tendency of the flow out of the BSF to change its exit angle and fall in varying places depending on pressure head.

*4.7.4.2 Training materials pertaining to safe storage with biosand filter*

In the materials distributed by CAWST, International Aid and the Kale Hewyet Church as collected in *Appendix F: Biosand Usage Instructions,* instructional material for the BSF leaves out cleaning of the associated storage units. Similarly, the SODIS materials collected from EAWAG only inform the user to clean the bottles before the initial use and not on a regular basis (see pictorial in *SODIS Effective Use* section). Training materials as well as labeling instructions associated with chlorine disinfectants often leave out cleaning of storage units, although this is recommended by manufacturers and distributors (see pictorial in *Sodium Hypochlorite Solution Effective Use* section as well as *Appendix G*). Likewise, very few of these materials and programs adequately stress the separation of raw and treated water. Many users were witnessed to clean their storage units and drinking cups using untreated source water with neither soap nor disinfectant directly before treating or drinking water.

*4.7.4.3 Storage unit cleaning frequency*

The recommendations for cleaning frequency of storage units as based on the frequency of filter cleaning found in the BSF and CWP *Effective Use* sections are based on using turbid source water without pretreatment. However, in the case of the first household visited in the Kale Heywet Church field sight in Ethiopia, the mother interviewed pretreated her source water by filtration in the riverbed, significantly decreasing turbidity such that she claimed not to have cleaned the storage unit in 4 months. If she was taught to clean her storage unit when cleaning her filter, this might explain why her storage unit was so dirty at the time of monitoring despite a well-functioning BSF. 26.3% of households visited in Earwaker's study of the KHC BSFs reported that they wait until slow flow to clean the filter, although regular cleaning was the norm. Moreover, about half of the users interviewed cleaned the filter more than once a week, under high turbidity conditions (Earwaker, 2005). Cleaning the safe storage unit on a weekly basis as recommended in the *Effective Use* sections for the BSF and CWP is a conservative estimate of the likelihood of recontamination through use occurring within a week and is not based on field trials or evidence. Recommended frequency of storage unit cleaning will depend on design of the unit, as well as the expected treatment efficiency of the HWTS system and effective safe storage practices, and will vary between implementations. Further research on rates of contamination within storage units is needed for all of the HWTS in varying situations to determine if cleaning of the storage units should be scheduled, tied to the frequency of filter cleaning, or done by inspection of the unit by the user.

## *4.8 PUR*

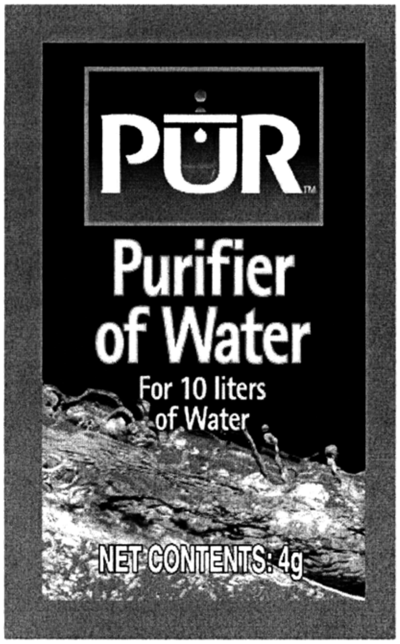



**Figure 15 PUR**

PUR™ Purifier of Water is the brand name given to Procter & Gamble's combined flocculent and disinfectant product. PUR works to treat source waters with a wide range of turbidity and pathogen load, providing a regulated dose of iron sulfate (352mg ferric iron) to remove suspended matter such as protozoa, viruses, sediment, humic matter, and Giardia and Cryptosporidium oocysts, as well as calcium hypochlorite to kill bacteria and other pathogens. Other ingredients include bentonite, sodium carbonate, polyacrylamide flocculant, and potassium permanganate, chemicals generally used in municipal water treatment that together achieve four major processes: precipitation, coagulation, flocculation and disinfection (Reller, 2003). PUR is the only mass-produced sachet combining these chemicals in solid form, and has been marketed successfully in many countries by PSI and others, as well as used by UNICEF, Americares, Samaritan's Purse, World Vision, CARE, and others in emergency situations ranging from cholera outbreaks in Ethiopia to flooding following the tsunami of 2005 to the earthquake aftermath in Pakistan in 2005 to flooding in Myanmar. One sachet treats ten liters of water and come in strips of 12. Two strips of 12 provide 240 liters of water, enough for a typical household for three weeks in emergency situations (Aquaya, 2008).

### 4.8.1 PUR Effective Use Brief

| PUR Effective Use Brief | |
|---|---|
| **Monitoring Observations** | |
| ***Treatment*** | 1. User demonstrates knowledge of treatment and dosing as intended by Proctor and Gamble, without prompting:<br>1.1. Add: Cut open one packet and add contents to ten liters of water.<br>1.2. Mix: Stir aggressively for 5 minutes and let sit for 5 minutes; if non-flocculated after the wait, stir again until floc falls out.<br>1.3. Filter: Poor water into clean storage container through a clean and dry cotton cloth that is free of holes.<br>1.4. Drink: Wait 20 minutes to drink. Do not consume if yellow. |
| | 2. Complete consumption of the ten liters of treated water should occur within 24 hours. |
| ***Safe Storage*** | 1. Two separate, dedicated 10 liter containers for fetching/flocculation and disinfection/storage are used, visible, clean, and have no leaks. |
| | 2. Safe storage container for treated water is located indoors, out of the sun, off of the floor, in a stable position and out of reach of animals and small children. |
| | 3. Design of safe storage unit incorporates a tap or a small sealable opening for pouring. |
| | 4. Lids are kept on tight, and only opened for addition or pouring of treated water. |
| ***Maintenance*** | 1. Rinse off the cloth filter after each use, with a final rinse of cloth filtered water and then leave cloth in the sun for decontamination. |
| | 2. Regular cleaning of cloth filter with soap. |
| | 3. Regular cleaning of the treatment and storage containers with soap or disinfectant. |
| | 4. Soap and/or disinfectant used to clean storage unit and cloth filter can be produced by user. |
| ***Replacement Period*** | 1. Product expires 3 years after date of manufacture, as is printed on sachet |
| ***Physical Inspection*** | 1. Water bottles for use during travel or school are clean and producible to the interviewer if consistent use is claimed outside the home. |
| | 2. The household contains a supply of unexpired sachets for consistent use. |
| | 3. A dedicated clean cup is associated with the safe storage unit. |
| **Water Quality Monitoring** | |
| ***Turbidity*** | Treated water is clear (Turbidity of <5 NTU) |
| ***Chlorine Residual*** | Free available chlorine presence is shown if treatment is claimed. |
| ***Microbial Testing*** | Microbial testing shows <10 *E.coli* CFU/100 ml. |

### 4.8.2 Monitoring Observation

*4.8.2.1 Treatment*

Information on appropriate treatment using PUR is drawn from selected promotional material specific to each implementing organization's training methods. These materials come in a variety of languages and can be quite detailed (see *Appendix F: PUR Usage instructions*). The schematic below is printed on the backside of PUR sachets in English. Other information on the packet includes the brand name, dosage information, weight, manufacturing date and subsequent expiration date, precautions against ingestion of the powder, manufacturer and trademark information, and ingredients

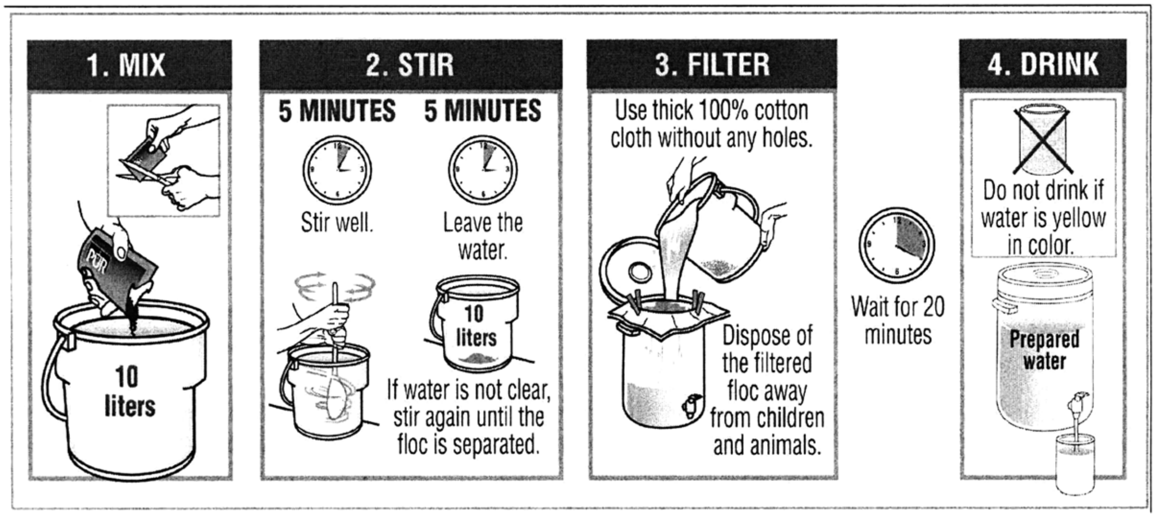



**Figure 16 PUR Usage Instructions printed on back of packet**

A yellow color may result from waters that are heavily laden with detergents or oils, and this water is not suitable for consumption, as noted in step 4 of Figure 16. Community-scale or individualized trainings are often utilized as part of implementations and/or social marketing campaigns in order to ensure correct use of the product and provide face-to-face training on how to correctly carry out the instructions included on the product package itself. Face-to-face instruction is very important in places where literacy rates are low or where regional dialects are more heavily used than national languages. Training sessions often stress that only treated drinking water should be consumed, that safe storage is important to keep the water potable, and that hand washing is an important part of diarrhea prevention. Free available chlorine (FAC) levels can fall under the Center for Disease Control (CDC) recommended 0.2 mg/L after 24 hours, and therefore usage should occur within that time (Aquaya, 2008). Filtered floc should be disposed of in the latrine or bushes away from children and animals. Environmental studies and assessment has shown no environmental concerns with floc disposal (Allgood, 2008).

*4.8.2.2 Safe Storage*

Safe storage is a necessary component of the PUR HWTS system. While the Safe Storage Effective Use Write-up contains much greater detail, the following safe storage characteristics are important to note in the home of PUR users. Upon entering the house for a monitoring visit, ask the user to take you to where the drinking water is stored.

- Is a dedicated safe storage container in use, separate from the container used for fetching and flocculation of water?
- Is 10 liters easily measurable in the fetching/flocculation container?
- Does the design of the safe storage unit incorporate a tap or a small sealable opening for pouring, such as to eliminate recontamination by the introduction of dirty objects for dipping such as ladles, cups or hands?
- Is the safe storage unit kept out of direct sunlight, as the sun quickens degradation of residual chlorine and speeds re-growth of bacteria?
- Is the lid to the unit kept on tight, and only opened for addition or pouring out of treated water?
- Is the unit clean and free of leaks, situated indoors, off of the floor, in a stable position and out of reach of animals and small children?

#### *4.8.2.3 Maintenance*

According to Dr. Greg Allgood, the Director of the Children's Safe Drinking Water Program at Procter and Gamble, no system maintenance is needed with the use of PUR other than cleaning of the buckets used to treat the water and washing of the filter cloth. PUR provides 2.0 mg/L of total chlorine to 10 liters of water, with 90% of samples showing greater than 0.5 mg/L FAC after 30 minutes of contact time, conforming to World Health Organization (WHO) and CDC standards for health and taste, respectively (WHO, 1993; CDC, 2005). Although sterile cloths and containers are not needed because the residual disinfection potential noted is at a maximum at the time when straining and transfer to storage take place, people are trained to wash the filter cloth between usages and to maintain clean storage containers (Allgood, 2008).

#### *4.8.2.4 Replacement Period*

PUR has a shelf life of 3 years. Household possession of expired PUR is a potential sign that disuse or hoarding may be taking place. If PUR is found to be expired, local distributors' supplies might need to be checked for being past their expiration dates.

#### *4.8.2.5 Physical Inspection*

Direct physical observation is a strong tool in the roster of operational monitoring techniques. When first entering the home, witness the hardware associated with treatment. Ask the user to demonstrate her/his treatment techniques, without any further prompting. Ask to see the straining cloth used and make sure it is clean, of minimal pore size and not ripped. Asking for a glass of water is often very informative, especially if you are willing to drink it. Did the user act hygienically while getting the water, or did they wash out the glass with dirty water and then dip it into the storage unit without washing their hands? These are two different behaviors with potentially very different outcomes.

As with all HWTS products, consistent use is very important to reduce the incidence of illness from water-borne pathogens. To ensure consistent use, there are a few simple correlations to make note of. During monitoring, purchasing habits can be asked of the user, with emphasis on regularity of purchasing. The expiration date for a PUR packet is 3 years after the date of production. Thus, old or expired packets are a good sign that the individual is hoarding rather than using PUR on a daily basis. Another useful check to ensure consistent use is the presence of any chlorine (free or total). Lack of a minimal chlorine presence shows that claims of active use are suspect. Another good question to ask in this vein is whether family members carry treated water or PUR packets while traveling. In order to confirm consistent use, ask the family member to present PUR packets in stock for daily use as well as clean water bottles for use when traveling.

### 4.8.3 Water Quality Monitoring

The main advantage of PUR over other HWTS products is its use of ferric sulfate as a primary coagulant. Ferric sulfate is one of two main control measures of the PUR product. Flocculation polymers and a bit of clay fill out the PUR sachet mixture in order to enhance the coagulation process. Flocculation is needed because the suspended particles that make up measurable turbidity harbor pathogens and needlessly consume FAC, making disinfection unviable. However, PUR is also useful in non-turbid water as it can flocculate out cryptosporidium and giardhia oocysts that are resistant to chlorine disinfection. According to Norton, of 100 samples of Bangladeshi pond water ranging from 6-92 NTU, upon treatment with PUR, 97% fell below 5 NTU as recommended by WHO for effective disinfection and general potability (WHO, 2004). Measuring turbidity to be less than 5 NTU is an appropriate operational monitoring method to see if PUR was used effectively such that coagulation is occurring properly and adequate disinfection can take place.

Disinfection with sodium hypochlorite is the second powerful control measure used in PUR, forming a system of multiple barriers within this single product. 2.0 mg/L total chlorine is provided in demineralized water (Allgood, 2008). The original disinfection takes place following flocculation and straining into the storage unit. The WHO (2006) stipulates that at least 0.5 mg/L FAC remains after 30 minutes contact time at a pH less than 8. As pH goes above 8, less and less of the full FAC becomes available for disinfection. Thus, if testing FAC directly after treatment, pH should be measured to make sure that treatment falls below pH 8. Measurement of FAC during a monitoring program, however, will most likely not occur directly after treatment. As long as 0.2mg/L FAC exists in water of at most 24 hours age, sufficient residual disinfection potential exists (CDC, 2005). PUR was designed to provide such a residual concentration given a range of up front disinfection and residual recontamination. Assuming that unreasonable recontamination has not occurred (can be loosely confirmed through physical observation of user habits), using an HACH FAC test strip, any pinkness on the Free Chlorine test indicates treatment with PUR and this is satisfactory to the chlorine requirement. Effectiveness of disinfection will further be confirmed with microbial water quality testing results.

In a laboratory setting, PUR is very effective in removing bacteria (7 log removal), viruses (4 log) and parasitic cysts like Giardia and Cryptosporidium (3 log) (http://www.psi.org/our_programs/products/Pur.html). These log removals meet US EPA standards for water purifiers and PUR Purifier of Water is approved for use in the US for emergency water treatment (Allgood, 2008). The large concentrations of pathogens needed to measure 7 log removal of bacteria usually do not exist in natural waters, and most studies from the field do not look at percent or log removal of bacteria, but rather report absolute numbers of *E.coli* present after treatment. Souter's analysis is consistent with such reductions, in which he found no *E.coli* among 320 samples of PUR-treated water in developing countries (Souter, 2003). Such low numbers may imply highly Effective Use among the households visited, but more realistic estimates lie in Reller's study from Guatemala in 2003. Forty-eight percent of households in this study conformed to WHO Guidelines for safe potable drinking water of <1 *E.coli* CFU/100ml, as per Table 2 Risk Levels from *E.coli*. Given such low results for *E.coli* in the field, measurement of less than 10 *E.coli* per 100ml shows that treatment was effectively administered (Reller, 2003).

### 4.8.4 Discussion

PUR is intended to be used on a daily basis, and thus has to be restocked regularly within the household. As with all other consumable products, a stable distribution network with visible and well positioned outlets is needed to enable widespread and consistent use of PUR. Population Services International (PSI) in Ethiopia attempts this by pushing the product throughout the country via sales representatives with their own vehicles while simultaneously establishing a vast distribution network through offering competitive margins to distributors, wholesalers and retailers through the sale from PSI at the cost of production. While the outlets that sell more do better business for themselves, PSI also targets the outlets in remote regions in line with their social marketing imperative. Even PSI's own implementation throughout Ethiopia is currently limited to the accessible (i.e., large) roads, and does not often reach remote areas as transport is expensive and limiting to these regions. In order to provide access in these remote areas, P&G and PSI work with a network of NGOs including local nurses associations, World Vision, CARE, Aga Khan Foundation, and others.

# 5. Determination of Effective Use from Monitoring Visits

This chapter provides a case study on how to use the Effective Use Monitoring Checklists (see *Appendix E* for forms covering the suite of technologies). Developed from the Effective Use Briefs and the recommended Water Quality Methods, these Effective Use Monitoring Checklists provide a standardized, user-friendly method with which to conduct rigorous household operational monitoring evaluations and can be easily tailored to individual organization's needs. In this chapter, this framework is applied to monitoring data collected from users of the biosand filters distributed by the Kale Heywet Church (KHC) near Addis Ababa, Ethiopia during January, 2008 (see *Appendix B* for program information and *Appendix C* for field notes on each of the households visited). Following a pictorial presentation and water quality data to familiarize the reader with the KHC implementation, sample Effective Use Monitoring Checklist forms are filled out for the two households pictured below. Results for all of the households visited in the form of a mock program evalauation are presented at the end of the chapter and discussed.

## *5.1 Kale Heywet Church Biosand Filter Program*

Starting with a pilot biosand project of 700 filters in 1999, Kale Heywet Church (KHC) scaled up their operations over the past six years to provide 8000 filters. With consistent funding by Samaritan's Purse of Canada, the BSF program at KHC employs a large field staff that stays in touch with their users and can respond to problems quickly.

Located a few hours east of Addis Ababa in the Ethiopian highlands, the community of Filtino received many of their biosand filters from Kale Heywet Church (KHC) and Samaritan's Purse's original pilot scale implementation in 1999, with filters working well since then and consistent community involvement of the technicians at the nearby factory/field office. A largely denuded countryside, the river and irrigation ditches that serve as water sources for BSF users have very turbid water (from 200-1000 TU measured in-house) and are of pH 8.5-9 (basic volcanic soils).

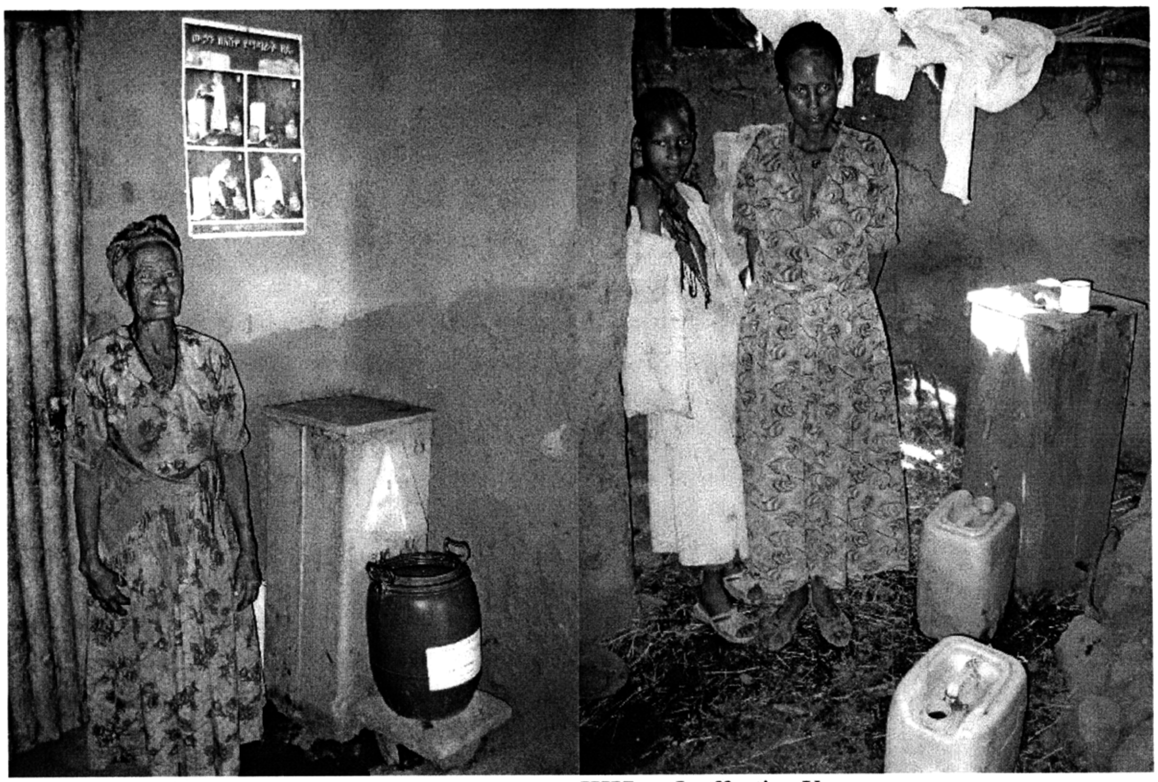
The water quality tests conducted among KHC BSF users during January are presented in Table 6. In terms of judging Effective Use through microbial water quality testing, the Petrifilm method used had a minimum level of detection of 100 *E.coli/* 100 ml, and was thus unable to judge microbial water quality, as Effective Use is <10 *E.coli*/100ml for most of the HWTS systems covered. Future work will continue to use the 3M Petrifilm method along with the 10 ml pre-dispensed Colilert MPN tube system as proposed in Chapter 3.

**Table 6 Water Quality Results for Kale Heywet Church Biosand Filter Users**

| | | | Unfiltered | | | Treated | | Storage | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HH | Date | FloRt L/hr | Turb TU | *E.coli*/ 100ml | T.coli/ 100ml | *E.coli*/ 100ml | T.coli/ 100ml | *E.coli*/ 100ml | T.coli/ 100ml | Turb TU |
| HH1 | 1/5/08 | | ~clear* | 500 | 2000 | | | <100 | 100 | clear* |
| HH2 | 1/5/08 | | 1000 | 2000 | 14000 | | | <100 | 25000 | clear* |
| HH3 | 1/5/08 | | 500 | 500 | 14000 | <100 | <100 | <100 | 1400 | clear* |
| HH4 | 1/12/08 | 12 | | <100 | 20000 | <100 | <100 | 700 | 3600 | |
| HH5 | 1/12/08 | 12 | | 5000 | 18000 | 100 | 6200 | 600 | 10400 | |
| HH3 | 1/12/08 | 30 | | <100 | 18000 | <100 | <100 | <100 | 2400 | |
| HH6 | 1/12/08 | 6 | 200 | 5000 | 14000 | <100 | 700 | 1000 | 1900 | -- |
| HH7 | 1/12/08 | 7 | | 1000 | 29000 | <100 | 1900 | 100 | 2600 | |

*"Clear" means that visually there was no visible turbidity; assumed turbidity of <5NTU because measurement using the turbidity tube was not possible due to minimal amount of sample available;

Source for HH 1-2 was a turbid river >100m away (no water quality data available). Source for HH3-HH8 was an open, flowing irrigation ditch of Turbidity >500TU possessing 4000 *E.coli*/100ml and 22000 T.coli/100ml, as tested during the second sampling visit.



**HH3: Effective Use**
Intermediate/low microbial risk in water taken from storage

**HH7: Ineffective Use**
High microbial risk in water taken from storage

**Figure 17 Effective and Ineffective Use among Kale Heywet Church BSF Users**

*Pictorial Analysis:* Note the elevated and dedicated safe storage unit in household three (HH3), with a separate small mouthed clean jerrycan for fetching water, tile floor, and visible presentation of KHC's maintenance poster and sticker. Note the improper placement of filter in household seven (HH7), located in a goat pen, accessible to animals, with holes in the thatched roof that allow direct sunlight onto the filter housing. Despite neither household showing a dedicated drinking cup for their filter, HH3 showed much better hygienic procedure when fetching water. The lack of a designated safe storage unit and unhygienic conditions in the picture of HH7 show that despite seemingly effective microbial treatment occurring with both filters, recontamination occurred both through observation and water quality testing in HH7 and not HH3 (see *KHC Water Quality Results* in Table 6).

## *5.2 Sample Effective Use Monitoring Checklists*

The following Figures 18 and 19 present as much data as was taken at the households pictured above.

**Figure 18 Example Monitoring Checklist for Household 3 of the Kale Heywet Church BSF Users**

| **Biosand Filter Effective Use Monitoring Checklist** | |
|---|---|
| Monitor Name: | Matt Stevenson |
| Community: | Filtino community, Oromia region, Ethiopia |
| Interviewee Name: | ---------, mother of the household and BSF caretaker |
| Household/Code: | HH3 |
| Date and Time: | January 12th around 12:00 PM |
| GPS Coordinates: | ____________ ____________ |
| Notes: Well kept house with clean tile floor and CGI roof. Has had BSF 8 years and likes it very much. | |
| **Instructions:** For each observation, fill in Yes, No, or NA for observations that do not apply. Add up the total #Yes, divide by the total # of observations made, and multiply by 100 for % Observational Effective Use. | |

| **Monitoring Observations** | **Checklist** | (Yes/No/ NA) |
|---|---|---|
| ***Treatment*** | 1. Water is added daily to the filter. | Yes |
| | 2. Uses separate containers to fetch/pour dirty water and store filtered water. | Yes |
| | 3. Adds water slowly with the diffuser plate in place. | Yes |
| | 4. Pretreatment is claimed for turbid waters (>100NTU). | Yes |
| | 5. The spout is unobstructed and clean. | Yes |
| | 6. Smooth and level sand bed at water depth of 4-6 cm. | NA |
| | 7. BSF is sitting flat on firm ground. | Yes |
| | 8. The lid to the filter is in place and clean. | Yes |
| | 9. System is out of direct sunlight. | Yes |
| | 10. System is out of reach of animals. | Yes |
| | 11. Filter has no visible leaks or cracks. | Yes |
| | 12. Filter flowrate is ~0.6 L/min. | Yes |
| ***Storage*** | 13. Dedicated safe storage unit is used. | Yes |
| | 14. Design of safe storage unit incorporates a tap or a small sealable opening for pouring. | No |
| | 15. The safe storage container has a lid that is kept on tight except for adding or pouring treated water. | Yes |

| | | |
|---|---|---|
| | 16. Safe storage container is located with the BSF indoors, out of the sun, off of the floor, in a stable position and out of reach of animals and small children. | Yes |
| | 17. Safe storage unit is visibly clean. | Yes |
| ***Maintenance*** | 18. User uses and demonstrates "swirl and dump" cleaning method: | |
| | 18.1. Adds ~4 liters of water to the top of the filter | Yes |
| | 18.2. Scoops out dirty water with small container, levels sand and replaces diffuser plate. | Yes |
| | 18.3. Fills with water and repeats the process if flow rate is still slow. | Yes |
| | 19. Filter cleaning schedule is determined by significant reduction in flowrate. | Yes |
| | 20. BSF cleaned less than once a week. | Yes |
| | 21. User cleans the spout and storage unit with treated water and soap or chlorine solution each week. | NA |
| | 22. Soap or disinfectant used to clean storage unit can be produced by user. | NA |
| ***Physical Inspection*** | 23. Water bottles for use during travel or school are clean and producible to the interviewer if consistent use is claimed outside the home. | No |
| | 24. User demonstrates hygienic method when asked to add water to filter and fetch a glass of water. | Yes |
| | 25. A dedicated clean drinking cup is associated with the safe storage unit. | Yes |
| **Percentage of observations passed** | **= #Yes / (#Yes + #No) X 100%** | **92%** |

**Notes:** Displays KHC maintenance materials on wall above filter; Generally hygienic usage of the system, despite lack of a dedicated clean drinking cup.

| **Water Quality Monitoring** | | ( Yes/No/ NA) |
|---|---|---|
| *Turbidity* | Treated water is clear (Turbidity of <5 NTU). | Yes |
| *Chlorine Residual* | Free available chlorine presence in safe storage if chlorine treatment is claimed | NA |
| *Microbial Testing* | Microbial testing shows <10 *E.coli* CFU/100 ml in water from both running spout and storage unit. | <100 *E.coli*/ 100ml |

**Notes:** Moderate recontamination shown through storage practices, although unable to deduce microbial Effective Use metric by just using the Petrifilm.

| | 24 hr Colilert (Yes/No) | | 24 hr Petrifilm (Count) | | # *E.coli*/ 100ml | **Risk Level** |
|---|---|---|---|---|---|---|
| Sample from running spout | Yellow? | Fluoresces? | # Blue w/gas | # w/gas | | |
| | --** | -- | 0 | 0 | <100 | Low/Int |
| Sample from storage of treated water | 24 hr Colilert (Yes/No) | | 24 hr Petrifilm (Count) | | # *E.coli*/ 100ml | **Risk Level** |
| | Yellow? | Fluoresces? | # Blue w/gas | # w/gas | | |
| | -- | -- | 0 | 14 | <100 | Low/Int |

Incubate Colilert and Petrifilm at body temperature (35°C) for 24 hours (or until results appear), then check:

| | |
|---|---|
| **Colilert**: If the water is clear: <10 Total Coliform/100ml and <10 *E.coli*/100ml<br>If the water is yellow: >10 Total Coliform/100ml<br>If the water is yellow and fluoresces: >10 Total Coliform/100ml and >10 *E.coli*/100ml<br>**Petrifilm:** # of colonies w/gas X 100= # of Total Coliform/100ml; # of Blue w/gas X 100= # of *E.coli*/100ml; No Blue colonies with gas= <100 *E.coli*/100ml; No colonies with gas = <100 TotalColiform/100ml.<br>**Risk Level:** Low is <10 *E.coli* /100ml; Intermediate is 10-100 *E.coli* /100ml; High is >100 *E.coli* /100ml. | |
| ***Sampling Procedure*** | 1. Take a sample of treated water from the storage unit for microbial analysis (if available). If chlorine treatment is claimed in stored water, test for presence of chlorine residual while at the household and use a Sodium Thiosulphate sampling bag for transporting sample to laboratory. Keep the sample out of the sun and start microbial tests within 6 hours. |
| | 2. Fill the BSF to a consistent level (not to the top). |
| | 3. Check the turbidity of the filtering water if it is visible and sufficient volume exists. |
| | 4. While taking a sample for microbial analysis from the pouring BSF spout, take a flow rate measurement by counting seconds until 100ml is full in the Whirlpak bag. |

*NA indicates that the question was not asked at the time of interview

**Not using Colilert at this time

**Figure 19 Example Monitoring Checklist for Household 7 of the Kale Heywet Church BSF Users**

| **Biosand Filter Effective Use Monitoring Checklist** | |
|---|---|
| Monitor Name: | Matt Stevenson |
| Community: | Filtino community, Oromia region, Ethiopia |
| Interviewee Name: | ---------, mother of the household and BSF caretaker |
| Household/Code: | HH7 |
| Date and Time: | January 12th around 2:30 PM |
| GPS Coordinates: | ____________________ ____________________ |

Notes: BSF kept in goat pen, with children drinking out of the spout directly. Has had the BSF for 9 years. Materially poorer than her neighbors and less educated.

**Instructions:** For each observation, fill in Yes, No, or NA for observations that do not apply. Add up the total #Yes, divide by the total # of observations made, and multiply by 100 for % Observational Effective Use.

| **Monitoring Observations** | **Checklist** | (Yes/No/ NA) |
|---|---|---|
| ***Treatment*** | 1. Water is added daily to the filter. | Yes |
| | 2. Uses separate containers to fetch/pour dirty water and store filtered water. | No |
| | 3. Adds water slowly with the diffuser plate in place. | Yes |
| | 4. Pretreatment is claimed for turbid waters (>100NTU). | No |
| | 5. The spout is unobstructed and clean. | No |
| | 6. Smooth and level sand bed at water depth of 4-6 cm. | NA |
| | 7. BSF is sitting flat on firm ground. | Yes |
| | 8. The lid to the filter is in place and clean. | Yes |
| | 9. System is out of direct sunlight. | No |
| | 10. System is out of reach of animals. | No |
| | 11. Filter has no visible leaks or cracks. | Yes |
| | 12. Filter flowrate is ~0.6 L/min. | Yes |
| ***Storage*** | 13. Dedicated safe storage unit is used. | No |
| | 14. Design of safe storage unit incorporates a tap or a small sealable opening for pouring. | No |

| | | |
|---|---|---|
| | 15. The safe storage container has a lid that is kept on tight except for adding or pouring treated water. | No |
| | 16. Safe storage container is located with the BSF indoors, out of the sun, off of the floor, in a stable position and out of reach of animals and small children. | No |
| | 17. Safe storage unit is visibly clean. | No |
| ***Maintenance*** | 18. User uses and demonstrates "swirl and dump" cleaning method: | |
| | 18.1. Adds ~4 liters of water to the top of the filter | No |
| | 18.2. Scoops out dirty water with small container, levels sand and replaces diffuser plate. | No |
| | 18.3. Fills with water and repeats the process if flow rate is still slow. | No |
| | 19. Filter cleaning schedule is determined by significant reduction in flowrate. | Yes |
| | 20. BSF cleaned less than once a week. | Yes |
| | 21. User cleans the spout and storage unit with treated water and soap or chlorine solution each week. | No |
| | 22. Soap or disinfectant used to clean storage unit can be produced by user. | No |
| ***Physical Inspection*** | 23. Water bottles for use during travel or school are clean and producible to the interviewer if consistent use is claimed outside the home. | No |
| | 24. User demonstrates hygienic method when asked to add water to filter and fetch a glass of water. | No |
| | 25. A dedicated clean drinking cup is associated with the safe storage unit. | No |
| **Percentage of observations passed** | **= #Yes / (#Yes + #No) X 100%** | **32%** |
| **Notes:** Removes sand to clean BSF; Washes a cup with unfiltered water when asked for a cup of water; | | |

| **Water Quality Monitoring** | | ( Yes/No/ NA) |
|---|---|---|
| *Turbidity* | Treated water is clear (Turbidity of <5 NTU). | No, 10NTU |
| *Chlorine Residual* | Free available chlorine presence in safe storage if chlorine treatment is claimed | -- |
| *Microbial Testing* | Microbial testing shows <10 *E.coli* CFU/100 ml in water from both running spout and storage unit. | No*** |
| **Notes:** Treatment is not working correctly; unsafe levels of recontamination occur in storage; Ineffective Use noted through both observation and water quality testing. | | |

| Sample from running spout | 24 hr Colilert (Yes/No) | | 24 hr Petrifilm (Count) | | # *E.coli*/ 100ml | **Risk Level** |
|---|---|---|---|---|---|---|
| | Yellow? | Fluoresces? | # Blue w/gas | # w/gas | | |
| | NA | NA | 0 | 4 | <100 | Low/Int |
| Sample from storage of treated water | 24 hr Colilert (Yes/No) | | 24 hr Petrifilm (Count) | | # *E.coli*/ 100ml | **Risk Level** |
| | Yellow? | Fluoresces? | # Blue w/gas | # w/gas | | |
| | NA | NA | 1 | 29 | 100 | High |

| |
|---|
| Incubate Colilert and Petrifilm at body temperature (35°C) for 24 hours (or until results appear), then check:<br>**Colilert:** If the water is clear: <10 Total Coliform/100ml and <10 *E.coli*/100ml<br>If the water is yellow: >10 Total Coliform/100ml<br>If the water is yellow and fluoresces: >10 Total Coliform/100ml and >10 *E.coli*/100ml<br>**Petrifilm:** # of colonies w/gas X 100= # of Total Coliform/100ml; # of Blue w/gas X 100= # of *E.coli*/100ml;<br>No Blue colonies with gas= <100 *E.coli*/100ml; No colonies with gas = <100 TotalColiform/100ml.<br>**Risk Level:** Low is <10 *E.coli* /100ml; Intermediate is 10-100 *E.coli* /100ml; High is >100 *E.coli* /100ml. |

| | |
|---|---|
| ***Sampling Procedure*** | 1. Take a sample of treated water from the storage unit for microbial analysis (if available). If chlorine treatment is claimed in stored water, test for presence of chlorine residual while at the household and use a Sodium Thiosulphate sampling bag for transporting sample to laboratory. Keep the sample out of the sun and start microbial tests within 6 hours. |
| | 2. Fill the BSF to a consistent level (not to the top). |
| | 3. Check the turbidity of the filtering water if it is visible and sufficient volume exists. |
| | 4. While taking a sample for microbial analysis from the pouring BSF spout, take a flow rate measurement by counting seconds until 100ml is full in the Whirlpak bag. |

*NA indicates that the question was not asked at the time of interview
**Not using Colilert at this time
***Microbial quality was marked as a failure if either the treated water from the spout or the stored water failed the Effective Use metric.

## *5.3 Discussion of Effective Use Monitoring Results*

**Table 7 Sample Household Monitoring Data Format for Kale Heywet Biosand Users**

| | Treatment | | | | | | | | | | | | Storage | | | | | Maint-enance | | | | | | | Physc Inspct | | | Monitoring Observation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HH | 1* | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18a | 18b | 18c | 19 | 20 | 21 | 22 | 23 | 24 | 25 | % of criteria passed |
| 1 | y | y | y | y | y | y | y | y | y | y | y | y | y | n | y | y | y | y | y | y | y | y | y | - | n | y | y | 92 |
| 2 | y | y | y | n | - | - | y | y | y | n | y | y | y | n | n | y | n | - | - | - | n | y | n | - | n | n | n | 52 |
| 3 | y | y | y | n | y | y | y | y | y | y | y | y | y | n | y | y | y | y | - | y | y | y | y | - | n | y | y | 88 |
| 4 | y | y | y | n | - | - | y | y | y | y | y | y | y | n | n | y | y | n | n | n | - | y | y | - | y | y | n | 70 |
| 5 | y | y | y | n | - | - | y | y | y | y | y | y | y | n | n | y | y | y | - | y | - | y | y | - | - | y | n | 81 |
| 6 | y | y | y | n | - | - | y | y | y | y | y | y | y | n | n | y | y | n | n | n | - | y | y | - | y | n | n | 65 |
| 7 | y | n | y | n | n | - | y | y | n | n | y | y | n | n | n | n | n | n | n | n | y | y | n | - | n | n | n | 32 |
| % | 100 | 86 | 100 | 14 | | | 100 | 100 | 86 | 71 | 100 | 100 | 86 | 0 | 29 | 86 | 71 | 50 | | 50 | | 100 | 71 | | 33 | 57 | 29 | 69 |

*Numbers refer to the line items on the Biosand Filter Monitoring Checklist (see Figures 18 and 19)

| | **Monitoring Observation** | **Water Quality** | | |
|---|---|---|---|---|
| HH | % | **Turbidity** | **Microbial from Spout** | **Microbial from Storage** |
| 1 | **92** | **Yes** | -- | <100 E.coli/100mL* |
| 2 | **52** | **Yes** | -- | **No** |
| 3 | **88** | **Yes** | <100 E.coli/100mL* | <100 E.coli/100mL* |
| 4 | **70** | **Yes** | <100 E.coli/100mL* | **No** |
| 5 | **81** | **Yes** | **No** | **No** |
| 6 | **65** | **Yes** | <100 E.coli/100mL* | **No** |
| 7 | **32** | **No** | <100 E.coli/100mL* | **No** |

*Could not judge Effective microbial treatment due to limit of resolution of Petrifilm

The results of this small data set show interesting positive correlations between the two complementary methods of Effective Use operational monitoring: Monitoring Observations and Water Quality Monitoring. With an average 73% adherence to Effective Use monitoring observations for the seven households visited, household 7 had the lowest monitoring observation score (32%) and passed neither of the water quality tests. Households 1 and 3, on the other hand, had an average 90% monitoring observation score, and failed neither water quality test. The noted agreement between monitoring observations and water quality testing suggests that they can act as reaffirming independent checks of Effective Use.

One of the water samples taken from the spout of the BSF was in the high risk category (HH5, see Table 6) and one of the treated water samples failed the turbidity test (HH7). With only two among the seven BSF users failing the treatment water quality measures, treatment was not where the largest lapses in Effective Use occurred. The Treatment category of Table 7 is filled with markings of correct action (note the high percentages along the bottom row corresponding to Treatment, averaging 86%) correlating with five out of the seven passing the water quality checks on treatment. Safe storage and handling (shown by Physical Inspection in this case) had much lower percentages of correct action (54% and 40%, respectively), and consequently five out of 7 households measured high risk from *E.coli* in their storage containers. While this discussion highlights a few trends, with larger data sets many more accurate correlations could be drawn to aid the implementing organizations to judge failure and successes in terms of attaining Effective Use in their HWTS programs.

# 6. Discussion

Throughout about 40 household visits made by this researcher during January, 2008, it was observed that numerous users were successful in meeting various criteria for Effective Use as laid out for the individual HWTS technologies, including correct treatment, safe storage, maintenance and water quality. The existence of appropriate training and/or monitoring programs was found to be one apparent cause of this success. When users failed the observational analysis, it was often due to hygiene or storage practices. Ineffective use all around was noticed in rare cases, which is a testament to the success of the HWTS implementations. A few of the most common results are recounted below.

## *6.1 Monitoring and Evaluation*

During household monitoring visits, the author witnessed many of the technicians, salespeople and community representatives correcting the actions of the HWTS users upon direct observation of their usage techniques. Involved with all stages of implementation, these people were intimately familiar with the training, technologies, and various aspects of implementations as well as with many of the users themselves. Their prior experience with the users and implementations allowed them to make appropriate recommendations on Effective Use to the users. Such monitoring was witnessed, for example, in Shak Ibrahim's retraining users during follow-up monitoring to the UNICEF/Pure Home Water distribution of CWPs to flood affected areas in Ghana (see *Appendix C*).

This type of constructive operational monitoring can occur throughout implementations and can contribute to substantial gains in % of households practicing Effective Use. Operational monitoring is distinguished here from verification monitoring as described in the WHO GDWQ 3$^{rd}$ Ed. that is often most useful for project evaluation and can benefit from having independent third party monitors. If operational monitoring is conducted by independent monitoring agents, however, it may lose the ability to correct improper use, limiting the overall effects of the operational monitoring campaign.

Monitoring observations as they pertain to Effective Use are normally correctable on the spot. While measurement of turbidity and residual FAC can automatically confirm claims of consistent use, appropriate dosing, and well functioning systems, microbial water quality monitoring acts primarily as a pass/fail metric and is not an active operational monitoring technique unless a second visit is planned and made to the households or community, in order to explain the results of the water quality testing. With a simple microbiology lesson to the community, Bob Metcalf has used the Petrifilm and Colilert results to inform community members (or HWTS users, in our case) of their own treatment efficacy and water quality. While adding extra cost, this second visit to the community or household could act as retraining and be incorporated into budgets at the outset.

Consistent use of HWTS technologies is not well understood or documented (Figueroa, 2005). Household operational monitoring of Effective Use only provides a snapshot of treatment and does not prove that people are drinking HWTS water on a consistent basis. Without consistent use, maximum health benefits may not be realized. Moreover, environmental conditions often greatly change the needs of HWTS throughout the year. Use of SODIS may be infeasible during the rainy season not only because of lack of solar radiation but due to the increase in turbidity of surface water source, necessitating filtration or use of PUR. Consistent and Sustained Use of HWTS may thus not be technology specific, but more generally apply to multiple water management techniques (Meierhofer, 2008).

## *6.2 Field Interviews*

While *Appendix C: Household Monitoring Reports* contains compiled notes on the field interviews, a few consistent concepts noted throughout the interviews are reviewed below.

Regular follow-up and long-term monitoring efforts were expensive but had the potential to support Effective Use, as witnessed in a few of the organizations (i.e., with the Kale Heywet Church and the Carter Center's Guinea Worm Eradication Project (GWEP)). With other implementations, however, monitoring and evaluation was not included and/or was often the last thing on the funding list. M&E was often not put into budgets upfront such that available funding was used up in other ways and M&E was never conducted. This occurred with International Aid's installation of biosand filters in Kpanvo community near Tamale, Ghana. Most of the monitoring funds were used up in the microbial testing of the filters a few days after installation, before the *schmutzdecke* had fully formed, optimal treatment results were measurable, or maintenance techniques could be analyzed. While this example singles out preliminary monitoring without proper foresight, improperly thought-out monitoring of HWTS is not uncommon.

For their consumable products, PSI in Ethiopia and the Medentech distributors in both Ethiopia and Ghana, namely EtMedix and Precision, respectively, had no programs allocated in their budgets for household monitoring. While the Aquatabs groups claimed that use of the product was simplified by the dosing method, with proven ability of Effective Use and health benefit, the managers of these groups seemed to rely on the assumption that because people bought the product they would use it properly. With these agencies neither collecting user information (name, address, etc.) nor visiting the households themselves, the author was unable to field-test the assumption of Effective and Sustained Use of the products that were purchased. However, PUR's initial entrance into South American markets as a commercial product only showed 5% consistent use following free distribution and user-claimed health impacts, shadowing doubt on the "if it is bought it is used" assumption (Luby, 2008). Instead of household behavioral monitoring, these three groups emphasized instead financial/commercial targets such as monitoring through the supply chain, by responding to customer and distributor complaints and tracking stock turnover.

When funding was used up following mass distributions of HWTS, such as with Enterprise Works' subsidized distribution of ceramic water purifiers (CWPs) near Accra, Ghana, behavioral monitoring and evaluation efforts became reliant upon voluntary activity by the community liaisons and salesmen and seemed unlikely to retain support of Enterprise Works. In contrast, developing a system of community volunteers that helps with initiation of distribution within the communities and who routinely checks usage of filters as done with the Carter Center GWEP and Pure Home Water encouraged community involvement in the project.

Organizations such as Oxfam and UNICEF have distributed PUR and sodium hypochlorite solution (Waterguard, as produced by PSI Ethiopia) in acute watery diarrhea (AWD, a.k.a. cholera) outbreaks in Ethiopia in recent years. While trainings are generally held in large community meetings for these products (see *Appendix G* for PSI's training materials), and use incurs visible health benefits as claimed by the users themselves, Sustained Use is often not noticed following the implementation. When hoarding of PUR was noticed in households following an Oxfam distribution in southern Ethiopia, the project switched to source protection as proper use was "not able to be monitored in the household" (see interview with Gladys Inzofu in *Appendix B*). Likewise, Tsegaye Gebre, Program Manager of Kale Heywet Church expressed doubt as to whether private organizations would be able to appropriately monitor the use of biosand filters. Given that his program spends about US $30 on the hardware for each filter, the main cost is in training, support staff, and continued monitoring of the users, even after 10 years of use. The total cost of each filter thus comes to about US $100, with Tsegaye expressing that the high degree of Effective Use and Sustained Use witnessed in his program is due in great part to the behavioral monitoring work that is so costly, and would not likely be supported by a for-profit venture.

## *6.3 Best Practices for Field Monitoring*

Below are four examples of "best practices" observed during field monitoring:

1. The Carter Center Guinea Worm Eradication Project (GWEP) working together with the Ghanaian Ministry of Health has an extensive system of community volunteers in place for weekly monitoring of each household using their cloth filters. While a conversation with Philip Downs, Assistant Director of GWEP for the Carter Center in Washington, D.C. during July 2008 has suggested that filters are replaced more often than needed, rather than based on breakage rates as assessed by community volunteers, >95% Effective Use of the cloth filters was witnessed throughout the surveying of 56 joint Pure Home Water *Kosim* and GWEP cloth filters by Kate Clopeck. This achievement is no doubt due to appropriate training, vigilant monitoring by local entities and active replacement of damaged filters.

2. Pure Home Water's (PHW) sale of the *Kosim* ceramic water purifier (CWP) is structured both through a salesperson from PHW and a community liaison from within the village. The salesperson provides training and technical support, while the community liaisons follow up with households to take new orders, monitor problems and secure replacement filters. In addition to continued user familiarity with the community representative, each *Kosim* filter storage unit has a sticker

with PHW's name, phone number and address as well as with a set of detailed pictorial and text instructions (PHW, 2008).

3. The joint PHW and UNICEF distribution of 5000 *Kosim* CWPs to flood affected residents of the Upper East Region, Ghana, had an ambitious program for a monitoring follow-up visit to 1 out of 5 houses who received a filter. This M&E program was planned into the initial funding for the distribution. A four-person PHW survey team covered a representative sample of the communities involved in the distribution. Planned and funded M&E programs are essential, as is flexibility in their execution. This is a good example of household monitoring of HWTS taking place within the confines of an emergency situation.

4. The Kale Heywet Church (KHC) biosand filter project has been consistently funded by Samaritan's Purse of Canada since its inception in 1999. Sustained funding has allowed KHC to plan a long-term monitoring and evaluation campaign with which to help enforce Effective Use amongst its users, keeping contact between users and KHC's technicians throughout this timeframe.

## *6.4 Common Threads in Household Monitoring*

A few themes of HWTS use common to many of the households visited in both Ethiopia and Ghana are examined here.

1. Effective Use was notably hampered by user's day to day responsibilities. In particular, pregnant mothers and those with newly born children were often unable to care for their biosand filters (BSFs) and ceramic water purifiers (CWPs). At Household 2 at the field location of the Kale Heywet Church BSF implementation (see *Appendix C*), a woman with a newborn was relying on children to fetch water for her. While she knew of the practice of riverbed filtration and knowledge of proper maintenance, the stresses of being pregnant prevented her from completing these tasks. Her storage unit was very dirty and without a lid, yet fecal contamination was not too great, showing proper treatment with the BSF, an amazingly robust device! However, from measuring the total *coliform* counts in the treated water, recontamination had clearly occurred in the storage unit and the water that this user and her newborn were consuming was in the WHO category of high risk of waterborne disease (see Table 2). Because no one else was able to maintain the system, the HWTS system that was designed to protect a mother and her children had failed them at this most crucial juncture, when health was at a premium to the mother and her baby. Similarly, in the Kpanvo village near Tamale, Ghana, a woman interviewed who was an owner of both the CWP and BSF had stopped using the CWP altogether during the last stretch of her pregnancy, as she too was relying on others to fetch water for her and admits that she was not able to properly manage her water at that time. With mothers as the sole attendants to the HWTS, safe water is not guaranteed whenever the mother is pregnant or otherwise predisposed and without assistance from another HWTS caretaker within the household, which could add up to weeks

out of the year. Similarly, sole caretaking as witnessed among men who purchase the *Kosim* from Pure Home Water in Northern Ghana resulted in no great improvement in access to clean water for the household, as some of these men locked their *Kosim* in their room for their sole personal use. Inclusive training of multiple users may be warranted for HWTS use, for in sharing the system, more people are likely to learn about proper water management and obstacles to Effective Use may be less likely to develop.

2. The frequency of cleaning by users of both BSF and CWP is higher than was anticipated. When asking about cleaning frequency during household interviews, it was very hard to get clear answers. During water testing of the Kpanvo BSFs, many of the users reported cleaning their BSF every 3 days. For the 16 samples tested using membrane filtration, results of treated water in safe storage as well as freshly treated during the monitoring visit all turned up negative for *E.coli* or with low risk (<10 *E.coli* per 100ml).

   In kpanvo and other settings, users had a hard time remembering the last time they cleaned their filters. People genuinely may not have been able to remember the last time they cleaned the unit because they clean it so often with the high turbidities encountered. Depending on the outcome of microbial water quality testing, such avid maintenance based on flow rate may be positive or counter productive. If the maintenance is scheduled (such as is warranted with the cleaning of the CWP's and BSF's safe storage units) and the user can not genuinely remember when they last cleaned the unit, then their scheduling mechanism is not working, and ineffective use is suspect.

3. One of the limitations of single-visit unannounced household visits is their inability to truly engage the interviewee. People often do not feel comfortable enough with strangers (especially foreigners) in their homes to answer certain questions. People may get the idea that they are supposed to answer a certain way, and thus answers to questions about frequency of cleaning or hygiene habits will not yield accurate answers. Similarly, people may be unwilling to answer questions about their family's or their own health, as these are private questions. While in my monitoring of about 40 households during the trip, it appeared that my own presence during the household visits contributed to causing all but one of the users to not answer questions pertaining to diarrhea prevalence, or flat out reject the possibility of their children having diarrhea in the foreseeable past, due to the wonders of their great HWTS product! When foreigners are left outside of the interview and translators from the region conduct the interviews, more positive answers are found (Greene, 2008). However, even these results are suspect as a health impact study of Aquatabs in Ethiopia reported growth in waterborne disease prevalence throughout the first two weeks of the implementation, showing people's reluctance to give truthful answers until monitors were known on first-name bases.

4. Emergency implementations of HWTS have limited ability to garner Consistent or Sustained Use among users. Henock Gezahegn of PSI complained of the inability to gain customers following emergency distributions, despite the instant and meaningful health gains witnessed during the use of their products. This "emergency product" mentality disrupts PSI's advertising of PUR and Watergaurd sodium hypochlorite solution as a "lifestyle product." Following a cholera outbreak when Watergaurd or PUR is distributed free of charge to the user, people may come away thinking that these products are only needed during cholera scares and thus they stop using the product and may tend to hoard a supply for the next time emergency conditions resurface. The goal of preventing the emergency through proper water management is thus lost. Outside of a state-declared emergency, people may be ignorant of the threat to their health posed by their water supply. So, despite their visible health impacts, neither Consistent nor Sustained Use occurs, hampering Effective Use. Such was the case with the Oxfam distribution described by Gladys Inzofu (*Appendix B*), which led Oxfam to switch to a strategy of source protection. Often in remote areas far away from the main roads, distribution networks are not easily established in emergency zones, such that when emergency organizations such as UNICEF and Oxfam that distribute consumable disinfectant HWTS products free of charge declare the emergency over and move onto the next project, even the users who may wish to continue HWTS use are left without outlets from which to buy the products nor knowledge with which to order the product. This facet is especially important for the CWP, for while Effective Use is witnessed following emergency distribution, replacement must be readily available when breakage occurs in order to maintain Sustained Use. Pure Home Water deals with this by posting their name, address, and telephone number on their CWP units. Despite lack of product info, the recipients of emergency aid or otherwise freely distributed HWTS are often unaware of the donating agency. In the case of the joint UNICEF/Pure Home Water distribution of 5000 CWPs to flood affected areas of Ghana, the name UNICEF, though recognizable to the people involved, was never uttered. Subsequent to PHW workers reporting on this lack of name recognition, UNICEF took it upon themselves to add UNICEF stickers to the CWPs. In another example, people who received BSFs from International Aid in Kpanvo village, Ghana, were unaware of both the parent agency and the impetus behind the distribution, claiming that the BSF was given to them "by the white man" (namely Carl Allen, the Peace Corps coordinator who provided major assistance during installation the filters in Kpanvo). Without adequate monitoring programs to follow these hastened and/or emergency implementations, new users will not know where to turn for replacement, with usage questions or when their HWTS has problems, greatly hindering Effective and Sustained Use. Such problems are often solved via direct purchasing of the products, community involvement during project planning, proper labeling with contact information, and appropriate monitoring set out prior to implementation.

5. The separation of raw and filtered water was not well understood among users of all of the technologies witnessed. With SODIS, CWP, BSF, and cloth filters, in

which there is no residual protection offered to HWTS treated waters, this is of special concern. Despite proper use and maintenance of HWTS systems, non-hygienic handling of treated water, including hands in storage units and washing drinking cups with source water was one of the most commonly observed reasons for not achieving Effective Use based on the author's observational monitoring. Revision of materials and training methods needs to include routine maintenance of storage units for all HWTS, stressing the separation of untreated and treated water, as well as using a dedicated clean cup for drinking.

## *6.5 Technology–Specific Observations*

### 6.5.1 Pretreatment

Various pretreatment techniques achieve better treatment efficiency and lengthen times between cleaning for a variety of HWTS techniques. In Northern Region, Ghana, settling in primary storage units or the container used for fetching water from the source brought turbidity consistently below 10NTU for the CWP, within the definitions of Effective Use (Swanton, 2008). Riverbed filtration was promoted by the training program of Kale Heywet Church, and Household 1 (*Appendix C*) had the best Effective Use witnessed for the program, reducing 1000NTU source water to almost clear before use. Pretreatment has the effect of reducing frequency of cleaning for both the BSF and CWP as well as storage units, decreasing potential ineffective use. In regions of seasonably high turbidity that can threaten the viability of certain HWTS techniques, settling and prefiltration may have the potential to bring turbidity down to levels suitable for Aquatabs, sodium hypochlorite solution, or SODIS, let alone lower the absolute risk level achieved through use of these HWTS. Settling, riverbed-sand filtration, alum coagulation and other pretreatment techniques need to be investigated and promoted to reduce the likelihood of diarrheal disease in conjunction with the use of HWTS.

### 6.5.2 Maximum turbidity for use with the biosand filter

The biosand filter (BSF) can be a commercially viable product, as proven by technicians who produce the filters for under US $10 as a side job in Machakos, Kenya, using a cylindrical concrete design (which saves on material and labor costs). As expressed by Tsegaye Gebre during an interview in January, 2008, the common belief was that BSFs cannot be sold due to the large amount of follow up needed to ensure proper use.

The biosand filter is often looked to as an HWTS product for use with raw waters of low and constant turbidities. CAWST recommends that biosand is used for raw waters with turbidity <50–100NTU (CAWST, 2007). During the dry seasons as witnessed in Ethiopia and Ghana during January, 2008, however, despite a high frequency of cleaning and lack of settling or other pre-treatment, the BSF showed an ability to reduce high turbidities as well or better than the CWP, consistently bringing turbidities to below 5NTU. Using BSFs with high turbidity waters showed promising results during field testing in Ethiopia and Ghana during January, especially in conjunction with pretreatment techniques of settling and river-bed filtration (see *Appendix C*). Further study under high turbidity conditions is needed to confirm or remove the CAWST recommendations of 50-100 NTU for influent waters to the BSF.

### 6.5.3 Dosing volume and pause times for the biosand filter

Recent research has shown that the BSF removes viruses with an efficiency of less than 90% (Stauber, 2007). Jenkins' found high variability in virus removal rates with the BSF, averaging 0.50 log removal with a standard deviation of 0.46 log. Viral, bacterial and turbidity reduction is markedly greater with long pause times between refilling as well as adding smaller amounts of water at a given time (Jenkins, 2008). These results agree with those found by Baumgartner, who showed that pause times longer than 12 hours using dosing volumes equivalent to the pore space within the sand matrix resulted in the best treatment. Baumgartner also showed that pause times greater than a day (36 hours) showed a decrease in treatment efficiency (Baumgartner, 2007). Sobsey recommends not exceeding the pore volume when adding water, adding once in the morning and once at night. Once the research into pause time and pore replacement volume dosing is formally presented, new methods of use must be investigated. Scheduled operation frameworks would require more training upon inception and possible retraining of current users, and the potential to follow the framework also has to be addressed.

### 6.5.4 Consistent use of PUR and other consumable HWTS

While Consistent Use is assumed by PSI Ethiopia of the repeat purchasers of PUR and Watergaurd, as reported by their retailers, very little monitoring of Constitent, Sustained and Effective Use of consumable products has been conducted. As demonstrated in the initial commercial distribution of PUR in Guatemala in 2003, commercial indicators (e.g., % of repeat customers) do not necessarily demonstrate Effective or Sustained Use of the product. The original study recorded a 39% reduction in diarrhea. Yet, of the 462 households surveyed after 6 months, only 18% of the houses deemed "active repeat users" through surveying results had residual FAC! Moreover, only 16% of households had at least one sachet in the house and 12% had purchased PUR within the last two weeks, usually only buying 4-5 sachets, which would not allow them to practice Consistent Use as per the Figueroa definition. Only 5% of total deemed "active repeat users" despite the large health impacts witnessed by users just a few months earlier (Reller, 2003). While the price of PUR was high (US $0.14 per sachet), and Procter and Gamble decided to distribute PUR as a subsidized or free product from then on, this study has worrying implications for Consistent Use of consumable HWTS.

The minimum recommended quantities of consumable HWTS products available at the time of a household monitoring visit, as laid out in the *Physical Inspection* sections of their *Effective Use Write-ups*, are intended as guidelines for demonstrating Consistent Use for these particular products, in conjunction with residual FAC present at the time of monitoring. These recommendations are not based on monitoring data, as little exists, and thus might suggest overly ambitious reserve quantities of product to be present in the household. Specific monitoring programs need to adjust minimum quantities of their consumable products present within the household to their specific circumstances and monitoring results. Both of these metrics should be seen to grow over time as the behavior change of Consistent Use is adopted. Likewise, if intermittent use of consumable HWTS is found to be the norm through future monitoring efforts (i.e., if hoarding of consumable disinfectants witnessed following emergency programs is the norm), health impact assessment on intermittent use may be warranted.

The intention of the Effective Use monitoring frameworks laid out for sodium hypochlorite solution, PUR and Aquatabs is to provide both commercial and non-profit agencies a low cost and efficient means of monitoring for free chlorine, microbial water quality, and overall Effective Use. If users are known and documented during distributions or at the kiosk during sales, monitoring visits can be arranged and Effective Use can be judged with consumables and even in emergency situations. This would provide two new avenues for HWTS monitoring where currently many assumptions exist, yet little factual evidence.

### 6.5.5 Ceramic Pot Filter

The main burden of waterborne diseases falls on children, especially those under the age of five. A single ceramic pot typically produces enough water for a family of five. As witnessed in Northern Region Ghana, only certain people in the household are seen to use the *Kosim,* in some instances limited just to the husband who purchased it. Since children are target end users of HWTS in the goal of reducing waterborne disease burden, then Effective Use of the ceramic water purifier (CWP) cannot be based on a single pot filter for an entire family in regions of large family sizes or elevated water consumption. However, purchasing and operating more than one filter is also a hindrance to Effective Use, so expectations for number of filters per family have to be reasonable and one filter is better than none.

# 7. Conclusion

Monitoring campaigns can lead to various improvements in the given distribution of HWTS. Following an evaluation of their pilot biosand filtration project that showed loss of sand due to their method of cleaning, the Kale Heywet Church changed its training protocol to teach a wet harrowing technique to the users in their scale-up project of almost 10,000 biosand filters. Similarly, refinements of the technologies and their distribution have been made to HWTS following operational monitoring.

High percentages of users practicing Effective Use of HWTS filtration technologies have been documented here, with vigilant monitoring campaigns associated with higher percentages of effectively used systems. Simplified household monitoring frameworks and associated field techniques for measuring water quality have been presented here with the intention of providing useful tools for organizations to conduct operational monitoring and gather data on their customers' usage. Through vigilant monitoring at the household, groups are able to increase the Effective Use of their HWTS during and after implementation.

The importance of this document will ultimately lie with the utilization of the Effective Use Briefs and Monitoring Checklists by members of the WHO-hosted Network on HWTS and others. Its inclusion in the MIT compendium of behavioral and commercial indicators, to be prepared by Kate Clopeck in 2009 will provide a body of work which organizations throughout the Network and the world can use to operationally monitor their implementations, both inexpensively and in real time.

Health-impact based cost effectiveness of HWTS compares well with that of improved sources yet requires significantly less capitol than the piped water systems that are ultimately the most desirable solution (Clasen, 2006). Many parts of this world, however, are decades away from receiving piped distribution networks with a clean and reliable supply of water, and HWTS provide an alternative approach in the goal of greater access to safe water. They require low capital investment, little infrastructure other than a suitable distribution network, and can promote self-sustaining business models.

The 2008 WHO/UNICEF/JMP Progress Report recognizes that the quality of source water may not reflect the quality at point of use. Source quality may thus not be as strongly associated with changes in diarrhea occurrence. There is "increasing evidence that simple, low-cost interventions at the community level are capable of improving the microbial quality of domestically stored water and of reducing the associated risks of diarrhea disease" (WHO, 2006). Both quantity and quality of drinking water have to be ensured in order to improve health. Although HWTS technologies do not improve access to larger quantities of safe water, they *can* ensure the safety of water at the point of use. HWTS can work hand-in-hand with improved sources to maintain quality of water to the home where it is needed most.

The beauty of HWTS technologies are that they puts the control over family health back into the family's hands, so that households are not left without access to clean water from stalled or unsuccessful larger scale government and donor water projects. Needless to say, HWTS goes hand-in-hand with continual development of water-services infrastructure, source improvement, and effective treatments such as oral rehydration therapy. Meanwhile, self-empowerment is the key to this intervention. The overall impact is in the hands of the user, and yet important work is yet to be done to ensure that people are able to use these technologies effectively.

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# *Appendix A: Behavior and Sustained Use Questionnaire*

HWTS Monitoring and Evaluation Project
Behavior and Sustained Use Questionnaire
Kate Clopeck and Matt Stevenson

Interest is strong among various Network partners to develop and widely share M&E tools. Until now, efforts to systematically monitor and evaluate (M&E) household water treatment and safe storage (HWTS) implementation and scale up have been largely restricted to individual organization's initiatives and information on M&E methods, targets, indicators, tools and results are few and exist mainly in unpublished literature. In

A new initiative to expand that preliminary work, called the "HWTS M&E Project," is a collaboration between USAID's Hygiene Improvement Project (HIP), the WHO Network Secretariat and a seven-person MIT team comprised of Masters of Engineering and Sloan School of Management MBA faculty and students, who will identify and share the M&E targets, indicators, tools and results applied by organizations engaged in HWTS implementation and scale up.

More information on the "HWTS M&E Project" can be found at:
http://web.mit.edu/watsan -> "HWTS M&E Project"

## Pre-Interview

1. Gather background information and business description of organization
2. If possible, gather background on contact being interviewed
3. Visit organization website (if available)

## Questionnaire:

***Introductions (5 Mins)***

- Interviewer introductions
- Interviewee introduction
- Walk through agenda and provide quick overview of purpose

***Product Questions ( > 5 Mins)***

- Can you briefly describe your product?
- Do you have a technical data sheet? (If yes, could you please send us this information as an e- copy or hard copy?)

***Behavioral Questions (15 minutes)***

- How do you define "Effective Use" of your product?
- How do you ensure that your product is being used effectively by households?
- How do you measure the outcomes of this work?

- Have you performed any health impact studies? (if yes, could you please send us this data or any relevant report)
- Have you ever performed any water quality testing of the HWTS product in user households? (if yes, what water quality measures have your tested, what test methods have you used, could you please send us this data or any relevant report)
- Do you provide customers with a step-by-step guide on product assembly, operation & maintenance or other general information that is provided to households who obtain your product? Do you have this as a hand-out, written on the product itself or what? Could you please provide an e-copy or hard copy). Is this always provided or only on request.
- Does the product you disseminate have a replacement period/expiration date. If yes, how is that information communicated to the users?

***Coverage and Sustained Use Questions (15 minutes)***

- What is your target population?
    - How was this determined?
    - How many houses have you reached do far?
        - How was measured? (sales vs follow up visits)?
        - Total sales volume?

- How do you measure coverage and sustained use of the product by your target audience?
- Do you distinguish between types of users (frequent/infrequent, correct/incorrect?)
- Do you have any other way of measuring coverage?
- How is the household drinking water treatment product delivered to the target group?
- Do you visit that group at the time of dissemination?
- Do you do follow-up visits for service visits?
- Do you follow-up for monitoring and evaluation?
    - How often? (1 month?-ROA, 1 year?)
    - What do you check for? (Methods?)
    - How many households?
    - How do you pick the households? (if not all costumers)
    - Could you please send any data?
    - How many employees are dedicated to follow-up visits. How much time?
    - If no follow-up visit, do you have any other way of measuring sustained use?
- Do you rely of self-reports of efficacy, staff monitors, village volunteers, other?
    - Could you please send us data or reports of monitoring?
    - Any comments/concerns with self-reporting?
- How many units of your product are needed to supply safe water for 1 year for one household?
- What training materials do you have for your product?
- Do you consider coverage/sustained use a metric for measuring the success of your product? Of your organization?
- Why do you think coverage and sustained use is so hard to measure?

## *Appendix B: Fieldtrip Interviews*

Tsegaye Gebremehin
Kale Heywet Church
January 5th 8th 12th 2008
Addis Ababa and Oromia Region, Ethiopia

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**Interviewee's Role and Organization**

- Business Manager for water and sanitation program (includes POU, hygiene training unit, and drilling operations) at Kale Heywet Church

**Implementation Background**

- Pilot biosand project of 700 filters in 1999; scale up with 8000 filters 3 years later
- Tsegaye describes demand for BSF as from small groups of people from within the community who are in contact with users of BSF and other HWTS technologies
- Funded by Samaritan's Purse and using the rectangular concrete BSF
- Employs a large field staff, with community education team, construction/installation team, and monitoring team with field office/factory in rural areas of implementation and sufficient vehicles for staff to quickly travel to site locations

**Training**

- Using Life-Water 5-step PHAST program with community health workers
- KHC BSF program spends ~$30-35 on construction, and 100$ total for a given filter with KHC health package
- KHC emphasizes joint hygiene training and proper use (health package) over the commercial benefit; claims the operation could not be self sufficient without Samaritan's Purse
- When the program found that they were losing sand through cleaning techniques which removed sand, they gathered the users for a health and maintenance meeting for group re-training to the wet harrowing cleaning method. They first taught the 2nd knuckle finger stir, then taught flat palm technique with later users, (see *BSF Effective Use Maintenance* section).
- Tsegaye finds that education package is more important than making a distinction between non-profit and for-profit BSF ventures

**Effective and Sustained Use**

- No expiration period is proposed; Tsegaye views the BSF as a typical wat/san infrastructure project with a normal 10-20 year lifespan
- James Webster of Cranfield University of Silsoe, UK (thesis advisor to Paul Earwaker, who wrote a masters thesis analyzing the KHC BSF implementation in 2005) found that 88% of pilot study BSFs were still operating 2 years after implementation, as written in his proposal for further scale up with KHC

- KHC monitoring staff questions users at household about their use habits ("which method is best?") and asks for demonstrations of usage and cleaning
- Samaritan's Purse has worked with KHC to develop treatment goals of 95% reduction and 10 *E.coli* per 100ml in treated water
- KHC sees sustained individual use because of ownership incurred through POU product (people gave labor and committed to making a latrine)
- Tsegaye claims that program is effective because good will of the church is perceived and trusted by the communities and individuals involved
- Empowering the community by including it in the manufacturing and post sales education processes helps to boost adoption and sustained use

**Monitoring and Evaluation Activities**

- Monitoring team conducts 1 month (see Earwaker Appendix) and 3 month visits to the households, and sometimes 6 month visits.
- The staff comprises of one technician and one local community representative per 100 community members
- Community members are encouraged to pay the technicians 2-3 birr (0.22-0.33USD)
- KHC keeps in touch with users, and is alerted to the few problems that occur
- 3 Water tests in last 3 years→found 90% reductions in *E.coli* and total coliforms
- Stays in touch/keeps presence in community and claims to hear through the grapevine if systems are not functioning appropriately (although we witnessed some that were not functioning well unannounced), and technicians then make household visits as needed

**Field Visit Notes**

- Two rounds of field visits involving 8 BSF users in total, conducted on January 5 and 12, with Monitoring Observations and Water Quality Results written up in *Appendix C: Household Monitoring Reports*

**Materials Collected**

- WHO presented evaluation
- Household handout from pilot intervention (see *Appendix F: BSF*)

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Henock Gezahegn <henock@psi.org.et>
Population Services International (PSI)
January 9th 2008
Addis Ababa, Ethiopia

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**Interviewee's Role and Organization**

- Program Manager and Business Strategist for PSI Ethiopia

**Implementation Background**

- PSI is the sole distributor for PUR in Ethiopia (branded Wuha-telel, literally translated "water-clarifier")
- PSI's Wahu-agar is a dilute bleach solution that is produced in a factory in Addis Ababa and provides 1.97ppm free available chlorine (FAC) to twenty liters of water with a single dose (one capful). Translated in this document as Watergaurd, the literal translation of Wahu-agar is "water-partner", implying PSI and their product are the friend of the user, changing the paradigm of the government as the sole provider of water.
- Waterguard is sold with full product cost recovery on a commercial model through a large and defined distribution network, through their own traveling salesmen and to international aid organizations for free distribution in emergencies, with the PSI ETH office setting the price at every step along the way. PSI's costs aside from the physical Waterguard product are funded through USAID and other partnering agencies.
- PSI increases efficiency of distribution by not overstocking retailers, using a rule of stocking to a maximum of 1.5 times the rotation volume per month (see G-Lab Report Appendix J).

**Training**

- Does community trainings with materials included in *Appendix G: PSI Participatory Hygiene and Sanitation Training Materials*, which are translated into Somali (not shown) for use in Muslim areas of the Eastern part of Ethiopia
- Trainings are conducted by salespeople
- Includes written and pictorial usage materials on all products, as shown in *Appendix F: PUR and Sodium Hypochlorite Solution Usage Materials*

**Effective and Sustained Use**

- PSI is marketing to change behavior (through increasing awareness and availability), so effective and sustained use metrics are important to them
- TRaC survey is conducted annually to look at behavioral determinants of peoples decisions on whether or not to use the range of PSI's products in order to stem diarrheal disease incidence and the prevalence of worms. The TRaC survey directly measures sustained and "frequent" use of PSI's products, including Waterguard and PUR.

**Monitoring and Evaluation Activities**

- PSI does not do household monitoring. This seems to be the norm among promoters of consumable HWTS products.
- PSI monitors through distribution channels in order to gauge complaints and problems with the product
- PSI monitors batch # and expiration date by tracking their stock in order to know their distribution/find the efficient outlets as well as to allow for product recall.
- PSI is currently using 1 year expiration in order to achieve critical rotation in the early stages of promotion, but PSI has convinced the CDC to extend Waterguard's expiration to 18 months, and is attempting to extend to 28 months as only a 5% decrease in the 1.5% hypochlorite solution is noticed within the 28 month timeframe because of addition of 0.1% NaOH (pH 11.9 stabilizes HOCl)
- PSI undertook a rapid assessment in the form of TRaC survey in 2006. From this survey, they can judge which behavioral constructs are determinant to the use of the product using segmentation tables and user/non-user ratios so that they can prioritize their marketing activities. One main finding of the TRaC survey is that self-efficacy and social norms are the largest determinant of purchasing and using PSI's various health products.
- PSI uses TRaC to judge social capitol, which is the capacity to change behavior: how often do users talk about the product? →Found to be more often in urban. Do users feel that they know how to use the product? Do they believe the product is good? Do they recommend it to their friends?
- PSI does not conduct health impact studies because effects of SWS, PUR, ORS and bed nets are already proven and documented

**Materials Collected**

- PHAST-style Watergaurd Training Materials → See *Appendix G*
- Gov. of ETH 2006 Rapid Assessment of Drinking Water Quality (RADWQ) (hard copy and electronic)
- 2005 MCH PSI demographics questionnaire
- PUR Packet branded and printed in Amharic by PSI

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Menassie Kifle – EtMedix, Program Manager
Kassahun Birru- Medentech, Africa Representative located in Addis
January 10th 2008
Addis Ababa, Ethiopia

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**Implementation Background**

- Starting in 2008, EtMedix, an established pharmaceutical distributor in Addis Ababa will repackage Aquatabs into boxes with the name EtMedix and sell to pharmacies, retailers, kiosks as a wholesaler as well as to NGOs for emergency use on a commercial basis, insuring full cost recovery for marketing, management and product
- Both businessmen interviewed had a limited understanding of how the product worked, to the point that they were conjecturing its advantages over other chlorine products and could not recommend appropriate usage procedures outside that on the existing packaging

**Training**

- None other than what is written on Aquatabs packaging (explained in *Aquatabs Effective Use* write-up)

**Effective and Sustained Use**

- EtMedix intends to market Aquatabs as a lifestyle product to promote disease prevention as well as to get government approval and co-promotion before breaking into the emergency market, in order to help with sustained use

**Monitoring and Evaluation Activities**

- None planned at outset of product launch
- No formal process to capture customer information
- Reliance on supply chain stakeholders for post sales services including customer complaints and customer service etc.
- Intended indicator: "Average number of customer complaints per customer." Although without the stated intention of monitoring customers, this metric might actually be the number of complaints per sleeve of Aquatabs sold, or some variation therein.
- Users are not going to be monitored

**Materials Collected**

- Preliminary market survey results

Gladys Inzofu <ginzofu@yahoo.com>
Oxfam
January 10th 2008
Addis Ababa, Ethiopia

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**Interviewee's Role and Organization**

- Consultant brought in to evaluate Oxfam's response to acute watery diarrhea (AWD, aka cholera) emergency outbreak in the Southern Nations, Nationalities, and People's Region (SNNPR) of Ethiopia, December, 2007.

**Implementation Background**

- Oxfam distributed Waterguard and PUR to communities hit by cholera in late 2007 for three months.
- Similar to UNICEF's responses, Inzofu found that the community's dependence and trust in the government for provision of water and government of Ethiopia not promoting POU as a permanent solution to celan water greatly hampered sustained use of the product following emergency distribution
- She claims that emergency implementation hampers the private sector implementation by changing user perception to that of only being needed in emergency. Similarly, free distribution makes users reluctant to pay for the products following the emergency.

**Effective and Sustained Use**

- By the end of 3 months of handing out PUR/Waterguard and the winding down of the emergency phase, Oxfam switched to source treatment because they found hoarding/disuse of the products in the home
- Unable to monitor household use effectively, so switched policy to that which they could monitor more easily (microbial water quality testing), yet did not create a safe solution either way in the home due mainly to recontamination.
- Although emergency was never declared by government, initial acceptance of PUR and Watergaurd was high due to visible health improvement and trainings. This was reversed once the tangible health impacts (death due to AWD) subsided and community was no longer in "emergency" situation, with Oxfam moving to development phase. People rejected that they were unsafe once the cholera died down and no effective exit strategy for the products was present. Thus, use was discontinued despite Oxfam still handing them out.
- AWD = problem, POU = solution; daily life ≠ problem, POU ≠ solution; It may take a generation of education and awareness to change belief and behavior systems.

**Monitoring and Evaluation Activities**

- Claims that evaluating usage post emergency is not feasible due to budgeting and timeline constraints

Jesse Jones Agbanyo – Product / General Manager
Ebenezer Aidoo – Sales and Marketing Executive
Precision dx (Sole distributor for Medentech in Ghana)
January 15th 2008
Accra, Ghana

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**Interviewee's Role and Organization**

- Both Jesse and Ebenezer joined Precision in 2007 to work on the launch of Aquatabs, when sole licensing of Aquatabs was granted by Medentech to Precision in Ghana
- Precision is now Medentech's partner in Ghana and will take over all importation and distribution of Aquatabs, as well as handling secondary distributors such as New Energy in Tamale. Their official launch is scheduled for February, 2008.

**Implementation Background**

- Precision's first business was the distribution of mosquito nets, which started in 2006
- Medentech's partnership with the Ghanaian government and AED has helped significantly to build awareness
- This partnership has supplemented Precision's marketing and training costs
- Government endorsements help significantly
- Precision also partners with Guiness Ghana for emergency relief
- Precision has special prices for NGOs
- Similar to at EtMedix in Addis, the businessmen at Precision had little technical knowledge of the Aquatab product(e.g., all parties had a limited understanding of free available chlorine and the differences between NaDDP HOCl), but had investigated the success of Aquatabs in other African markets (e.g., Kenya) and were astute businessmen.

**Training**

- Aquatabs/Medentech has partnered with the USAID Academy for Educational Development (AED) to help develop educational materials
    - This partnership was initiated by Kevin O'Callaghan because it was essential for Aquatabs success
- Launching in Cape Coast first in early 2008, piggybacking on the training of 600 community health volunteers by the government and AED. Precision plans to specifically train these volunteers on use of the Aquatabs at the same time

**Effective and Sustained Use**

- Plans to work with AED to monitor usage, yet has no specifics at this time.

**Monitoring and Evaluation Activities**

- Similar to other consumable social/commercial marketing programs, Ebenezer did a willingness to pay (WTP) study at outset of program, and concluded that 5 pesuis/67mg Aquatab was reasonable. Thus, he set the price per tab at 4 pesuis (~ $0.04). It was unclear how they intend to monitor the WTP once the product hits the streets.
- Household monitoring will not likely be part of their program. The author did not hear them say that monitoring is part of the budget

**Materials Collected**

- N-193 Hardcopy of Initial Market Survey in June 2007
- Sleeve of Aquatabs, labeled with instructions and Precision dx's name (directions written out in Usage section of *Aquatabs Effective Use*)

Abaazan Peter Adagwine, Shak Ibrahim, Peter Alhassan
Pure Home Water
January 2008
Tamale and Upper East Region, Ghana

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**Interviewee's Role and Organization**

- Sales representatives and multi-faceted employees of Pure Home Water (PHW), a social enterprise and legally registered non-profit organization based in Tamale, Ghana founded in 2005 by Susan Murcott, with local partners

**Implementation Background**

Three implementation models:

- Salespeople go directly into targeted communities and provide a demonstration and training of the ceramic water purifier locally branded as the *Kosim* filter. After a community liaison collects money from community members, PHW delivers filters to households with appropriate training in house, and make a $1 US on each filter sold
- Emergency distribution of filters in Upper East (UE) Region to flood-affected victims (FAVs) under UNICEF funding.
- Retail sales through shops in district capitols of Tamale (Northern Region) and Bolgatanga (Upper East), with new retail operations intended also in Wa (Upper West).

**Training**

- Distributes a poster relating health to clean water to proper and consistent use of the *Kosim* to most users
- Group training to FAVs in UE by salesman, using posters and engaging group participation
- Community demonstrations and training as part of first visit to new communities

**Effective and Sustained Use**

- Kate Clopeck's survey of PHW users for a total of 221 surveys in 28 villages in January 2008 specifically targeted "sustained use"
- See more specifics in *Appendix C: Household Monitoring Reports*

**Monitoring and Evaluation Activities**

- Many of Murcott's student projects through MIT have helped to boost monitoring and reporting capabilities of PHW staff, whose responsibilities focus on sales and administration
- Salespeople do a good job keeping in touch with users in various communities (from what I saw), but demand for new *Kosim* filters cannot be met at key times (i.e., following the arvest, due to manufacturing constraints and a large priority order from UNICEF in January 2008), limiting the ability of PHW to

reach communities in Northern Region in the first half of 2008 and making salespeople not meet their projected deliveries to communities

- community volunteers work with PHW salesmen to gather money, hold community meetings, install and keep in touch with users of the filter in their community after installation

**Field Visit Notes**

- Author accompanied Kate Clopeck in one day of her surveying, with "Monitoring Observations and Water Quality Results" written up in *Appendix C: Household Monitoring Reports*
- Author went with Shak and Abaazzan to the Upper East Region for three days to distribute filters for the UNICEF flood relief contract; did some monitoring while there, and reported on this under "Monitoring Observations" in *Appendix C*

**Materials Collected**

Murcott, S. (2005). "Behavioral and financial targets behavioral and financial targets in implementing, scaling up, in implementing, scaling up, monitoring and evaluating monitoring and evaluating household water treatment household water treatment and safe storage technologies and safe storage technologies". Annual Meeting of International Network to Promote HWTS, Quito, Ecuador.

Murcott, S. (2006). "Implementation, Critical Factors and Challenges to Scale-Up of Household Drinking Water Treatment and Safe Storage Systems." Background Paper on HWTS for the Electronic Conference May 12-22, 2006, Hosted by USAID / Hygiene Improvement Project (HIP).

Murcott, S. (2007) "Guinea Worm Cloth Filter: Household Water Treatment and Safe Storage Product and Implementation Fact Sheet." http://stellar.mit.edu/S/project/hwts-network/materials.html#topic3/

Pure Home Water-Ghana, (2008) "Ceramic Pot ("Kosim") Filter Training Manual." http://stellar.mit.edu/S/project/hwts-network/materials.html#topic6

| | | |
|---|---|---|
| Mumuni K. Osman | Jim Niquette | Carl Allen |
| International Aid | GWEP, Carter Center | Peace Corps |
| January 24th 2008 | January 25th 2008 | January 2008 |
| Tamale, Ghana | Tamale, Ghana | Tamale, Ghana |

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**Interviewee's Role and Organization**

- Mumuni is the Program Manager (Country Water Initiative) for International Aid in Ghana as well as the leader of Watersites, his Ghanaian consultancy to NGOs in the water and sanitation sector
- Includes info from an informal lunch meeting with Jim Niquette, Resident Technical Advisor of the Guinea Worm Eradication Program (GWEP) based in Tamale, on behalf of the Carter Center, January 25th 2008
- Includes info from conversations with Carl Allen, Peace Corps Volunteer in Tamale who helped with installing the filters and liaison to the affected communities

**Implementation Background**

- International Aid partnered/hired Mumuni to install a large number (2250 were delivered to Accra in a container in 2007) of the HydrAid cylindrical plastic biosand filters (BSFs) that are manufactured in the US; in 2006, Mumuni went to Aquinas College in Michigan for a week long training held by Dr. David Manz, the designer of the original BSF
- Mumuni started implementation in Kpanvo, near Tamale, Ghana with 100 BSFs in partnership with the Carter Center and the voluntary assistance of Carl Allen
- International Aid's intent was to give these original 2000+ BSFs away for free to partner organizations while the partner agency was left to handle the implementation in their active communities
- Niquette says that this was not understood by the Carter Center when joining on, and the policies of the Carter Center do not allow them to collaborate/partner on this basis, so he can not get funding for implementation or monitoring and Carter Center's involvement is finished

**Training**

- Adventist Development and Relief Association (ADRA), a faith-based organization operating in Northern Region Ghana, was to do a training of biosand construction in February, 2008 prior to implementing 500 filters after collecting baseline survey in 5 communities in which they currently operate. ADRA will bear implementation costs minus hardware, but will eventually be on their own for monitoring. Mumuni hopes to use the 500 filter users for an International-Aid funded health impact study under the direction of Dr. Mark Sobsey of the University of North Carolina.
- Hands out CAWST BSF usage poster, included in *Appendix F: BSF Usage Instructions*

**Effective and Sustained Use**

- Post implementation in Kpanvo, Mumuni is currently collecting money from BSF users to show investment in BSF as well as to provide users with jerry cans in order to encourage safe storage. These actions, although necessary to effective use of the BSF and Safe Storage, were not put into the action plan or funding upfront and seem like an afterthought.

**Monitoring and Evaluation Activities**

- Mumuni claims to have "given" the Carter Center 100 filters, and helped install them and test them with the understanding that they would do monitoring of the systems once installed
- Carter Center's GWEP community volunteer for Kpanvo was enlisted to help monitor the BSF use while conducting household visits in the community, although Mumuni claimed that his assistance was not necessary and that Mumuni himself would be able to establish community-based assistance for his program on his own, if needed.
- Carl Allen and Jim Niquette provided physical assistance for training and installing the filters and have not been able to do much follow up. KCarl completed his Peace Corps assignment and left Ghana as of April 2008.
- Mumuni did microbial testing the day after installation, and got inconsistent results from the filters (this information was not provided to the author, although the testing was premature as the *schmutzdecke* would not have developed). He has no more money to spend on water quality testing. He was interested to see the microbial results of Izumi Kikkawa and Sophie Walewijk.
- Mumuni self-monitored the program following implementation and witnessed "appreciation" and neighbors using the filters too.

**Field Visit Notes**

- The MIT-Pure Home Water-Peace Corps team, including Susan Murcott, Peter Alhassan, Sophie Walewijk, Izumi Kikkawa, Mike Dreyfuss, the GWEP volunteer and the author conducted surveys in 7 Kpanvo households and took water quality samples in 30 households (see Kikkawa, p.98-101). The surveys were especially useful in comparing user-acceptability of the BSF with the Pure Home Water *Kosim* ceramic pot filter that was already in use in many of the households, apparently unbeknown to the BSF implementers at the time of installation.
- Monitoring observations, water quality data w, and pictures for 7 of the households using both *Kosim* and BSF has been written up in *Appendix C: Household Monitoring Reporting*

**Materials Collected**

- Flowrate analysis of "Sibi" BSFs in August and September 2007
- Household questionnaire on BSF usage with answers from visits (Internal report)

Atsu Titiati
Enterprise Works
January 29th 2008
Cantonments, Accra, Ghana

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**Interviewee's Role and Organization**

- Titiati is the general manager of Enterprise Works, a Washington D.C.-based non-profit supporting the enterprise/market approach to development with local offices in many poor and middle-income countries.

**Implementation Background**

- In 2006, Enterprise Works received funding for an initial 5000 ceramic pot filters from Diageo Foundation PLC UK; Guinness Ghana followed up with 4000 more filters for flood affected victims; 1000 additional filters were donated from an anonymous donor at Guinness UK (parent company to Diageo)
- CWP is branded the *Adokuro* filter, a Twi word meaning the clean, naturally filtered water that comes from under trees in the forest
- Enterprise Works is a customer of Ceramica Tamakloe, buying and distributing exactly the same product (minus the taps) as Pure Home Water in Tamale
- At first Enterprise Works was selling with full cost recovery to the funder, but when sales were too slow, Diageo asked Titiati to sell at 50% subsidy of the original selling price of $5 US.

**Choosing the communities**

- Titiati does not target communities with very turbid water sources for the use of the ceramic filter, as he does not want the customers to be dissatisfied with insufficient flow rates
- Once a community has been identified (generally a peri-urban area on the outskirts of Accra), a community meeting is organized with the help of the assembly man or chief
- At the meeting, Enterprise Works introduces the filter and tells of its importance to health. They then appoint a retailer within the community (usually someone with a shop, often a trusted community figure chosen by chief or the chief himself, but someone who agrees to do household trainings to end users and health promotion (as trained by Enterprise Works), and provided with training material to hand out to users (same as Potters for Peace Materials in *Appendix F: Ceramic Pot Filter Usage Instructions*)
- Sammy, Enterprise Works' field liaison for the community visited by the author chose to distribute filters in the community because it was close to the road and to Accra. He originally arranged meetings through the chief to streamline things

**Training**

- Titiati claims that the CWP requires a lot of health education, through both the retailer and promoter; need to teach health impact for people to want to afford 15 Cedis (~$15 US) for the filter (a profitable cost, given high cost from Tamakloe manufacturer)
- (PFP) The Potters for Peace training materials distributed by Enterprise Works claim 3 a year life span for the filter because colloidal silver wears out (see *Appendix F: Ceramic Pot Filter Usage Instructions*)
- Supplied a brush for cleaning in beginning of program, but could only recommend correct brush to be used when funds fell short later in program

**Effective and Sustained Use**

- Enterprise Works undertook testing the flowrate of each batch of filters, as Tamakloe was not doing this (although required to by production protocol). Titiati was displeased with the slow production and inconsistent quality.

**Monitoring and Evaluation Activities**

- Monitoring is a deliverable for Diageo (funder) from Enterprise Works
- Retailers take 3$ of the 5$ selling cost, and are now buying straight from CT (some confusion noticed in the field about who was supposed to place order, Enterprise Works or retailer)
- Retailer keeps a record of users for monitoring purposes
- Titiati said that "the generation for the pot filter is passing now," and, unhappy with the performance of the filter (both treatment and sales-based), he plans not to sell any more filters, and is looking for new technologies to promote, such as the Tulip ceramic vacuum filter(?); Diageo contract finished in November, 2007, and there is no more money in the budget for M&E, but retailers are expected to keep in touch with consumers in their communities, and to report broken pots or need for new pots such that Enterprise Works can order more filter from Tamakloe

**Field Visit Notes**

- Field visits to two villages in a peri-urban area outside of Accra, monitoring 6 households in total, were conducted on January 29, with Monitoring Observations written up in *Appendix F: Household Monitoring Reports*

**Materials Collected**

- Hardcopy of CWP promotional fliers (Rivera format) and training materials

## *Appendix C: Household Monitoring Reports*



These reports give an overview of the household monitoring visits conducted in January, 2008. Refer to *Appendix B: Field Interviews* for background information on the implementing agencies and their specific projects.

Kale Heywet Church biosand filter users
Filtino and Gondogorba communities, near Debre Zeyt town, Oromia region, Ethiopia
January 5th and 12th 2008

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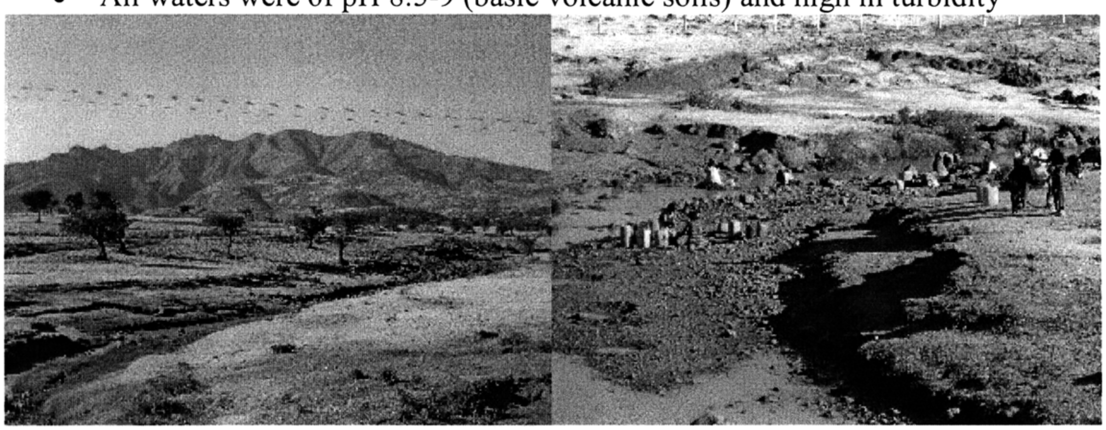
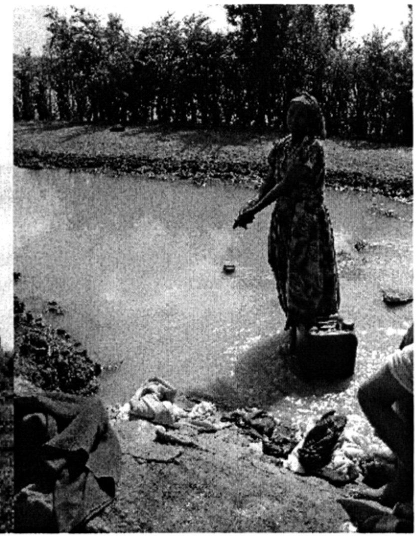
**Field Site Overview**

- The community of Filtino received many of their biosand filters from Kale Heywet Church (KHC) and Samaritan's Purse's original pilot scale implementation in 1999, with filters working well since then and consistent community involvement of the technicians at the nearby factory/field office for the program if any problems are reported, as has been rare over the past 9 years of use; Many of the users had blue plastic "safe storage" containers with lids that had holes in them in order to catch the treated water, as handed out by KHC with their scaled up implementation since 2003
- The sight is located a few hours east of Addis Ababa, in the Ethiopian highlands, within the Oromia region of Ethiopia that surrounds Addis Ababa. A largely denuded countryside, the rivers that serve as water sources for residents of Gondogorba, the first community visited, neighboring Filtino, flow with very turbid water (up to 1000 TU measured in-house). This area is home to small-scale agriculturalists who generally do not own their own land, as can be witnessed from the large flower farm adjacent to the community, from whose irrigation ditch the women of Filtino fetch their water.
- The author went to sight with different KHC employed technicians on each of the two Saturdays, reaching the villages with a ride in the KHC field vehicle. Because Saturday is market day, many houses with BSFs were empty, and often children answered the questions in lieu of their mothers, the main caretakers for the BSF who were away at the market.
- All waters were of pH 8.5-9 (basic volcanic soils) and high in turbidity



Note the holes dug in the riverbank for pre-filtering the turbid water. Use of such pre-filtering by HH1 resulted in collected water of significantly lower turbidity and pathogen load as well as correspondingly long filter run times in between cleaning.



This irrigation ditch serves as the sole source for Filtino Village=250NTU, 20°C, flowing

**Results**

Observational Monitoring Results for Kale Heywet Church Biosand Users

| HH | Pre-treat | Days since Cleaning | Cleaning Method | Storage clean? | Storage cover? | Handling | Dist to Source (m) | Use (Liter /day) | Proper Use? * |
|---|---|---|---|---|---|---|---|---|---|
| HH1 | Riverbed filtation | 120, not needed! | Stir w/ finger** | Clean | Yes | Clean cup | >100 | 60-120 | Yes |
| HH2 | None | 60, unable w/child | ? | No | No | Dirty hands in storage | >100 | ? | No |
| HH3 | None | 7 | Stir w/ finger** | Clean | Yes | Clean cup | 100 | 100 | Yes |
| HH4 | None | 7 | Remove sand | Clean | No | Good | <100 | 50 | No |
| HH5 | None | 7 | Stir w/ finger** | Clean | No | Good | <50 | >50 | Yes |
| HH6 | None | 14 | Remove sand | Clean | No | w/hand | 100? | 100 | No |
| HH7 | None | 7 | Remove sand | Very bad | No | Wash w/ Dirty water, use hand | >100 | 50? | No |

*Proper Use is defined by passing the main components use as labeled in the *Observational Monitoring* section of the *Biosand Filter Effective Use* write-up.

**Stir w/ finger refers to a wet harrowing cleaning method involving stirring the top few centimeters of sand with the finger down to the second knuckle and then scooping out dirty water, as promoted by KHC and Samaritan's Purse.

**Water Quality Methods:** In order to look at treatment efficiency and likelihood of diarrheal disease to the user, water was tested for bacterial quality. The 3M Petrifilm allows for counts of greater than 1 colony forming unit (CFU) per ml (which is equivalent to ≥100 CFU per 100 ml of both *E.coli* and total heterotrophic coliforms) by the simple addition of 1 ml of sample to the disposable film plate under sterile conditions followed by incubation. All samples were taken in Whirlpak bags with sodium thiosulphate, kept on ice for <6 hours before addition to the Petrifilms and incubated at 36±2 degrees Celsius for 24 hours, as called for in the Petrifilm protocol. The author carried a portable laboratory setup including a phase-change incubator designed by Amy Smith of MIT. This incubator required reheating after 12 hours of night time ambient temperatures in order to achieve the stated sustained temperature range.

Water Quality Results

| | | | **Unfiltered** | | | **Treated** | | **Storage** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HH | Date | Flow Rate L/hr | Turb TU | *E.coli/* 100ml | T.coli/ 100ml | *E.coli/* 100ml | T.coli/ 100ml | *E.coli/* 100ml | T.coli/ 100ml | Turb TU |
| HH1 | 1/5/08 | | <5* | 500 | 2000 | | | <100 | 100 | <5* |
| HH2 | 1/5/08 | | 1000 | 2000 | 14000 | | | <100 | 25000 | <5* |
| HH3 | 1/5/08 | | 500 | 500 | 14000 | <100 | <100 | <100 | 1400 | <5* |
| HH4 | 1/12/08 | 12 | | <100 | 20000 | <100 | <100 | 700 | 3600 | |
| HH5 | 1/12/08 | 12 | | 5000 | 18000 | 100 | 6200 | 600 | 10400 | |
| HH3 | 1/12/08 | 30 | | <100 | 18000 | <100 | <100 | <100 | 2400 | |
| HH6 | 1/12/08 | 6 | 200 | 5000 | 14000 | <100 | 700 | 1000 | 1900 | -- |
| HH7 | 1/12/08 | 7 | | 1000 | 29000 | <100 | 1900 | 100 | 2600 | |

*visually clear; assumed turbidity of <5NTU was not measured due to minimal amount of sample available
** Source for HH3-HH8 was an open, flowing irrigation ditch of Turbidity >500TU possessing 4000 *E.coli*/100ml and 22000 T.coli/100ml.

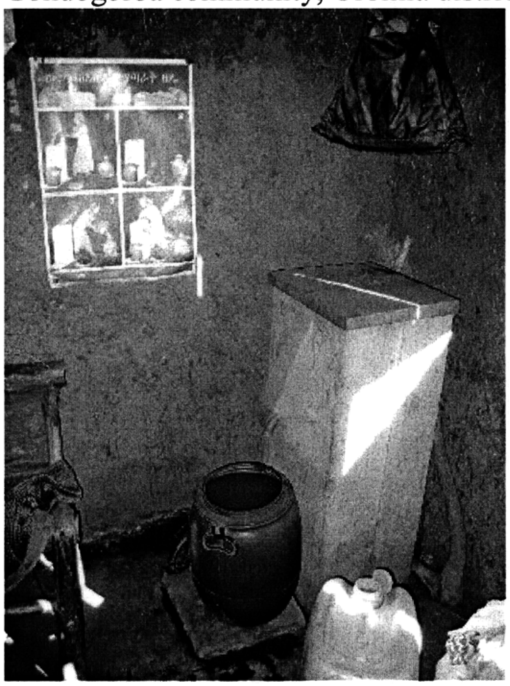
Treatment and Effective Use through Water Quality Monitoring for Kale Heywet Church Biosand Filter Users

| | **Removal via Treatment** | | | | **Actual Removal via Storage** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| HH | *E.coli* % | T.coli % | T.coli Log | Absolute Risk* | *E.coli* % | T.coli % | T.coli log | Absolute Risk* | Contam via Storage | Effe ctive Use? |
| HH1 | - | - | - | Low/int | >80 | 95 | 1.3 | Low/int | No | ?** |
| HH2 | - | - | - | Low/int | >95 | -80 | -0.3 | Low/int | ? | No |
| HH3 | >80 | 99.3 | 2.2 | Low/int | >80 | 90 | 1.0 | Low/int | No | ?** |
| HH4 | - | 99.5 | 2.3 | Low/int | recontam | 80 | 0.7 | High | Yes | No |
| HH5 | 98 | 65 | 0.5 | High | 88 | 40 | 0.2 | High | Yes | No |
| HH3 | - | 99.5 | 2.3 | Low/int | - | 85 | 0.9 | Low/int | No | ?** |
| HH6 | 98 | 95 | 1.3 | Low/int | 80 | 85 | 0.9 | High | Yes | No |
| HH7 | 90 | 93 | 1.2 | Low/int | 90 | 90 | 1.0 | High | Yes | No |

* Risk levels based on WHO *E.coli* risk categories (WHO, 1997). Presence of *E.coli* on the 3M Petrifilm indicates high risk water with >100 *E.coli*/100ml.
** ? Question marks indicate that the level of detection for *E.coli* of the Petrifilm method is above that needed to discern low risk from microbial contamination and thus Effective Use was not judged for these results.

- Despite claims by technicians and the program manager Tsegaye of retraining all users to maintain the filter by stirring the top sand layer down to the second knuckle, some users were still removing sand to clean the filter. Retraining was needed due to losses of sand incurred by cleaning method which involves the removal of sand during the pilot implementation of 1999.

***Household # 1***
1/5/08
Gondogorba community, Oromia district, Ethiopia



Note the elevated and dedicated safe storage unit, separate small-mouthed jerrycan for fetching water, tile floor, and visible presentation of KHC's maintenance poster although they are missing a suitable top for the storage (top was in place when I walked in, but has a hole for the dripping of the filtered water and was not very clean). This first household was a good example of positive Effective Use in terms of Observational Monitoring.

**Name and status of person interviewed**
Mother of a family of four who is the primary water fetcher and caretaker of BSF, which she has had for over 5 years

**Household visit notes**

- 30 minutes carrying time from river source
- Does she like it? "It takes whatever dirt we bring" and is adamant about lack of diarrhea in her family of four
- Corrugated zinc plated iron roofing (CGI) and dirt/tile floor
- Her pit latrine had "no flies" and was thus clean, as part of KHCs intervention was to provide safe concrete bases to improve the pit latrines
- Mother was uncomfortable, especially at the beginning

**Monitoring Observation**

- See notes on picture above
- Storage clean, but not properly covered
- Claims that she uses BSF treated water for all uses (except washing, which can be done with riverbed-filtered water) during the wet season, when the turbidity is higher; preferable for cooking because njera (fermented unleavened bread) gets better holes in it with BSF water

- Mother claims consistent use: will not drink non-filtered water; family will either bring their own in water bottles, or drink before and after going to market/work; she worries about sickness with non-filtered water
- Filters 2-4 X 30L jerrycans per day; neighbors use the filtered water too
- Claims that is takes 30 minutes for 20L to filter; she likes the slow flow rate (makes the water clear and cold→advantage of concrete biosand)
- Filter has not been cleaned in last 4-5 months; filter tends to block up during heavy rains (more turbid water, using the filtered water for all uses)
- She pre-filters at the source by digging into the riverbed and pulling water from there, bringing the water down from 1000NTU to nearly clear!
- Brought clean, dry cups when the technician was prompted to ask for a glass of water

**Water Quality Monitoring**

- Clearish influent from effective riverbed filtration at source; <5NTU effluent
- Good flowrate (not measured)
- Effectively removed *E.coli,* within the limits of detection of 3M Petrifilm (<100 *E.coli* per 100ml); best stored-water quality surveyed, as effective use protocol were carefully followed by this user

**Effective Use Assessment**

- Most effective use witnessed of all the KHC filters, especially because of prefiltering through the riverbank

*Household # 2*
1/5/08
Gondogorba community, Oromia district, Ethiopia

**Name and status of person interviewed**

- Mother, sole caretaker for the BSF

**Household visit notes**

- She admits that she has not been able to upkeep her BSF or clean her storage unit as she is a young mother with two small children, one newly born. She thus relies on her nieces/neighbor's children to get water, and it is too much to ask of them to filter it through the riverbank, as she has been trained. → BSF presented too much maintenance for a mother with a newborn and a turbid water source to keep up with; she knows it
- markedly poorer living conditions than HH1, her neighbor
- Chicken was inside, with access to the open storage unit
- Corrugated iron (CGI) roof, tile floor
- I did not run the interview very long as she was recently pregnant and I felt that I was invading her privacy, with her husband away.

**Monitoring Observation**

- Storage unit very dirty with the top off and a dirty cup fallen inside
- woman put her hands (dirty from handling the baby) into the storage to pull out the cup, and fetched water that way
- I did not witness flowrate, as there was not enough water around to filter
- Raw water in storage: 1000+TU
- Not cleaned in a long while

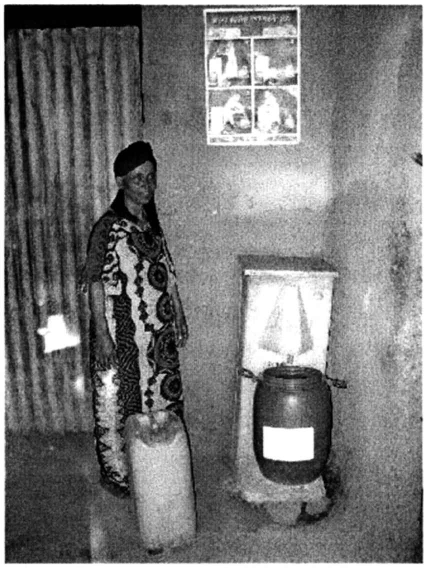
**Water Quality Monitoring**

- Despite all signs of neglect and improper water handling, the water in storage was of low/moderate risk (<100 *E.coli* per 100ml), with effective treatment of turbidity (<5NTU)

**Effective Use Assessment**

- Failed the monitoring due to a lack of ability to properly maintain the system, yet still managed to create a moderate risk water with low turbidity

*Household # 3*



1/5/08; revisited and retested 1/12/08 for confirmation
Filtino community, Oromia district, Ethiopia

Notes from Picture: Shares positive hygiene and observational monitoring characteristics as HH1, as well as conditions suitable to minimal contamination. Note the elevated and dedicated safe storage unit, separate small mouthed clean jerrycan for fetching water, tile floor, and visible presentation of KHC's maintenance poster and sticker although they are missing a suitable top for the storage. The user was rightfully proud of her BSF, as was her neighbor, who was very helpful on the second interview as Ashetee was at the market.

**Name and status of person interviewed**

Ashetee, the mother of the household and main caretaker of the BSF, as picture above.

**Household visit notes**

- Has had the filter 8 years, likes it; she and her husband were happy users of the BSF and happy and proud to share info on it
- Appreciates that it was free, but would pay *any amount* to buy one, even 1000birr (110$) when prompted
- No animals in house; CGI roof, dirt floor
- 7 people drink from the filter
- They prefer BSF to chlorination (better taste and cool), and does not desire a borehole because she has the BSF

**Monitoring Observation**

- Uncovered storage
- No pre-treatment from irrigation-ditch source
- Fetches 4X25 liters every day from source 100m away
- With 500TU influent from the source, she cleans the filter weekly
- On second testing, flowing at 30 L/hour with just an inch of water above the diffuser→fast; user does not know when last time it was cleaned

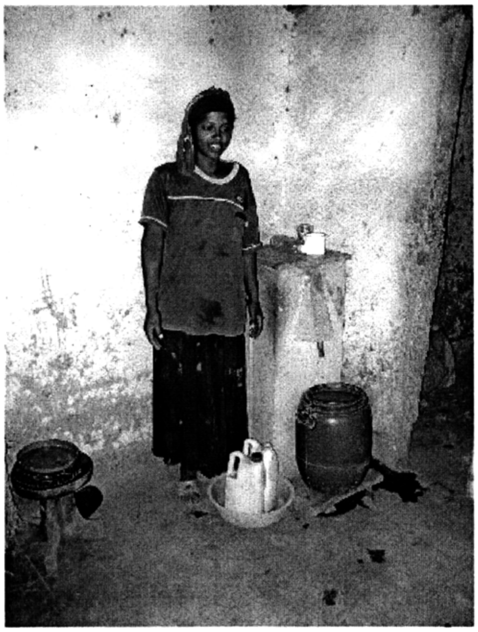
**Water Quality Monitoring**

- Total coliform (TC) recontamination in storage as compared to directly treated water, but absolute level of risk low/moderate (<100 *E.coli* per 100ml)
- Same treatment and storage characteristics during second monitoring round, but influent was only moderate risk during second week

**Effective Use Assessment**

- effective on both fronts, although could have used a top on the storage in order to eliminate the minor recontamination noticed in storage

***Household # 4***
1/12/08



Filtino community, Oromia district, Ethiopia

**Name and status of person interviewed**

- Fanu Gareshu, mother of the household and primary caretaker of the BSF

**Household visit notes**

- Household *never* has diarrhea
- CGI roof, tiled floor
- Chickens inside

**Monitoring Observation**

- Very happy with filter, shows her appreciation to the technician as he is part of KHC
- Treats 50L/day
- Only drinks from BSF, shows bottle used for traveling and carrying water
- Lid on BSF, and diffuser in place, but diffuser has sedimented sludge on it
- Missing lid for storage and dips cup in it to fetch us a glass of water but is careful not to get her hand wet
- Cleans the filter every week by removing the top layer of sand to a bucket, uses filtered water to stir and rinse the sand, pours off water, replaces sand, and uses the water right away
- Storage unit raised off the ground

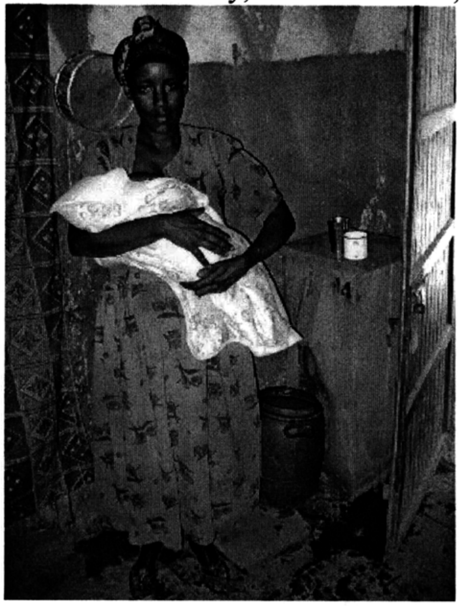
**Water Quality Monitoring**

- With filter reservoir filled, flowrate=12L/hour
- Effective reduction in turbidity (<5NTU) as well as *E.coli* as far as can be known (<100/100ml)
- Large recontamination in the storage unit→need to ask: how often do you clean the storage?

**Effective Use Assessment**

- While observed use characteristics do not set her apart from HH3 in any significant way, she treats her water well with the BSF but suffers massive recontamination from unsafe storage practices→how can usage characteristics be more refined?

***Household # 5***
1/12/08
Filtino community, Oromia district, Ethiopia



**Name and status of person interviewed**

- Zenagu Gutama, mother of the household and primary caretaker for BSF

**Household visit notes**

- BSF located in dark empty room behind door, and has been in use for 7 years
- CGI roof with pigeons, tile floor
- Family of 4, no diarrhea this week

**Monitoring Observation**

- BSF treated water used for drinking, cooking, and washing of bodies, but not for washing clothes
- Storage is raised off of the ground but has no cover
- Cleans every week, by stirring the sand surface and scooping off the water, as retrained

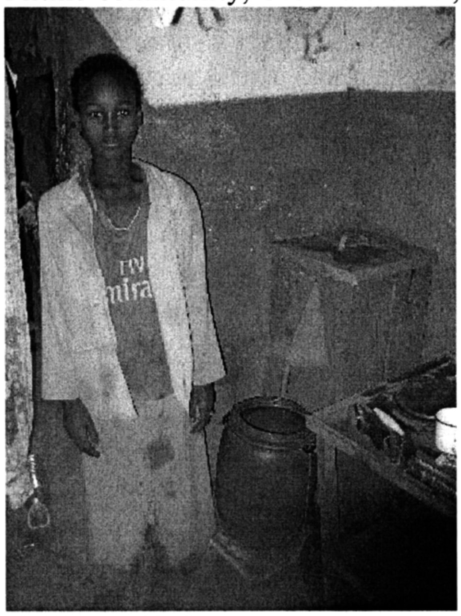
**Water Quality Monitoring**

- 12L/hr, but not sure how full the filter was at time of measurement
- Treated water had at least 100 *E.coli*/100ml, and stored water had 600 *E.coli*/100ml= not properly treated or stored

**Effective Use Assessment**

- Ineffective treatment and storage
- Need to cover those storage units and handle properly
- Do not know why the filter did not work→should have asked when was last time cleaned, but forgot

*Household # 6*
1/12/08
Filtino community, Oromia district, Ethiopia



**Name and status of person interviewed**

- Pre-adolescent daughter who fetches water, fills and knows how to operate filter, although her mother generally does the maintenance
- She is very candid and frank and proud, without the pretenses and worries exhibited by the adult interviewees, and can speak a bit of English (educated, unlike her sister)

**Household visit notes**

- BSF serves 8 people in the household
- CGI roof, dirt floor
- In use for 7 years

**Monitoring Observation**

- Storage for unfiltered water is out of the sun
- Storage is raised off of the ground but has no cover, and is almost empty despite actively filtering upon our arrival
- Claims 80 L/day is filtered, yet this would mean constant filtering.
- Not cleaned for at least 2 weeks prior, but cleans every 2-3 weeks or 15 days
- When her mother or father cleanse it, they remove sand for washing, using treated water, like in HH4
- When asked for a glass of water, she brings a seemingly clean ladle that gets dirtied by being upside down on the wet lid of the filter; washes a glass with treated water, and then rubs her hand in it before pouring water

**Water Quality Monitoring**

- When filled to two inches from the top, flowrate=6 L/hr
- 200TU influent, too clean to measure treated water (probably <10NTU)
- Effective treatment (<100 *E.coli* per 100ml), yet very bad recontamination through storage and handling (1000 *E.coli* per 100ml)

**Effective Use Assessment**

- Monitoring observations and water quality assessment both show effective treatment from the BSF, and both show ineffective handling and storage. However, without asking for a glass of water, I would not have noticed the bad handling, as there was little water in an otherwise visibly clean storage unit.

*Household # 7*
1/12/08
Filtino community, Oromia district, Ethiopia

**Name and status of person interviewed**

- Bekelu Kebeda, the mother of the household and caretaker of the BSF

**Household visit notes**

- Markedly poorer and less healthy household than the neighbors I just had visited
- 9 people in family; kwariorsher belly on 3 year old, showing protein deficiency and/or worms, but mother claims no diarrhea

**Monitoring Observation**

- Improper placement of filter (see picture): located in a goat pen, accessible to animals, holes in thatched roof allowed direct sunlight of the filter housing, mud/hay floor with sheep poop surrounding filter
- Hygiene: mother slapped young son away from drinking directly from the tap (she knew it was incorrect, but had not taught the children correctly; conversely, the kid's best bet was to get it straight from the filter, as the storage unit was very dirty.
- This filter was 9 years old, from the pilot distribution when the blue plastic safe storage containers were not in use, and as such, a jerrycan that was identical in wear and dirtiness to the one used to fetch water (claimed they were of separate uses, but I was not convinced), but still dirty, without lid, and open access to animals
- Claim consistent use, that they are "never too far not to drink it"
- Cleaning: removes sand to clean once a week
- Hygiene: when fetching a glass of water, cleaned the cup with unfiltered water and hand before pouring filtered water into it

**Water Quality Monitoring**

- 7L/min flowrate (water level unknown)
- Turbidity: 210TU→10TU: fails the effectiveness test (<5NTU after treatment)
- Inside water temp = 20°C; cool despite direct sunlight
- Seemingly effective microbial treatment (<100 *E.coli* per 100ml), and only 100 *E.coli*/100ml in storage, which fails the test (high risk), but is better than many of the other filters sampled)

**Effective Use Assessment**

- Ineffective observed usage results in adequate treatment without significant recontamination (recontaminates to the level expected by Levy, 2002 in *Safe Storage* section.

Survey conducted by Kate Clopeck concerning sustained use of the *Kosim* ceramic pot filter in the rural villages west of Tamale, Northern Region, Ghana.
Accompanied by author for two days, with PHW salesman Peter Alhassan translating
Pure Home Water
January 17th and 18th 2008

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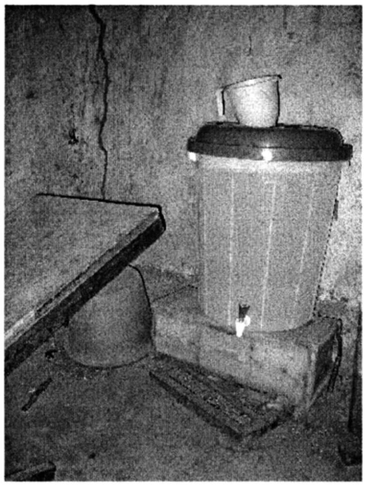
**Synopsis:**
The largest survey of monitored usage done in the field in January and July, 2008 was Kate Clopeck's survey of 221 CWP users associated with Pure Home Water in Northern Region, Ghana. Much was learned from this survey in terms of appropriate survey questions, included in the *Best Practices for field monitoring* of the Results Chapter and *Common threads in household monitoring* of the Discussion Chapter. Although not conclusive for judging Effective Use, Petrifilm analyses of the 56 filters investigated by Kate Clopeck resulted in only one showing of *E.coli*, resulting in a high risk level (as defined by the WHO) for one filter and low/intermediate risk (<100 *E.coli* per 100 ml) for the other 55 samples. The average *total coliform* count of treated water from storage units was 1000 *T.coli* / 100ml. The results of this survey will be formally presented by Clopeck in her thesis and available at http://web.mit.edu/watsan after June 2009.

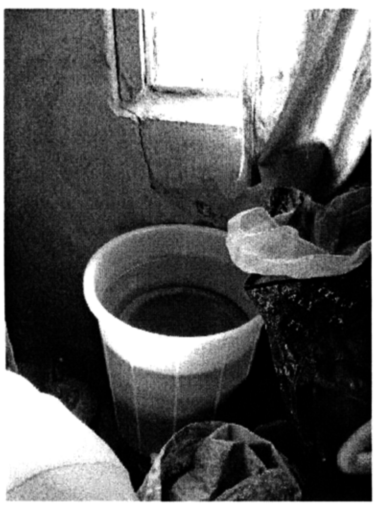
**Field Survey Overview**

- Survey instrument developed by Kate Clopeck is included at the end of these notes
- Water Quality: Of 56 household samples of treated water taken from the taps of the *Kosim* ceramic pot filter, storage units, only one had reportable (200 *E.coli*/100ml) counts of *E.coli* using the Petrifilm method. Thus moderate or low risk was associated with >98% of users. An average of 1000 Total coliforms per 100 ml (range between less than 100 and over 10000 per 100 ml) was found for treated waters. Significant sources of *E.coli* and total coliforms were found from stored untreated waters, indicating reductions through treatment.
- Throughout this survey, prefiltration with the Guinea Worm Eradication Project (GWEP) cloth filter was investigated and almost 100% effective use (proper use, storage, condition, and cleaning as well as knowledge of the Carter Center community volunteer) was witnessed among people also using the *Kosim* filter. Although these cloth filters were inspected by the survey conducters, the question of whether prefiltration occurs on a regular basis was led on by Peter Alhassan and may not have led to truthful answers. Either the Carter Center or Pure Home Water community volunteer for the village led us to the necessary *Kosim* users for surveying as they knew everyone in the village. Carter Center volunteers claimed to do weekly monitoring of the households and inspection of their cloth filters.

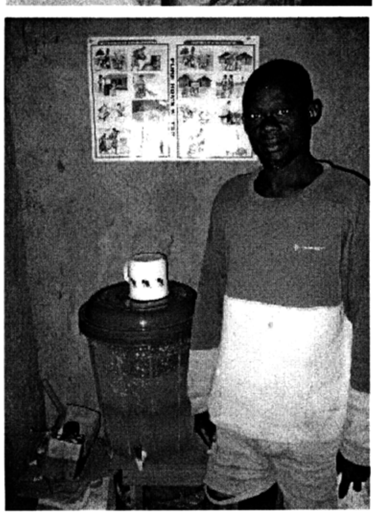


1/18/2008: (House 901-907) In Kpilo village located next to Peter Alhassan's own village, visited on my second day with Kate and Peter, people were not using the filter but were rather using the storage unit for piped water, as piped water happened to be flowing that week.

All of the household samples showed <100CFU/100ml for both *E.coli* and TC, including water directly from the pipe source, water directly stored without filtration, as well as water stored after filtering. I lament that I did not test these water sources for residual chlorination, one likely cause of the high microbial quality witnessed. All of the storage units were very clean, nonetheless. So, no post contamination through storage and/or filtration was noted, and effective use was noted among these households from both monitoring observation and water quality monitoring based on safe storage and hygiene practices. In the homes 901-907, often the filters were not located in proper places, as never letting them touch the ground was explicitly emphasized in PHW trainings (see picture above, left).



In the same community of Kpilo a few houses were found not to have proper knowledge of how to use the filter, including one man who had inherited the filter from his brother and had no knowledge of its intended use as well as one woman who left the filter on the bottom of the storage unit which was full of (piped) water (see picture on left). Although the water was clean and the filter could have provided some minor cooling from this use, improper training and knowledge of this user was suspected.



Pictured to the left is an educated man from the community with the flowing piped water who collaborated with Peter Alhassan to sell/gain support/distribute filters within his community. He had excellent use of his filter (clean cup on top of clean filter, half full of water, stably situated, and displaying the PHW training poster above the filter), especially for the fact that despite the filter being located in the head of household's room, he encouraged his children to use it directly (rare among men, the author observed, who may control of their CWP by locking it their room and using it only themselves).

**Figure 20 GWSC liaison for Kpilo**

In the house of the community liaison (pictured above) who collected user fees for the piped water distributed Kpilo by the Ghana Water and Sewerage Company (GWSC), I saw the bill for the community's piped water on this man's chair, and asked to look at it. The community was charged 83GHC for 126m$^3$ flowing over 20 days. That's about 1.50USD/m$^3$, or .15¢ US cents per liter. Although the man said he is employed to collect 1GHC from each of 98 users in the community every month, the backlogged bill for the community was 1,200GHC (~1200USD), at least a ten month backlog without interest. While people complain of intermittent flow of the prized and trusted pipe-born water in their community, the GWSC is apparently providing it with a large subsidy and without expecting return payment from the community.

*Use* by the man who collects user fees:

- This man used the *Kosim* unit for storage when the pipe was running and for filtration when the surface and other unimproved sources had to be used (I did not witness the dam/stream for this community and cannot comment on when this was used).
- He fills the entire storage unit twice a week
- He dad to fix his tap with a polyethylene bag (pictured on the previous page)
- Likes the look of the filter; sees it as new, clean, expensive, useful
- Does not let his child touch the filter
- Loves the tap!
- He was one of the few people I met who answered that his 3 year old has had diarrhea during the last week

Water Quality Results

| Household Number | Date Collected | Household samples E.coli/100ml | Household samples T.coli/100ml | Method |
|---|---|---|---|---|
| 302 | 1/10/2008 | <100 | 200 | Petrifilm |
| 303 | 1/10/2008 | <100 | 200 | PF |
| 304 | 1/10/2008 | <100 | 1400 | PF |
| 305 | 1/10/2008 | <100 | 10000 | PF |
| 306 | 1/10/2008 | <100 | 500 | PF |
| 307 | 1/10/2008 | <100 | 5800 | PF |
| 308 | 1/10/2008 | 200 | 5600 | PF |
| 309 | 1/10/2008 | <100 | <100 | PF |
| 401 | 1/11/2008 | <100 | 1400 | PF |
| 402 | 1/11/2008 | <100 | 400 | PF |
| 403 | 1/11/2008 | <100 | 10000 | PF |
| 404 | 1/11/2008 | <100 | 100 | PF |
| 405 | 1/11/2008 | <100 | 300 | PF |
| 407 | 1/11/2008 | <100 | 200 | PF |
| 409 | 1/11/2008 | <100 | 100 | PF |
| 410 | 1/11/2008 | <100 | 100 | PF |
| 411 | 1/11/2008 | <100 | <100 | PF |
| 412 | 1/11/2008 | <100 | 500 | PF |

| | | | | |
|---|---|---|---|---|
| 501 | 1/14/2008 | <100 | 100 | PF |
| 502 | 1/14/2008 | <100 | 100 | PF |
| 504 | 1/14/2008 | <100 | <100 | PF |
| 506 | 1/14/2008 | <100 | <100 | PF |
| 507 | 1/14/2008 | <100 | 200 | PF |
| 509 | 1/14/2008 | <100 | 800 | PF |
| 510 | 1/14/2008 | <100 | 2700 | PF |
| 511 | 1/14/2008 | <100 | 7700 | PF |
| 512 | 1/14/2008 | <100 | 3900 | PF |
| 601 | 1/15/2008 | <100 | <100 | PF |
| 603 | 1/15/2008 | <100 | 1200 | PF |
| 605 | 1/15/2008 | <100 | 500 | PF |
| 606 | 1/15/2008 | <100 | <100 | PF |
| 607 | 1/15/2008 | <100 | <100 | PF |
| 608 | 1/15/2008 | <100 | <100 | PF |
| 609 | 1/15/2008 | <100 | <100 | PF |
| 611 | 1/15/2008 | <100 | 100 | PF |
| 612 | 1/15/2008 | <100 | <100 | PF |
| 613 | 1/15/2008 | <100 | <100 | PF |
| 702 | 1/16/2008 | <100 | <100 | PF |
| 706 | 1/16/2008 | <100 | 900 | PF |
| 709 | 1/16/2008 | <100 | <100 | PF |
| 712 | 1/16/2008 | <100 | <100 | PF |
| 801 | 1/17/2008 | <100 | 100 | PF |
| 802 | 1/17/2008 | <100 | <100 | PF |
| 804 | 1/17/2008 | <100 | 100 | PF |
| 805 | 1/17/2008 | <100 | <100 | PF |
| 807 | 1/17/2008 | <100 | 100 | PF |
| 808 | 1/17/2008 | <100 | 200 | PF |
| 809 | 1/17/2008 | <100 | <100 | PF |
| 810 | 1/17/2008 | <100 | <100 | PF |
| 901 | 1/18/2008 | <100 | <100 | PF |
| 902 | 1/18/2008 | <100 | <100 | PF |
| 903 | 1/18/2008 | <100 | <100 | PF |
| 904 | 1/18/2008 | <100 | <100 | PF |
| 905 | 1/18/2008 | <100 | <100 | PF |
| 906 | 1/18/2008 | <100 | <100 | PF |
| 907 | 1/18/2008 | <100 | <100 | PF |
| **Average** | (Arithmetic) | **<100** | **1000** | |

**Addendum: Kate Clopeck's Sustained Use Survey (January, 2008)**
Ghana Household Survey: Sustained Use of the Kosim Filter

Hello, my name is Kate Clopeck, and I am student from MIT in the United States. We are conducting a household survey about the KOSIM filter you purchased from Pure Home Water. We would like to talk with a woman of the household for about 30 minutes. Participation is voluntary; you may decline to answer any or all of the questions, and you may end the questionnaire early if you wish. All information will be kept confidential. Do you understand? Will you be willing to participate?

| | |
|---|---|
| Yes | |
| No | |

(If no, thank and close)

Identification code: ___ ___ ___ and GPS Setting ________________________

Date of interview: ___/___/___

Interviewer: ____________________________

Name of person interviewed:___________ _________________
**Last Name** **First Name(s)**

Age and gender of respondent: ____________________________

Household status: _____________________________________

**Filter Use**

1. Can you show me the water you use for drinking?

OBSERVE:

a. How high is the filter from the ground?
b. Is the ceramic filter installed in the unit?
c. Do they use water from the bottom of the Kosim unit?
d. Is the filter covered with a lid?
e. Is there water in the bottom unit?

2. From where do you collect water?

3. Is the water dirty from that source?

4. How did you first hear about this kind of filter?

5. Is your filter working?

6. When did you purchase your filter? (check this with PHW records)

7. Did you receive any training papers when you bought your filter?

    a. If yes, can you please show me these materials?

8. From whom did you purchase the filter?

9. Did the sales person come to your house and show you how to use filter?

10. Can you act out for me how you use the filter?

OBSERVE

    a. Clean the filter first?
    b. Filter with cloth filter first?
    c. Use Alum?
    d. Let water settle?

11. How many people use the filter every day?

12. How many adults? How many children?

13. Who collects the water to be filtered?

14. Do you ever drink unfiltered water?

    a. If yes, why?

15. Can you show me the water that you use for cooking?

    a. Where does this water come from?
    b. Do you filter this water?

OBSERVE:

    c. Does the water appear turbid?
    d. Showed cloth filter? (if applicable)
    e. Is the water being stored in a covered container?

16. Can you show me the water that you use for cleaning the dishes?

    a. Do you filter this water?

OBSERVE:

b. Does the water appear turbid?
c. Showed cloth filter? (if applicable)
d. Is the water being stored in a covered container?

17. Can you show me the water that you use for washing your hands?

a. Do you filter this water

OBSERVE:

b. Does the water appear turbid?
c. Showed cloth filter? (if applicable)
d. Is the water being stored in a covered container?

18. How often do you filter water (days/week)?

19. Is it hard work?

a. If yes, why?

*20. Do you ever buy water?(DO NOT ASK IN RURAL)*

*a. If yes, from whom?*
*b. Can you show me some of the water you have bought?*

**Filter Maintenance**

21. When was the last time you cleaned the filter and the storage unit?

22. Did the sales person come to your house and show you how to clean the filter?

a. Did this person provide you with a brush to clean the filter?

OBSERVE

a. Saw brush?

23. Can you act out for me how you clean the filter?

OBSERVE:

a. Did they only touch the top lip of the filter?
b. Do they place the filter on a cloth that has been washed in chlorinated or bleached water?
c. Did the place the filter on the lid of the unit?
d. Did the place the filter in a clean basin?

e. Do they fill the filter halfway with filtered water?
f. Do they use the provided brush?
g. Do they only brush the inside of the unit?
h. Did they clean the storage unit?
i. Did they use soap and filtered water to clean the storage unit?
j. Did they use filtered water to clean the storage unit? Cloth filter?
k. Did they use pipe water to clean the storage unit?
l. Did they disinfect the storage unit after cleaning?
m. Did they disinfect the spigot?

## Perception

26. Do you like the taste of filtered water?

27. What does it taste like?

28. Is the filter easy to use?

29. What do you like about the look of the filter?

30. Have you had any problems with the filter breaking?

    a. If yes, can you show me what the problem is/was?

31. Before you got the filter, did you treat the water at all?

    a. If so, how?
    b. Can you show me?
    c. Did that work?

32. When was the last time someone in your house had diarrhea?
    a. how old was this person?

Thank you!

Pure Home Water/UNICEF
Distribution of ceramic pot filters to flood affected communities
January 21-23, 2008
Pwalugu, Arigu, and Baluugu communities, Upper East Region, Ghana

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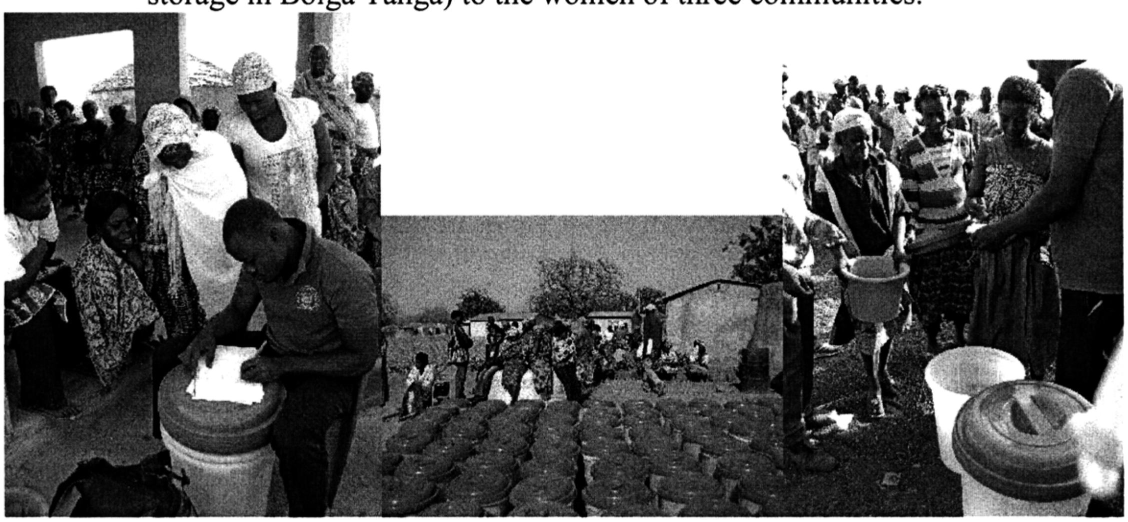
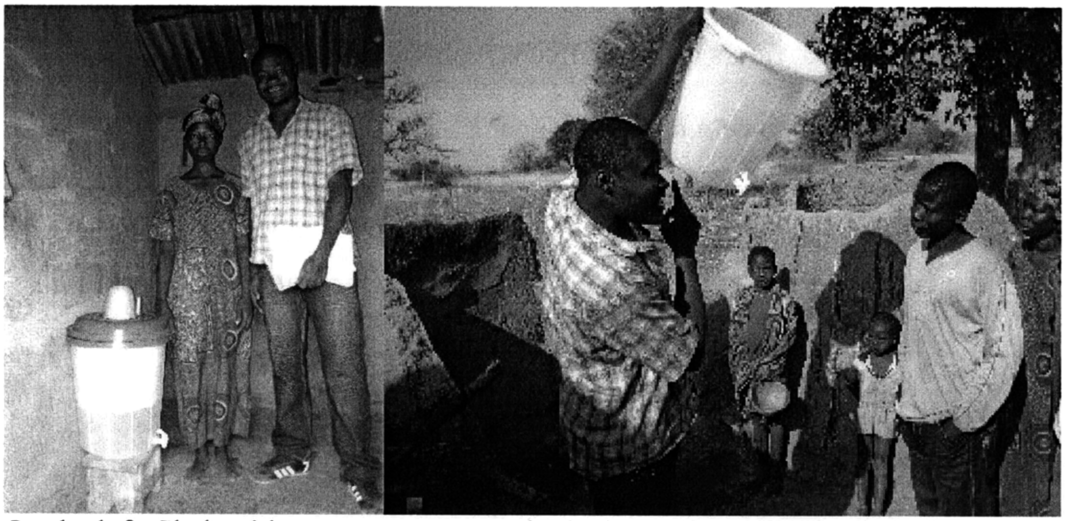
**Sight Overview**

- In their flood relief efforts in the Upper East Region following large scale flooding during September 2007, UNICEF purchased 5,000 CWPs from Pure Home Water to distribute to these communities of displaced people who had recently moved back into their homes and were rebuilding their lives.
- The author went with PHW staff Shak and Peter for three days to the Upper East to accompany them in their delivery of the filters, distributing them and conducting trainings to the women of the communities, and then to monitor users who had received the filters during the previous weeks. We distributed around 400 filters (as many as could fit in the truck, and then some from storage in Bolga Tanga) to the women of three communities.



(1) Shak gathering signatures of *Kosim* recipients; (2) Long lines gathered around the assembled filters; (3) Women participating in the group training on how to assemble, use, and maintain the filter.

The procedure of filter distribution was inefficient. The community liaison aided the PHW staff in gathering the women of the community together, who waited while filter parts were organized and signatures of recipients were taken. After recipients were thus identified, a group presentation was made by the PHW staff on how to assemble, operate and maintain the *Kosim.* Certain women did all this and did not receive a filter (UNICEF's was to give one to each household, but the truck held well less than the number of women that showed up), resulting in arguing and a bit of confusion over who would get the last few filters.



On the left, Shak with a young woman who had excellent effective use characteristics: very clean setup, stably situated, tap not leaking, half full, actively filtering, good maintenance techniques, and a clean cup associated with use of the filter. This same woman was very helpful in assisting Shak to reeducate and reassemble the filter of her neighbor (shown demonstrating correct tap installation and storage cleaning on the right). This neighbor had many user faults including lifting the filter with water in it, placing the filter on the floor, situating the filter on a non-stable, non-flat base, and generally poor hygienic habits including washing the system and her drinking cup with unfiltered water, a common user habit witnessed throughout all of the author's monitoring visits.

**Household visit notes**

After two days of distributing filters and conducting trainings, the team conducted monitoring of 5 households to which filters had been distributed the week before. The monitoring program was supposed to cover every household a few weeks after distribution, but it was clear that the PHW staff charged with distribution were not the best-suited to carry out the follow-up monitoring. A separate monitoring campaign by independent agents was established in June 2008.

**Monitoring Observation**

All around good use among the 5 HH's visited during follow up monitoring by the PHW staff and the author in January 2008, despite a few leaky taps and unstable bases (corrected by Shak).

**Water Quality Monitoring**

Waters were visually clear after treatment, with no microbial water quality measurements taken. Unknown source.

**Effective Use Assessment**

Very good from an observational standpoint, despite a few leaky taps and one old woman's ignorance of proper use (adequately retrained). It was impressive that people went from not knowing anything about this system to adopting it very well in the few hours that Shak had spent distributing these filters the previous week. Group training was effective.

International Aid and Pure Home Water households with both biosand and *Kosim* ceramic pot filters; Carter Center and Carl Allen of Peace Corps helped with installation
January 20th 2008
Kpanvo community, Tamale, Ghana

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1/20/2008 Comparative Survey among joint Kosim and Biosand Users
Kpavno Community

A team comprised of Peter Alhassan, Matt Stevenson, and Susan Murcott conducted a written survey among three households of the Kpavno community who had purchased the *Kosim* filter midway through 2007 and then received a free Hydraid Biosand filter from International Aid late December, 2007. Peter Alhassan conducted the survey in the local language of Dagbani.

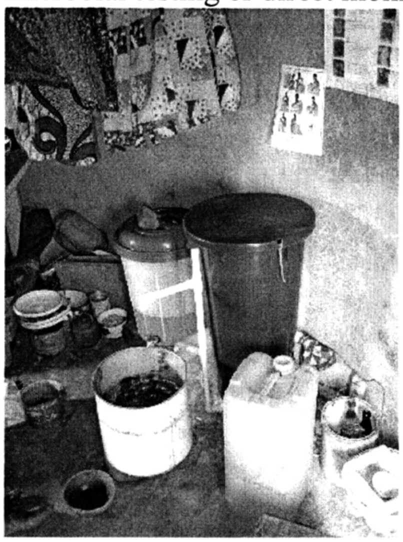
**Water Quality Monitoring:**
Sophie Walewijk of Stanford University conducted membrane filtration microbial tests of many of the Kpanvo biosand filters in households that were visited and informally interviewed by this author. Using a membrane filtration method from the 11th Edition (Standard Methods, 1960), Walewijk conducted testing of 100ml samples using the Millipore portable membrane filtration unit with a 47 μm filter paper and mColi-Blue24 broth incubating for 24 hours at 35° ± 1° C. By this method, counts of *E.coli* and Total Coliforms in 100ml of sample can be determined, yielding the resolution necessary to investigate low risk conditions that are generally created through the use of HWTS technologies.

Water Quality Results for International Aid Biosand Filter Users

| House hold | Sample | Date | Flowrate L/hr | Turbid TU | *E.coli*/ 100ml | T.coli/ 100ml | Method ** | Effective Use |
|---|---|---|---|---|---|---|---|---|
| HH1 | BSF Inlet | 1/21/08 | | | <1 | 100000 | MF | |
| HH1 | BSF Outlet | 1/21/08 | | | <1 | 350 | MF | Yes |
| HH1 | BSF Inlet | 1/18/08 | | 28 | <100 | 4100 | PF | |
| HH1 | BSF Outlet | 1/18/08 | 32 | .3 | <100 | <100 | PF | ?* |
| HH1 | BSF Storage | 1/18/08 | | 2.3 | <100 | 2100 | PF | ?* |
| HH2 | Raw/BSF In | 1/20/08 | | | <1 | 21000 | MF | |
| HH2 | BSF Outlet | 1/20/08 | | | <1 | 600 | MF | Yes |
| HH2 | CWP Storage | 1/20/08 | | | <1 | 11 | MF | Yes |
| HH2 | BSF Inlet | 1/19/08 | | 15 | <100 | 2500 | PF | |
| HH2 | BSF Outlet | 1/19/08 | 8.6 | 2.7 | <100 | 4600 | PF | ?* |
| HH2 | BSF Storage | 1/19/08 | | 2.4 | <100 | 1300 | PF | ?* |
| HH3 | BSF Inlet | 1/22/08 | | 40 | <100 | 36000 | PF | |
| HH3 | BSF Outlet | 1/22/08 | 12 | (6) | <100 | 100 | PF | ?* |
| HH3 | BSF Storage | 1/22/08 | | (15) | <100 | 900 | PF | ?* |

* Question marks indicate that the level of detection for *E.coli* of the Petrifilm method is above that needed to discern low risk from microbial contamination and thus Effective Use was not judged for these results.
** Petrifilm =PF; Membrane filtered = MF

**Results Overview:**
HH1 achieved Effective Use of BSF from monitoring observation. Microbial testing shows that filter treated water has <1 *E.coli*/100ml, conforming to WHO guidelines and within our definition of effective treatment. The storage unit was clean to the eye and did not store water for a long period of time. Unfortunately, due to limited time and testing capability, the storage unit of HH1 was not tested and we cannot conclude that the storage practices were effective. Disuse of *Kosim* was described for HH1, such that no microbial testing or direct monitoring of the *Kosim* was possible.



Household 2 HWTS water management

At HH2, effective microbial treatment was measured in both the BSF and the CWP. BSF storage practices are not ideal, however, consisting of an open, rusted iron can. He was well informed of usage procedures for both systems. The women of the house preferred the biosand for its quick pouring and access, while the husband enjoyed the taste of his *Kosim* CWP.

Effectiveness of treatment is seemingly insured in the BSF of HH3, yet probable recontamination occurs in the storage unit because it is rusty and uncovered and accessible (microbial testing hints at this with regrowth of total heterotrophic coliforms, although the Petrifilm method by itself lacks the resolution to show low levels of risk from *E.*coli). She practices secondary safe storage in her CWP storage unit when primary storage overflows.

**Full Interviews:**

First Respondent:

Rematu Musah is a 29 year woman who had given birth the previous day. She was very gracious to have given us an interview. She is the wife of the head of the household and lives in a brick house with cement floors, a corrugated iron roof and a limited rainwater harvesting capability. She collects the water herself from the Kpanvo dugout throughout the year.

When Peter asked her for water, she brought a tin full of Guinea worm cloth-filtered dugout water from a large ceramic pot in the courtyard. This water had a turbidity of 60 Turbidity Units.

After learning about the Kosim filter from a demonstration in town by the Pure Home Water (PHW) volunteer Nachina, Rematu purchased her Kosim filter for 60,000 (~US $6) cedis through 3 installments of 20,000 cedis (~US $2), 7 months prior to our visit. At the time of the visit, the Kosim was dismantled, with the storage unit in a separate room and the clay pot filter being used for storage. We asked her to put the filter together in our surveying room for comparison purposes.

She claims to have used the filter for the last two months of the dry season before utilizing unfiltered rainwater when the rains came. After the rainwater was depleted, she was in the third trimester of her pregnancy and relied on others to fetch water. Because of this added burden, she was not able to put her Kosim filter into service for the few months after the rainy season. She solely cloth-filtered (good condition) her water until she received a Biosand filter in late December. The Biosand filter was actively in use when we entered, with a low visible flow rate.

When asked about maintenance of her Kosim filter, she responded that when cleaning is needed (3 times per week), she places the filter on a clean surface and uses the provided brush to clean out the ceramic with Kosim-filtered water, and then uses cloth-filtered water, soap and sponge to clean the plastic storage unit. The Kosim filtered water's taste was described as "pure water" by her.

Currently, Rematu uses the cloth filter followed by Biosand to treat her water. She is the only person who operates and maintains the Biosand filter. When Peter asked her about how she had heard about the Biosand filter, she originally responded that it was through Pure Home Water. Whether this was actually her perception of the Biosand intervention or not is debatable, as we seemed to clarify later that she received it from a white man, probably Carl of the Peace Corps (hence the possible confusion as Matt and Susan are also both white). Something may have been lost in translation here, but it is obvious that she did not relate Carter Center or International Aid with donating her Biosand filter. Regardless, she received the filter a month before our visit, and with it came a laminated pictorial cleaning instruction from CAWST (see *Appendix F: Biosand Filter Usage Instructions* and picture below). Peter claimed that training for the filter happened at the house, but this too may have been a mis-interpretation, as evidenced in a later interview. The filter was placed out of direct sunlight in her bedroom, was actively filtering and spotlessly clean, with a small uncovered white wash basin (also very clean) for storage. Six people (two adults) use the filter for drinking every day. Water is constantly added to the filter, and she claims to clean it every two days. Whether this high cleaning rate is based on need due to the high turbidity and consequent clogging, or based on a recommendation to clean the filter every three days as instructed by Carl is unclear, but Rematu said that the water becomes dirty after a few days. Because this high rate of cleaning is common to many of the Biosand households in Kpanvo, accurate microbiological testing will tell us if this is a sound cleaning regimen, or whether is it continually disturbing the *schmutzdecke* (see data tables that follow for each of the three households, as well as compiled data in the *Field Results* chapter). To that end, the cleaning style described by Rematu is very gentle and most likely not very obstructive of the biological layer. To clean, first she rinses the filter, and then attempts to make the top of the sand smooth by rubbing it softly with the open face of her hand. After another "rinse," it is ready to filter again. She also was very rare in that she claimed to clean the storage unit with soap and sponge using filtered water (a visual inspection of the storage container confirmed its cleanliness, but hopefully we can also test it microbiologically). These cleaning techniques contributed to an overall impression of effective use of the biosand through observational monitoring characteristics.

Rematu describes the taste of the biosand water as good, like "pure water," similar to her claim about the *Kosim*. The Biosand filter is easy to use and has caused her no problems. She likes the Biosand because it is beautiful as well as its clean water. She likes the "model" (a seeming buzz word to Peter, unclear of the intended translation) of the Kosim, saying that it is transportable, and produces clean and cool water. She could not say a bad thing about them, she explained, because she liked them both, and they were too important not to like. She seemed too uncomfortable during the interview to make opinionated claims. This could be attributable to many things, including a reluctance to show strong opinions in front of her two male and/or white interviewers. It is possible that she simply did not have strong preferences between the two filters, and her answers to questions on which produced better water, health, taste, and aesthetics were positive to each filter. She did however claim that the Biosand filtered faster and that the spigot of the Kosim was too slow, as compared to the open storage unit of the Biosand. She reported no recent diarrhea in the household, although these results are suspect based on her noticed discomfort in answering this question to strangers.

When asked if she would buy one for a friend, Rematu replied that she would buy a Kosim for someone else, as to ensure that the storage container was safe for them. As for herself, she knows how to keep the storage container clean, and would only buy the Biosand for herself. Willingness to pay for either filter was not inquired.

Effective Use judgment:

- Observationally, the user showed very effective practices with the BSF. Microbial testing confirmed this by showing that *E.coli* from the filter is <1/100ml, conforming to WHO guidelines. The storage unit was clean to the eye and did not store water for a long period of time, yet no microbial water test was done from storage and we cannot conclude that the storage practices were effective.
- Disuse but seemingly ineffective use of *Kosim*, but did not witness first hand and no microbial testing.

Rematu's Water Quality Results

| Data source | Sample | Date | Flowrat L/hr | Turbid TU | *E.coli*/ 100ml | T.coli/ 100ml | Notes |
|---|---|---|---|---|---|---|---|
| Sophie | BSF Inlet | 1/21/08 | | | 0 | 100000 | Membrane filtered = MF |
| Sophie | BSF Outlet | 1/21/08 | .3(?) | | 0 | 350 | MF |
| Izumi | BSF Inlet | 1/18/08 | | 28 | <100 | 4100 | *has not cleaned ever |
| Izumi | BSF Outlet | 1/18/08 | 32 | .3 | <100 | <100 | →same data source? |
| Izumi | BSF Storage | 1/18/08 | | 2.3 | <100 | 2100 | Petrifilm =PF |

Second Respondent

At the second household we came to, both the Kosim and the Biosand are used in parallel to provide drinking water. The "landlord," or head of the household was home, named Suliemana Ibraham. His wife, who maintains the filters, was out fetching firewood, and we were not able to garner adequate information on cleaning practices from either Suliemana or his adolescent daughter as they were not the custodians of the two filters. His wife and children retrieve water from the same Kpanvo dugout as Rematu throughout the year, unless their dugout is dried up, when they have to travel to the next community to collect water from their dugout.

The two filters sat side by side out of the sun in a food store room of concrete floor and thatched roof that seemed not to have access by animals, both with plenty of filtered water in storage (the *Kosim* storage was half full and both were actively filtering). The *Kosim* unit was raised three inches off of the floor. No vessel was nearby to drink from, and when Peter asked for a drink of water, the young daughter found two very dirty cans with which she sampled from the two storage units, dipping directly into the small open-top steel drum under the Biosand, though there was a ladle-cup already inside.

This man bought his Kosim filter 8 months prior to the interview for 60,000 cedis (~US 6$. He heard about it during a community demonstration by Nachina, the PHW community liaison, and later purchased it from him. Suliemana received no training materials about the filter other than this PHW-led community demonstration. The liaison also made one trip to his house during installation to fix a leaking gasket seal (washer) on the tap. Although his household used the cloth filter before buying the Kosim, they had cases of Guineaworm in their family. Suliemana told us that God answered his prayers with Pure Home Water, and that it has solved the Guineaworm problem. The cleaning brush for the Kosim was present, and Suliemana claims that the Kosim is cleaned every three days (but not actually by him, such that this information may be unreliable). The filter was very clean inside. The daughter also claimed that the Kosim storage was cleaned with soap and sponge using cloth-filtered water.

Suliemana likes his Kosim very much, and compares the taste to that of piped water. He claims that it is easy to use, and said rather inconsistently that he has had no problems with it, although he admitted to a leak in the tap earlier.

He was introduced to the Biosand filter by the teacher, Joseph, who is the community volunteer for the Carter Center Guinea Worm Eradication Project. One month ago, a group of people (notably including mostly white people) came to his house with the filter and showed him how to use it, and provided the CAWST poster and appropriate sponge that International Aid recommended to use for decanting dirty water during cleaning, which resembles that used to pour off oil, a common practice in Northern Ghana. Four people, including two adults drink from the Biosand filter. He has no complaints about the Biosand breaking.

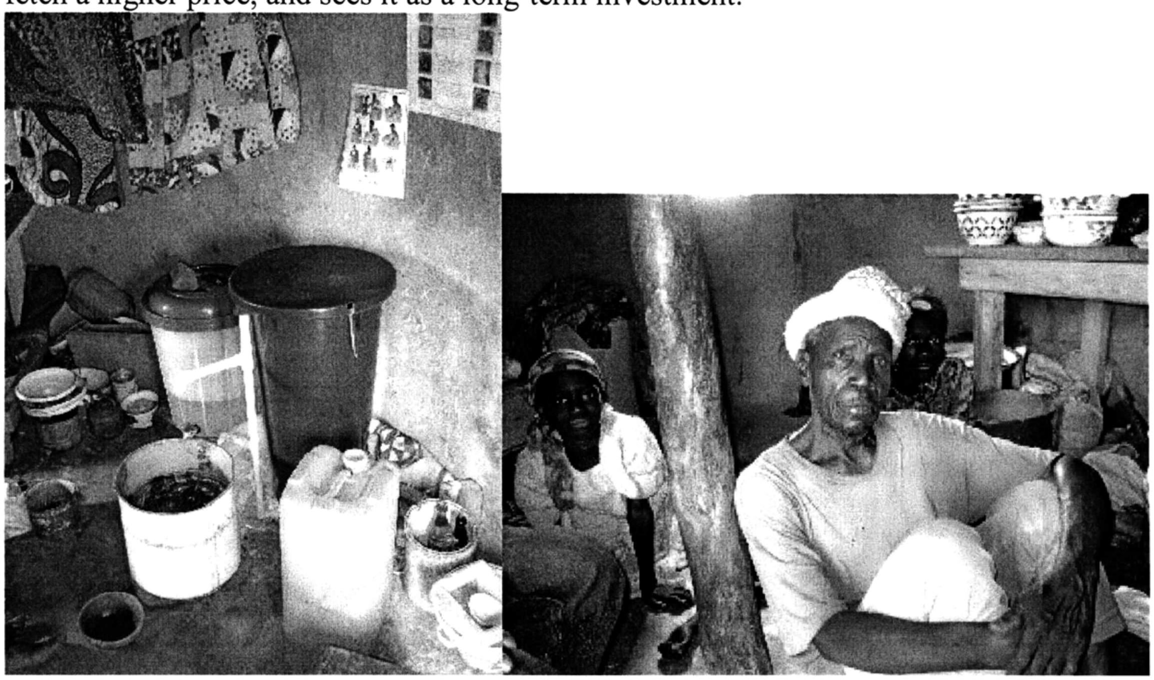
For Suliemana, the Biosand changes the scent of the water to that resembling algal growth, and prefers the cool and earthy water of the Kosim, in which the natural scent is not altered. He will only drink tea made from the Kosim. Later in the interview, however, he says that the taste of Biosand is like piped water, with similar taste to Kosim.

The women in his family, however, prefer the Biosand's taste as they perceive it to add some type of chemical treatment, and they like using it for cooking as well, as the flowrate is plentiful. In some cases, the flowrate is too high, and Suliemana complained that you cannot leave the biosand alone for it will overflow. He shares the sentiment with Rematu that while the Biosand water is cleaner, it is more susceptible to contamination after treatment. He wishes to fit a spigot to the Biosand to avoid contamination, and said ultimately that a Biosand with a tap would clean the water much better than the Kosim.

A spigot would ruin the perceived benefit to the women, as they appreciate the ability of the Biosand to produce a lot of water to an open storage vessel so that they can fetch water quickly so as not to spoil when making TZ (tea-zed), a complaint that Rematu also shared. His wife prefers to make soup from the Biosand water as well.

In terms of perceived health impact, Suliemana did not comment on any notable diarrhea yet said that his wife's stomach pains have lessened since drinking from the Biosand.

Suliemana prefers the Kosim, and the women in the family prefer the Biosand. Part of this preference may be a wish to see a return on his recent investment in the Kosim (author's conjecture). In response to our comparative questions (# 47-58 on survey), he responded that the Biosand cleans the water better and had a very interesting explanation. He took a wooden bowl to show us the clarity of the stored water from both filters, describing the Biosand water as "light," or clear like kerosene, and then the water from the Kosim as "thick," or dirty with some particulates. They used to use the Kosim more, but it is now easier to use the Biosand because of the fast flow rate. The children like it. The Biosand design looks better to him. He would recommend the Biosand over the Kosim, and after a good long thought, gave his estimated price of 100,000 cedis (~US $10) for the Biosand, based on his buying the Kosim at 60,000 cedis (~US $6). He thus values the Biosand a reasonable amount more than the Kosim. He expects the Biosand to fetch a higher price, and sees it as a long-term investment.



(1) Suliemana's *Kosim*, BSF, metal BSF storage, and fetching jerrycan. BSF storage practices are not ideal (uncovered rusty drum). Note the BSF training material shown. (2) Suliemana and his daughter during interview

Suliemana's Water Quality Results:

| Sample | Date | Flowrat L/hr | Turbid TU | *E.coli*/ 100ml | T.coli/ 100ml | Notes |
|---|---|---|---|---|---|---|
| Raw/BSF In | 1/20/08 | | | 0 | 21000 | MF |
| BSF Outlet | 1/20/08 | | | 0 | 600 | MF |

| | | | | | | |
|---|---|---|---|---|---|---|
| CWP Storage | 1/20/08 | | | 0 | 11 | MF |
| BSF Inlet | 1/19/08 | | 15 | <100 | 2500 | PF |
| BSF Outlet | 1/19/08 | 8.6 | 2.7 | <100 | 4600 | PF |
| BSF Storage | 1/19/08 | | 2.4 | <100 | 1300 | PF |

Suliemana and his wife showed effective microbial treatment for both of their BSF and CWP.

Respondent 3

Mata Baba is the woman in charge of water procurement in her house. She lives in brick wall house with cement floors and corrugated iron roofing, and has a newborn child. After hearing about the Kosim from the community liaison Nachina, she bought one for 60,000 cedis (~US $6) of her own money 7 months ago. She used it happily until receiving a Biosand "as a gift from whites" one month ago. She now uses the Kosim storage unit for occasional overflowing of the metal drum in which she stores the Biosand treated water, for she likes the tap on the Kosim. At the time of the interview, the ceramic filter was sitting on the bottom of the storage unit, moist and with condensation inside.

Mata Baba and her husband are the only ones who operate the BSF, but seven people in total drink from it. They add water every day to the BSF, and she indicated that she tends to clean it every two days (!) The cleaning method is that described by the previous two households, namely using the palm of the hand to flatten the top layer and using the sponge provided to extract the dirty water. Peter told us that Mata Bata cleans the open storage unit that receives the Biosand filtered water three times a week with sponge and soap and cloth-filtered water, but this is a bit hard to believe. The taste is that of "piped water."

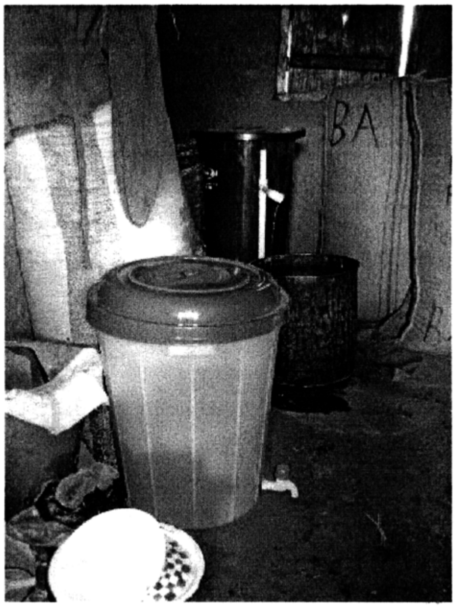
When asked to fetch a glass of water, the woman's daughter went to the ceramic storage pot in the yard to fetch water to clean a glass that she then dipped into the Biosand storage container and gave to Peter for to drink.

Mata Baba appreciates that there is always water available with the Biosand, which she did not say for the Kosim. She also likes being able to fetch it quickly, without having to wait for the tap to pour. As for the Kosim, it looks good, has a nice tap and always has water on hand (a little inconsistent). For the preference questions of taste, clean water, flowrate, ease of use, and health impact, Biosand was rated better by this woman. Both filters look equally good, however. She has noticed a reduction in the number of skin boils since using these products, and would recommend the Biosand to her relatives. She said the maximum that she could pay for the Biosand was 100,000 cedis (~US $10), but would pay up to 200,000 cedis (~US $20) if she had the money available. She had the strongest inclination in favor of the BSF of the households interviewed in Kpanvo.

Mata Baba's Water Quality Results:

| Sample | Date | Flowrat L/hr | Turbid TU | *E.coli*/ 100ml | T.coli/ 100ml | Notes |
|---|---|---|---|---|---|---|
| BSF Inlet | 1/22/08 | | 40 | <100 | 36000 | Uses everyday, PF |
| BSF Outlet | 1/22/08 | 12 | (6) | <100 | 100 | Cleans when she can, PF |
| BSF Storage | 1/22/08 | | (15) | <100 | 900 | PF |

Effectiveness of treatment is seemingly insured, yet probable recontamination in the storage unit for BSF because it is rusty and uncovered and accessible (microbial testing hints at this with regrowth of total coliforms). Secondary safe storage in CWP storage unit, although would recommend chlorine treatment.




Water Quality: Although the design flow rate of the HydrAid BSF is 47 L/hr, the flow rates were not measured at maximum head. The average flow rate was 17 L/hr, much slower than the design flowrate but in good operation range (Kikkawa, 2008).

Note the picture of Mata Baba's *Kosim* and BSF: *Kosim* storage unit was empty, and located on the floor, inaccessible to use and with risk of contamination to the tap. Unsuitable rusty metal.

*Jan. 23, 2008. Peter Alhassan, Susan Murcott and Joseph, the Kpanvo school teacher, conducted the same survey described above, translated into Dagbani orally by Peter Alhassan. On this day, four households of the Kpavno community who had purchased the Kosim filter midway through 2007 and then received a Biosand filter as part of an International Aid donation in late December, 2007 were surveyed. Water samples were subsequently collected and analyzed.*

**Respondent 4 – Dawni (grandfather) and Ayishetu (grandmother)**

Dawni and Ayishetu were the elders of this household. Peter Alhassan referred to Dawni as "senior sister." (Miscommunication?). This household also collects their water from Kpanvo Dam. The daughter of the household, who is responsible for the operation and maintenance of the filters, was not at home at the time of this survey. Therefore, the questions were answered by Dawni first, and Ayishetu second.

At the time of this survey, only the BSF was being used. They had used the Kosim and it had been kept in the daughters (and her husband's?) bedroom. Their 2-year old, whom we met, also slept in that room. The Kosim had been on an unstable stool directly beside the bed. The child had knocked the Kosim over in the night and had broken the pot. The Kosim also leaked, because the hole was too large for the tap. And, there was a black washer – only one, not two as should be the case. The washer did not fit properly for the size of the hole and diameter of the tap. In addition, the hole was rough – it was not properly filed down, which also may have contributed to the leakage. This was a mute point though, because they were not using the Kosim after it broke. After that, they received their Biosand filter. They use the Biosand filter and it is kept in a common room.

This family also said it had been given 10 Lifestraw filters (one for every family member) – they brought out several of the small size black ones to show us. These were given out in November 2007, according to Dawni, and every person in Kvanpo has one. He said they use it when they go to their farm fields and get thirsty. In Dec. 2007, three people in Kvanpo had guinea worm. Now, they are cured and there are no new cases, according to Dawni.

This household received their BSF in December from Carl/Osman. They received training materials. We observed that they used their water collection can (the 40 liter metal type) as their receiving water container. When Susan questioned them about this, Ayishetu, who was doing the demonstration of how they use the BSF, said that they used jerry cans as receiving containers. There were two jerry cans beside the BSF. Ayishetu commented that they were both leaky and she sent someone to get a non-leaky jerry can. It was brought, and the interesting thing was that when we observed decanted BSF filtered water going into the jerry can, one had to watch it, because of the narrow opening. You couldn't just let it flow, as you could with a wide, open-mouthed receiving container.

There were about 10 people in this household using the BSF, including 4 children. They clean the filter 3 times per week. They received instructions in their home on how to clean the filter. They like the taste of the filtered water, it is not hard to use the filter and they have not had any problems with it. They like the "good water, not spoiled." There is nothing they don't like about the filter.

Regarding the Kosim (which they no longer use because it is broken), they liked the taste of Kosim filtered water. It "never tastes salty, just like pipe-borne water." The Kosim was not difficult to use. Before they acquired the Kosim, did they treat the water at all? Yes, they treated the dam water at the source with Abate, about every three months.

Q: How long did they have the Kosim?
A: Long time.
Q: Who was responsible for it?
A: Rabi, their daughter.
Q: How did they hear about the Kosim?
A: Nachina, the PHW liaison
Q: How much did they pay.
A: They paid GHC 2, which was partial payment.
Q: Did they receive any training papers with the Kosim
A: No.
Q: Did the sales person come to their house?
A: No. They learned about it at the PHW demonstration.
Q: How often do they pour water into the ceramic pot?
A: They add whenever the water gets low.

Q: How often did you clean the Kosim?
A: Every day
Q: Did the sales person come to your house and show you how to clean the filter?
A: No, they learned at the PHW demonstration
Q: Was a brush provided?
A: Yes.

Comparing the BSF and Kosim, they liked both filters. Both cleaned the water well. The BSF was faster, in terms of flowrate. The BSF was easier to use, but you have to watch it. The Kosim you could leave and go back later – you didn't need to watch it. In contrast, you have to stay close to the BSF when you pour water into it (as we observed when they tried to filter directly into a jerry can). The BSF flows like piped water. If they were going to buy one of these two filters for their family, they would buy the BSF. How much would they want to pay? They would want to pay GHS 6 (they knew that this was the cost of the Kosim). They stated that they had no diarrhea in their family.

**Respondant 5 – Ibrahim Abdul Rahaman**

Ibrahim Abdul Rahaman is the village chairman and this was the second visit our MIT team had paid to his home – we had stopped by there briefly the previous week with Carl, Sophie, Izumi and others. However, we didn't know this household had a Kosim when we paid our first visit. In addition to being the village chairman, Mr. Rahaman is a butcher by trade, which was explained to us as meaning that he is a bit wealthier. He has three wives: 1$^{st}$ = Lansah, 2$^{nd}$ = Asibi and we didn't learn the name of the third. Neither were available, so he became our survey respondent.

Their water source is Kpanvo Dam, which they say dries up in April or May. Ibrahim's wife and children collect the water.

Ibrahim had purchased the Kosim and kept it in his room for his private use. His also had roughness around the tap hole from not having been properly filed down.

Regarding who is responsible for cleaning the BSF, it was his 1st and 2$^{nd}$ wives. Ibrahim first heard about the BSF in the community, then his household became the site of the first installation, together with the installation at the chief's palace. The BSF is working well, and it has been doing so for the 2 months since its installation.

Observation of their storage post BSF filtration showed that there was likely contamination – they used random jerry cans which did not appear clean. Ibrahim also said that although they have lifestraw filters, they prefer to take jerry cans of BSF water with them to the fields – they found it easier.

The number of people using the BSF was 15, with 4 adults (1 husband, 3 wives) + about 11 children. The BSF was last cleaned the day before yesterday and it was cleaned about every 4 days. The verbal, but not acted out, description of how to clean the BSF seemed accurate. Ibrahim said that he and his family liked the taste of BSF water, that it tasted like pipe0borne water. It was not difficult to use and they had no problems with the BSF.

Regarding the experience with the Kosim, he likes the taste of the Kosim as well. "It tastes like BSF water." The only difficulty he has had with the Kosim is leakage – exact same problem as Respondant #4 – roughness around hole, the hole is too big for the tap, and again, there was only one washer (black) which was not the right size. They have not had any problem with the Kosim breaking – on the other hand, it is only in Ibrahim's room, not shared with the women and children.

Comparing the BSF and Kosim, he prefers the Kosim, his wives prefer the biosand. Which water tastes better – the same. Kosim cleans the water better, the BSF has a faster flow rate. The BSF is easier to use. Both filters are good for health. The Kosim is a better model because it has a tap. Ibrahim suggests adding a tap to the BSF. He paid GHS 6 for the Kosim, and he would pay GHS 10 - 20 for the BSF. Would he pay up to GHS 20 for the Kosim? No, only up to GHS 10. Regarding diarrhea in the family – yes, they have seen a change in the rates of diarrhea since they started using the filters.

**Respondant #6: Bhinayili = father, Mde. Absuli = mother, Idurisu Adbuli = unmarried son, age 16.**

In this household, Idruisu, the 16 year old son had purchased the Kosim, and he kept it in his room. The BSF was used generally by the household, and it was kept in a common room. It was maintained by his mother, Mde. Abduli, and she answered the BSF questions.

The household received the BSF one month ago from Carl/Osman/IA. They came to the house to do the installation. In terms of acting out how to clean the BSF, Mde. Abduli demonstrated correct cleaning procedures. She used a cup, not a sponge, to decant the BSF during cleaning. She explained that there were about 12 people who used the filter every day, including 7 children and 5 adults. They like the taste of BSF water – it tastes like "pure water." The filter is not hard to use.

The last time the BSF was cleaned was yesterday and she uses BSF filtered water to clean the filter. Mde. Abduli said that if she doesn't clean it every two days, the water will come out dirty, looking like dam water.

We were shown into Idurisu's room, and the Kosim pot was on the floor and the storage container, which was on a small stool with the Kosim pot under it, was nearly full to the brim with water. It was unclear how he could have filtered so much water through the Kosim pot, so it was unclear whether this was all filtered water or only partly filtered water.

When asked if he liked the taste of filtered water the answer was yes, that it tasted like piped water. The Kosim filter was not difficult to use. Before he obtained the filter, he did not treat his water.

The comparison between the two filters included the father, mother and son. What they liked about the BSF was that the water was "light" and very clean, cleaner than the Kosim. The water from the BSF tastes good and there was nothing they did not like about the BSF. Mde. Abduli likes the "mold shape" of the Kosim and there is nothing they don't like about the Kosim either. All three liked the BSF better – the father said he liked it because it removed bacteria and guinea worm and that it was fast. Both the father and mother thought the BSF water tasted better than the Kosim. It was faster, they use it more often, it was easier and better for their health. It also looked better. If they were going to buy a filter for their family, they would pay GHS 6 for the Kosim and they would pay GHS 10 for the BSF, but they would not pay GHS 15 for a BSF – that was too much. They had not seen any change in the family's diarrhea as a result of using the filters.

**Respondant #7: Amim Fuseini**

Amim Fuseini is a health extension worker at the Kpanvo Health Clinic. He is the nephew of the chief of Kakpagayili, where we had been the previous day. When we met him at Kakpagayili, he had explained that when he was with his uncle, he used the Kosim regularly, but that when he was at home in Kpanvo, he used the BSF, as his household, like all in Kpanvo, had received a free one.

Amin is age 28, married with one child. His family gets its water from Kpanvo Dam, and his wife collects it. Because we visited him at the Health Clinic, we did not see his BSF, however, he was able to compare them for us.

Asked if he likes the taste of Kosim water, the answer was yes. It tastes "like chemical." Sometimes the same, sometimes different. (?) The only problem with the Kosim is the slow rate of flow, but if you have several Kosim, no problem.

Asked if he treated the water before he had the Kosim, the answer was yes, he used the guinea worm cloth and also, used alum when the dam was turbid. Alum was purchased in Tamale, and it was not so easy to use, and it was expensive.

Amin's wife had received their BSF from Joseph, the school teacher, who had come to his house during the installation. There were 5 people who used the BSF every day, including 3 children and 2 adults. The BSF was filled once per day. Cleaning took place once the flow rate comes to a stop – that is the indication that it is time to clean it. That is the latest cleaning instructions they have received. Previousl7y, they were told to clean the filter every 3 days. This is what was told to them by Carl/Osman.

Do they like the taste of BSF water – yes, it tastes "like chemical." "It seems like they put some chemical into it." The filter is not difficult to use and they have no problems with it.

Comparing the BSF and Kosim, the BSF is easy to fetch water – there is no delay. However, it is a lot of work to regularly clean the BSF – every several days.

What they like about the Kosim water is that it is cool. What they don't like about the Kosim is that if you don't wash the pot, after several days, the filter will not flow. Also, if you are not careful, the filter can break.

Which water tastes better? Both
Which cleans the water better? Both
Which one filters faster? Both
Which do you use more often? BSF.
Which is easier to use? Kosim
Which water is better for your health? Don't know.
Which filter looks better? Both.

What are they willing to pay for either filter? They would pay GHS 2 for either.

Because everyone in the community who wanted a Kosim had to pay for it, only 7 or 8 people got it, but Osman/Carl/IA have brought clean water to everyone in the community via the BSF distribution. According to Amin, most youth have no jobs and most adults don't have three square meals per day in this community, so although people may want a filter, they cannot afford to pay for it.

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According to the school teacher, Joseph, the only problem with the Kosim is the breakage. Apart from that, there is no problem. With the BSF, if one is not patient, it is a lot of work to wash it. As soon as you use it, you need to clean it. This requires a lot of water, and water is in limited supply and is hard to come by. Whereas the cloth filter only removes guinea worm, the Kosim and BSF take out all bacteria, same as with piped water. With alum, a chemical, if you use too much, you will get stomach pains, and it may not removal bacteria.

Household 8
Nachine Ziblila, Male, ~50 years old, maybe less

Nchine's wives and children collect water from Kpanvo dam throughout the year. When asked for a glass of water, he cleaned out a cup (using unfiltered water) and brought *Kosim*-filtered water to us. It had clay particles in it, making it seem as if the storage unit had not been cleaned recently. The *Kosim* was not situated correctly, only a few inches off the ground on a wobbly piece of Styrofoam. Storage was almost empty. Nachine is the community liason for PHW, and thus received his filter from Shak as a donation along with that of the chief's filter. He perceives the filter rate as adequate to his needs. His GWEP cloth filter had holes in it. He cleaned the *Kosim* two days ago correctly, except that he claims to use unfiltered water to clean the storage unit of the *Kosim*. Influent turbidity level from clay-pot storage is 40 TU.

Nachine and his wives prefer to use BSF water if that unit is full, and will use *Kosim* water if no BSF water is available. They received the BSF 1 month ago, and still have the CAWST training materials posted on the wall above the unit. Cleans the BSF 4 times a week, saying that they had forgotten to clean it that morning, which emphasizes that more cleaning was thought to be better cleaning. Could not determine if they clean the BSF correctly through translational issues and time restraints. Has no permanent storage, and filters directly for use. Wife prefers taste of BSF, but Nachine does not show a preference and uses the *Kosim* once the BSF water is finished.

| | a | | b | | c | |
|---|---|---|---|---|---|---|
| **name** | ***E.Coli*** **CFU/100 ml** | **Total CFU/100 ml** | ***E.Coli*** **CFU/100 ml** | **Total CFU/100 ml** | ***E.Coli*** **CFU/100 ml** | **Total CFU/100 ml** |
| Abdulai-Iduriso | 0 | 18000 | 0 | 7 | 0 | 100 |
| Ibrahim-Abdul-Rahaman | 0 | 4000 | 0 | 980 | | |
| Fuseinikipem | 5000 | 116000 | 0 | 1400 | 0 | 1100 |

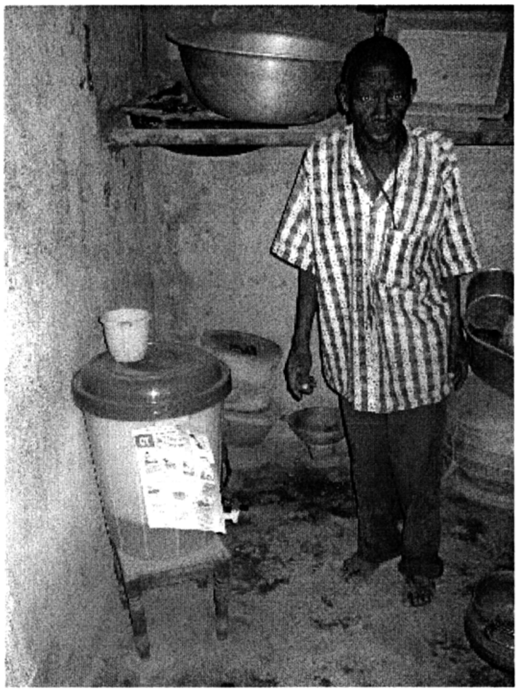
Guided by Sammy, a field attendant for Enterprise Works who collaborates directly with the monitored communities
Enterprise Works
January 29th 2008
Ahentia Community, Afutu Ewutu Senya District, Central Region
A peri-urban area one hour west of Accra, in villages a few miles north of the main road.

---

**Synopsis:**
Of 6 filter users monitored, 5 of them passed by demonstrating excellent use of the CWP, showing 83% of households practicing Effective Use for this small subset of users. The one remaining household claimed consistent use yet their filter had not been filled in three days, and showed poor hygiene in her handling technique. No water quality measurements were made.

**Field Site Overview for first village, with the Chief as Community Retailer**

- No microbial water quality measurements were taken at this site
- HH1-HH5 reside in a village which was sold 130 CWP filters produced by Ceramica Tamakloe (CT), Accra, identical to the ones sold in Tamale by Pure Home Water. This was the first community in which Enterprise Works (EW) sold filters. The first 30 filters sold at US $12 on installments, but due to low selling rates, the last 100 were subsidized at US $5. For each filter sold, the chief (the appointed retailer in this village) receives US $2. He stopped selling filters in July, and although 4 filters have broken, he has not contacted CT or EW to buy replacements, as he has not received any money for the replacements from users (he probably does not receive a commission on the replacements). When a user has a problem, he comes to the chief with a question, and then the chief visits the house (according to the chief). One of the chief's 3 filters was currently broken. He would like to sell more. He has seen many of the taps spoil. A borehole is the main source for the village, as "the *harmattan* [dry season dusty winds] has finished the river source."
- Perceived Health Benefit: Chief sees reduction in guinea worm using the filter, and has stopped using the Carter Center cloth that he and most other villagers possess in lieu of the ceramic pot's effects. He has not seen diarrhea in a long time, and his friend attributes his lack of eye problems to the filter.
- Cleaning: The chief teaches this cleaning regiment to users, for a commission: Every three weeks, wash the storage unit with soap and sponge, use a brush to clean the pot. (Note the teaching that cleaning is done on a time basis, and probably assumed the clean borehole water for a source. EW encourages a nylon fishnet sponge for cleaning but does not provide one as part of their sales).



*Household # 1*

The Chief and retailer for the community, with one of his filters.

**Name and status of person interviewed**

- Chief's house, interviewed his wife briefly

**Household visit notes**

- She says the water has a "fine taste on the tongue"

**Monitoring Observation**

- Filter is set up in clean entryway, on stable table off of the ground.
- Ceramic pot is empty but damp, storage half full→good technique
- Separate drinking glass used just for filter
- Tap is dirty
- Cleans twice in three weeks

**Effective Use Assessment**

- Other than dirty tap, very well used.

*Household # 2*

**Name and status of person interviewed**

- Chief's neighbor

**Monitoring Observation**

- Same as previous case, except non-dirty tap.

**Effective Use Assessment**

- Very good, based on monitoring observation alone

*Household # 3*

**Name and status of person interviewed**

- Gladys, daughter of owner of the CWP

**Household visit notes**

- Her father bought the CWP from the chief
- 5 people drink from it
- Lots of flies in house

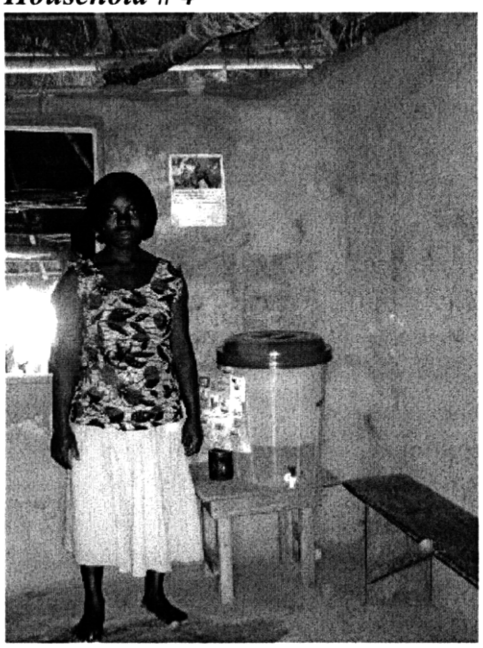
**Monitoring Observation**

- No designated drinking cup
- Little water in pot, has not filled for three days
- Has had the filter for about a year now, and says that it has stopped diarrhea for a long time
- Filter is dark with dirt, yet is cleaned every four days
- Uses sponge and no soap to clean the pot
- Sponge for cleaning and training materials are kept in father's room, and not available for me to see
- When asked for a glass of water, she rinses the cup with filtered water yet washes with her unclean hands before pouring a cup→ineffective hygiene
- No clay dust in the sampled water=clean storage unit(?)

**Effective Use Assessment**

- Can not be using is it for all drinking purposes if filled three days ago→ suspect inconsistent use
- Having no designated drinking cup and not washing hands before handling inside of cup negates the potential benefits of CWP→ineffectively used

***Household # 4***



**Name and status of person interviewed**

- Gifty, the mother of home and caretaker of CWP

**Household visit notes**

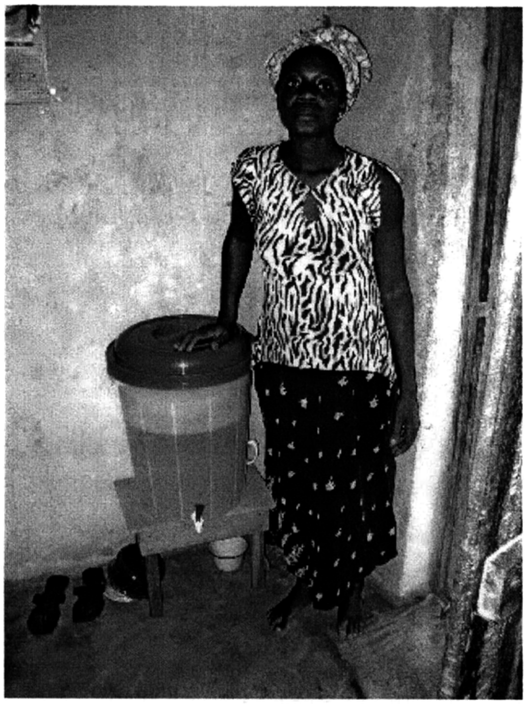
- CWP stays in the parent's bedroom, with a thatch roof and cement floor
- Gifty learned of the CWP from a display given by EW staff member Sammy in the village

**Monitoring Observation**

- Although pot is empty, she claims that it has been consistently filled throughout the past 4 days
- CWP sits on specially fabricated table (see picture above)
- A dedicated drinking cup sits next to the CWP
- User displays the usage poster on the side of the CWP
- She grabbed a nylon sponge from the kitchen to demonstrate proper cleaning of the pot
- CWP "reduces small-small sickness that has been worrying them"; no diarrhea in a very long time

**Effective Use Assessment**

- Very well informed, and attentive to her CWP



*Household # 5*

**Name and status of person interviewed**

- Joyce, the mother of home and caretaker of CWP

**Household visit notes**

- clean cement floor, CGI roof
- paid US $12 (full price, unsubsidized)

**Monitoring Observation**

- Using the CWP for 1 year so far
- CWP sits on specially fabricated table (see picture above)
- a dedicated drinking cup sits next to the CWP, although it does not look very clean
- Joyce learned how to use and clean the CWP from a demonstration training given by Sammy in the village
- She keeps it full, with water above the bottom of the pot in storage
- Cleaned it three days ago with a nylon sponge
- Looks like there is a crack in it (I did not inspect due to there being water in the pot, but it still holds water while filtering), but she is not worried about cracks in the filter until it breaks→misperception of how the unit works??

**Effective Use Assessment**

- Monitoring observation checked out all round

**Site Overview for 2nd village, with Emmanuel Amponasah as Community Retailer**

- This site was less than a mile away from the previous one, a bit more towards the main road but just as rural.
- As the retailer for the community, Emmanuel sold 40 filters. He finds that without subsidies, at US $12 as currently charged by the producer Tamakloe, the filters will not sell.
- Training: Promotes the use of ceramic water purifier (CWP) by wearing "good water" T-shirt and talking up the health benefits. He notices that diseases such as malaria, bilharzias, diarrhea have come down since using the filter.

- Monitoring by community retailer: Two weeks after installation, he went around to the houses and checked up on them. Found one bad filter, which was replaced. Last time he checked the filters was with Sammy (my liaison for the day) in November, and found no problems except one leaky tap, which they fixed.
- Sources of water in the community: rain water harvesting, 2 boreholes, and 1 hand dug well with a pump. Emmanuel does not pretreat the water, never did.
- He claims consistent use for his family of five, and says that he buys sachet water when out of the home. He likes the taste of the clay.
- His children (ages unknown) fetch water from the storage unit, but he has had no breakage of the tap.

*Household # 6*

**Name and status of person interviewed**

- Hannah, mother of household and caretaker of CWP

**Household visit notes**

- Reduced diarrhea rate, can't remember last incident
- Would buy again for 7-8GHC if she had the ability to pay, but she was under financial strain at the time

**Monitoring Observation**

- Half-full storage
- Clean tap
- Sitting on blocks
- Two separate cups for drinking
- Pot almost full
- Lid dirty
- Filtered water is clean
- Filter in use for a year
- Cleaning: cleans when dirt in pot→done last week, with good flow; uses nylon sponge, esp. for filter; puts pot in clean basin while washing
- Learned how to clean it by household visit by retailer because she was not at community meeting, though her husband was
- Refills pot when it drains to empty
- Was prefiltering with a white cloth filter (not the one handed out by GWEP) at one time, but not anymore.

**Effective Use Assessment**

- Achieved the observational monitoring effective use criteria

**Compiled Field Results from Ethiopia and Ghana**

| Organization and Household | Filter Type | Days since Cleaning | Cleaning Method | Storage clean? | Storage cover? | Handling | Proper Use?* | Flow Rate L/hr | Treated *E.coli*/ 100ml | Stored *E.coli*/ 100ml | Recon-tam via Storage | Water Quality | Effective Use? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KHC HH1 | BSF | 120, not needed! | Stir w/ finger** | Clean | Yes | Clean cup | Yes | - | - | <100 | No | Good | Yes |
| KHC HH2 | BSF | 60, unable w/child | ? | No | No | Dirty hands in storage | No | - | - | <100 | ? | Bad | No |
| KHC HH3 | BSF | 7 | Stir w/ finger** | Clean | Yes | Clean cup | Yes | 30 | <100 | <100 | No | Good | Yes |
| KHC HH4 | BSF | 7 | Remove sand | Clean | No | Good | No | 12 | <100 | 700 | Yes | No | No |
| KHC HH5 | BSF | 7 | Stir w/ finger** | Clean | No | Good | Yes | 12 | 100 | 600 | Yes | No | No |
| KHC HH6 | BSF | 14 | Remove sand | Clean | No | w/dirty hand | No | 6 | <100 | 1000 | Yes | No | No |
| KHC HH7 | BSF | 7 | Remove sand | Very poor | No | Dirty water uses hand | No | 7 | <100 | 100 | Yes | No | No |
| IntAid HH1 | BSF | 2 | Flat Palm Harrow | Clean | No | Very Clean | Yes | 32 | <1 | <100 | ? | Good | Yes |
| IntAid HH2 | BSF | - | Flat Palm Harrow | Clean | No | Dirty cup | No | 9 | <1 | <100 | ? | Good | ? |
| IntAid HH2 | CWP | 3 | Good | Clean | Yes | - | Yes | - | - | <1 | No | Good | Yes |
| IntAid HH3 | BSF | 7 | Flat Palm Harrow | Clean | No | Clean cup | No | 12 | <100 | <100 | ? | Good | ? |
| EW HH1 | CWP | 10 | Good | Tap dirty | Yes | Clean cup | Yes | - | - | - | - | - | - |
| EW HH2 | CWP | - | Good | Yes | Yes | Clean cup | Yes | - | - | - | - | - | - |
| EW HH3 | CWP | 4 | No | Storage empty | Yes | Dirty hand | No | - | - | - | - | - | - |
| EW HH4 | CWP | - | Good | Yes | Yes | Clean cup | Yes | - | - | - | - | - | - |
| EW HH5 | CWP | 3 | Good | Yes | Yes | Clean cup | Yes | - | - | - | - | - | - |
| EW HH6 | CWP | 7 | Good | Lid Dirty | Yes | Good | Yes | - | - | - | - | - | - |

*Proper Use is defined by passing the main components use as labeled in the *Observational Monitoring* section of the *Biosand Filter Effective Use* write-up.

**Stir w/ finger is a wet harrowing cleaning method of stirring the top few centimeters of sand with the finger down to the second knuckle and then scooping out dirty water.

# *Appendix D: Portable Laboratory Testing Addendums*

DelAgua Turbidity Tube Instructions (from www.delagua.org)
3M Petrifilm Instructions (from Bob Metcalf)
IDEXX Colilert Instructions (from Bob Metcalf)

**Turbidity Analysis using the DelAgua Turbidity Tube**

Note: The turbidity tubes cover the range 5 to 2,000 TU

1. Remove the two turbidity tubes from their clips in the lid of the test kit case. Carefully push the upper tube (open at both ends) squarely into the lower tube. Look through the open end of the tube at the black circle printed on the base of the tube. Ensure that there is good illumination available. Normal daylight is adequate for this purpose.

2. Fill the turbidity tube with the water sample to the very top. Allow a few moments for the water to settle (as there may be formation of bubbles) before you read the tube. Hold the tube between the thumb and index finger at the joint of the two tubes. Have your arm fully extended. Do not strain to see the black circle as this can sometimes cause biased results. Continue to pour small amounts of the water slowly out of the tube checking each time to see if you can see the black circle. As soon as you can clearly see the black circle then read the level on the outer markings on the tube.

3. Alternatively, pour the water sample into the tube from the sample cup until the black circle just disappears when viewed from the top of the tube. Avoid creating bubbles, as these may cause false readings.

4. The turbidity tubes are graduated in a logarithmic scale with the most critical values. The result is the value of the line nearest the water level. This permits a reasonable estimation of the turbidity of the water sample. As the scale is Logarithmic it will be difficult to get an accurate reading when the water level is between scales. It is always better to take the reading which appears below the water level.

Taken from:

OXFAM – DELAGUA (2000) "Portable Water Testing Kit Users Manual." (abridged web download version) Revised and updated 4th edition. www.delagua.org

## *E. coli* Count Petrifilm (made by the 3M Company, St. Paul, MN)

The ***E. coli*** Count Petrifilm is a reliable, sample-ready medium system for enumerating ***E. coli*** and coliforms. It is regularly used in the food industry to sample meat, seafood, and poultry ***E. coli*** Count Petrifilms contain:

- violet red bile nutrients, which includes lactose. The bile salts and crystal violet in the medium inhibit Gram positive bacteria.
- a cold water soluble gelling agent
- a glucuronidase indicator (BCIG, 5-bromo-4 chloro-3 indolyl-beta D Glucuronide) to identify to identify ***E. coli*** (the same enzyme which hydrolyzes MUG in the Colilert test)
- a tetrazolium indicator which Gram negative bacteria reduce to a red color to enhance colony visualization.

All coliform bacteria ferment lactose to produce gas bubbles. The bubbles are trapped around the coliform colony. This will distinguish coliform bacteria from other Gram negative bacteria which do not produce gas bubbles from lactose.

In addition, glucuronidase, produced by most ***E. coli***, will hydrolyze the glucuronide from BCIG. The BCI produces a blue precipitate around the colony allowing visual identification of ***E. coli***, distinguishing it from non-***E. coli*** coliform colonies which are red with gas bubbles.

## Directions for Use:

1. Place the ***E. coli*** Count Petrifilm on a flat surface.
2. Lift top film and dispense 1 ml of sample onto the center of the red, dried nutrients.
3. Slowly roll the top film down onto the sample to prevent entrapment of air bubbles.
4. Distribute sample evenly within the circular well using a gentle downward pressure on the center of the plastic spreader (flat side down). *Do not slide spreader across the film.* Remove spreader and leave plate undisturbed for one minute to permit solidification of the gel.

5.3M instructions state to incubate Petrifilms 24 +/- 2 hr in a 35°C incubator in a horizontal position with the clear side up. You can stack up to 10 petrifilms. When there is no incubator, I've had success placing the Petrifilms between two pieces of firm cardboard, securing with rubber bands, and incubating the stack close to my body during the day, sleeping on them at night. Blue colonies often are visible in 10 hr, which then grow larger in size and produce gas bubbles with further incubation.

### Results and Interpretation

***E. coli*** colonies will appear **blue** (glucuronidase activity on BCIG) **with gas bubbles** (from fermentation of lactose). One or more *E. coli* colonies signifies heavily contaminated water, which should be pasteurized or disinfected before drinking.

Non ***E. coli*** coliform colonies will be **red with a gas bubble** (from lactose fermentation)

Non-coliform Gram Negative bacteria form red colonies without a gas bubble.

Do not count colonies on the white foam dam since they are removed from the selective influence of the medium.

According to 3M guidelines, some ***E. coli*** colonies may require additional time to form the blue precipitate, and incubation for an additional 24 hr will detect these. However, my experience is that the results visible by 18 hours are the same as results at 24 and 48 hours.

Very high concentrations of ***E. coli*** will cause the growth area to turn a bluish color with individual colonies too tiny to distinguish. Very high concentrations of coliforms (non ***E. coli***) will cause the growth area to turn a dark reddish color with individual colonies too tiny to distinguish. If this occurs, further dilution of the sample is required to obtain a more accurate count.

To isolate colonies for further identification, lift the top film and pick the colony from the gel.

# The Colilert MPN Test

Manufactured by IDEXX Laboratories, Inc, One IDEXX Drive, Westbrook, ME 04092

The Colilert MPN test for water is a defined substrate medium, not containing organic sources of nitrogen and with only two carbon sources for bacteria to attack to obtain energy:

1) **ONPG** (Ortho-nitro-phenol-beta D-Galactopyranoside). Coliform bacteria can be induced to produce the ***beta-galactosidase*** enzyme, which hydrolyses the bond between ONP and G (the sugar). This is the same enzyme which breaks the bond between galactose and glucose in lactose. ONPG is colorless. ***ONP***, however, ***has a bright yellow color***

2) **MUG** (4-methyl-umbelliferone-beta-D-Glucuronide). Among the coliform bacteria, only ***E. coli*** produces the constitutive enzyme ***beta-glucuronidase***, which hydrolyzes the bond between the indicator part, MU (methylumbelliferone), and the sugar, G (glucuronide). The glucuronide. is metabolized to enable growth of ***E. coli***. MUG is colorless. MU, however, fluoresces blue when a long wave UV light (340 nm) shines on it.

The Colilert test was been developed to detect low levels of total coliform bacteria and ***E. coli*** simultaneously in potable and other waters within 24 hours

When testing water in developing countries, which is often heavily contaminated, I have used the Colilert MPN test, a single tube for 10 ml of the water sample. If ***E. coli*** is present, tubes will fluoresce blue within 10-18 hours, depending on the level of ***E. coli*** contamination.

### Directions for Using Whirl-Pak to Collect Water Samples

You can collect a water sample using a sterile plastic ***Whirl-Pak***. Carefully tear off the top plastic section. The inside of the Whirl-Pak is sterile, and you should be careful not to contaminate it with your fingers, as you open the Whirl-Pak by pulling away on the two white tabs in the top center of the bag. Collect a water sample - running water into the Whirl-Pak, or by dipping the Whirl-Pak into a water source (and not your hands with it!), or by using the ***sterile plastic pipette*** to collect water and add to the Whirl-Pak. Fill the Whirl-Pak to the 4 oz level, or a little above the 100 ml level Once the sample has been collected, pull the ends of the wires together to close the bag Then you can whirl it a few times to seal it! You should process the sample within a few hours Most of the time you could collect the sample and do the inoculations right away

### Colilert Procedure

1. Carefully remove a sterile pipette from its package.
2. Carefully remove the cap of the Colilert tube so as not to contaminate it. Add 10 ml of the water sample to the tube – to the mark on the tube. Place the pipette in its package to save it for inoculating a Petrifilm with this same water sample.
3. Replace the cap. Mix, by inverting the tube several times, to dissolve the nutrients. The sample will be clear.
4. Incubate the tube at body temperature -- 35°C, to promote good bacterial growth Tubes can be placed in a small sac, or sock, and held close to the body – and slept on at night.
5. Examine tubes after incubation for up to 24 hr, both in the light and in the dark, using a UV light I've found that results are often evident in 10-18 hours (10 hr with heavy contamination, 18 hr with lesser contamination). On rare occasions, *E. coli* will outnumber non *E. coli* coliforms. In this case, tubes will fluoresce under UV light for a few hours before the tube turns yellow. This is because *E. coli* first uses up MUG, before it uses ONPG.

**Results**: If tubes are **clear, no coliforms** present, water safe to drink.

If tubes are **yellow**, but there is no fluorescence under UV light, **coliform bacteria other than *E. coli* are pesent**. These are likely to come from the environment, and do not have public health significance in water which is not chlorinated.

If the tube is **yellow and fluoresces blue** when a long-wave UV light shines on it, at least one ***E. coli*** was present in the water sample. and the water poses a substantial health risk The Colilert MPN test is a Presence/Absence test for coliform bacteria and *E. coli*. To perform a quantitative test on heavily contaminated water (1 or more *E coli*/ml), the *E. coli* Count Petrifilm is used.

## *Appendix E: Effective Use Monitoring Checklists*

Sodium Hypochlorite Solution
Aquatabs
SODIS
Cloth Filter
Ceramic Pot Filter
Biosand Filter
PUR

| Sodium Hypochlorite Solution Effective Use Monitoring Checklist | | |
|---|---|---|
| Monitor Name: | | |
| Community: | | |
| Interviewee Name: | | |
| Household/Code: | | |
| Date and Time: | | |
| GPS Coordinates: | ____________________ ____________________ | |
| Notes: | | |
| **Instructions:** For each observation, fill in Yes, No, or NA for observations that do not apply. Add up the total #Yes, divide by the total # of observations made, and multiply by 100 for % Observational Effective Use. | | |
| **Monitoring Observations** | **Checklist** | ( Yes/No/ NA) |
| ***Treatment*** | 1. User demonstrates knowledge of treatment and dosing as intended by manufacturer's specifications, without prompting from the monitor: | |
| | 1.1. Add a single dose to clear water of the correct volume. | |
| | 1.2. Double dose for water that is visibly dirty and/or from an unimproved source. | |
| | 1.3. Allow visibly dirty (turbid) water to settle and/or filter through a clean folded cloth before double dosing. | |
| | 1.4. Shake thoroughly after chlorine addition. | |
| | 1.5. Let sit for 30 minutes prior to drinking. | |
| ***Storage*** | 6. Separate containers for fetching water and disinfection/storage of water are used. | |
| | 7. The dosing volume as specified on the hypochlorite product is easily measurable in the safe storage container used for treatment and storage. | |
| | 8. The design of the safe storage unit (for treatment) has a tap or a small sealable opening for pouring. | |
| | 9. Safe storage container is clean, and has no leaks. | |
| | 10. Safe storage container is out of the sun. | |
| | 11. Safe storage container is indoors. | |
| | 12. Safe storage container is raised off the floor and stably situated. | |
| | 13. Safe storage container is out of reach of animals and small children. | |
| | 14. Lids are kept on tight, and only opened for addition or pouring of treated water. | |
| ***Maintenance*** | 15. Regularly scheduled cleaning of the storage unit. | |
| | 16. Soap or disinfectant used to clean storage unit can be produced by user. | |

| | | |
|---|---|---|
| ***Replacement Period*** | 17. User knows expiration date as specified by manufacturer or distributor on bottle. | |
| ***Physical Inspection*** | 18. Unexpired sodium hypochlorite solution sufficient for at least ten treatments is in stock and easily accessible if consistent use is claimed. | |
| | 19. Water bottles for use during travel or school are clean and producible to the interviewer if consistent use is claimed outside the home. | |
| | 20. A dedicated clean cup is used with the safe storage unit. | |
| **Percentage of observations passed** | **= #Yes / (#Yes + #No) X 100%** | |
| **Notes:** | | |

| **Water Quality Monitoring** | | ( Yes/No/ NA) |
|---|---|---|
| *Chlorine Residual* | Free available chlorine presence is shown if treatment is claimed. | |
| *Microbial Testing* | Microbial testing shows <10 *E.coli* CFU/100 ml. | |
| **Notes:** | | |

| Sample from Storage of Treated Water | 24 hr Colilert (Yes/No) | | 24 hr Petrifilm (Count) | | # *E.coli*/ 100ml | **Risk Level** |
|---|---|---|---|---|---|---|
| | Yellow? | Fluoresces? | # Blue w/gas | # w/gas | | |
| | | | | | | |

Incubate Colilert and Petrifilm at body temperature (35°C) for 24 hours (or until results appear), then check:
**Colilert**: If the water is clear: <10 Total Coliform/100ml and <10 *E.coli*/100ml
If the water is yellow: >10 Total Coliform/100ml
If the water is yellow and fluoresces: >10 Total Coliform/100ml and >10 *E.coli*/100ml
**Petrifilm:** # of colonies w/gas X 100= # of Total Coliform/100ml; # of Blue w/gas X 100= # of *E.coli*/100ml;
No Blue colonies with gas= <100 *E.coli*/100ml; No colonies with gas = <100 TotalColiform/100ml.
**Risk Level:** Low is <10 *E.coli* /100ml; Intermediate is 10-100 *E.coli* /100ml; High is >100 *E.coli* /100ml.

| | |
|---|---|
| ***Sampling Procedure*** | 1. Test for presence of chlorine residual in stored water while at the household if chlorine treatment is claimed. |
| | 2. Take a sample of treated water from the storage unit for microbial analysis. Use a Sodium Thiosulphate sampling bag if transporting sample to laboratory. Keep the sample out of the sun and start microbial test within 6 hours. |

| Aquatabs Effective Use Monitoring Checklist | | |
|---|---|---|
| Monitor Name: | | |
| Community: | | |
| Interviewee Name: | | |
| Household/Code: | | |
| Date and Time: | | |
| GPS Coordinates: | ____________________ ____________________ | |
| Notes: | | |
| **Instructions:** For each observation, fill in Yes, No, or NA for observations that do not apply. Add up the total #Yes, divide by the total # of observations made, and multiply by 100 for % Observational Effective Use. | | |
| **Monitoring Observations** | **Checklist** | ( Yes/No/ NA) |
| ***Treatment*** | 1. User demonstrates knowledge of treatment and dosing as intended by manufacturer's specifications, without prompting from the monitor: | |
| | 1.1. Add 1 tablet per 20 liters of clear water | |
| | 1.2. Add 2 tablets for 20 liters of visibly turbid water | |
| | 1.3. Before double dosing, filter the water through a clean folded cloth. | |
| | 1.4. Let sit for 30 minutes prior to drinking. | |
| | 5. Pretreatment is practiced for turbid waters. | |
| ***Storage*** | 6. Two separate 20 liter containers for fetching and disinfection/storage are used. | |
| | 7. Design of safe storage unit (for treatment) has a tap or a small sealable opening for pouring. | |
| | 8. Safe storage container is clean, and has no leaks. | |
| | 9. Safe storage container is out of the sun. | |
| | 10. Safe storage container is indoors. | |
| | 11. Safe storage container is raised off the floor and stably situated. | |
| | 12. Safe storage container is out of reach of animals and small children. | |
| | 13. Lids are kept on tight, and only opened for addition or pouring of treated water. | |
| ***Maintenance*** | 14. Regularly scheduled cleaning of the storage unit. | |
| | 15. Soap or disinfectant used to clean storage unit can be produced by user. | |
| ***Replacement Period*** | 16. User knows that product expires 5 years after date of manufacture, as printed on Aquatab sleeve. | |
| ***Physical Inspection*** | 17. Water bottles for use during travel or school are clean and producible to the interviewer if consistent use is claimed outside the home. | |
| | 18. At least one sleeve of ten non-expired tablets is in stock and easily accessible. | |

| | | |
|---|---|---|
| | 19. A dedicated clean cup is associated with the safe storage unit. | |
| **Percentage of observations passed = #Yes / (#Yes + #No) X 100%** | | |
| **Notes:** | | |

| **Water Quality Monitoring** | | ( Yes/No/ NA) |
|---|---|---|
| *Turbidity* | Turbidity is <80 NTU. | |
| *Chlorine Residual* | Free available chlorine presence is shown if treatment is claimed. | |
| *Microbial Testing* | Microbial testing shows <10 *E.coli* CFU/100 ml. | |
| **Notes:** | | |

| Sample from Storage of Treated Water | 24 hr Colilert (Yes/No) | | 24 hr Petrifilm (Count) | | # *E.coli*/ 100ml | **Risk Level** |
|---|---|---|---|---|---|---|
| | Yellow? | Fluoresces? | # Blue w/gas | # w/gas | | |
| | | | | | | |

Incubate Colilert and Petrifilm at body temperature (35°C) for 24 hours (or until results appear), then check:

**Colilert**: If the water is clear: <10 Total Coliform/100ml and <10 *E.coli*/100ml
If the water is yellow: >10 Total Coliform/100ml
If the water is yellow and fluoresces: >10 Total Coliform/100ml and >10 *E.coli*/100ml

**Petrifilm:** # of colonies w/gas X 100= # of Total Coliform/100ml; # of Blue w/gas X 100= # of *E.coli*/100ml;
No Blue colonies with gas= <100 *E.coli*/100ml; No colonies with gas = <100 TotalColiform/100ml.

**Risk Level:** Low is <10 *E.coli* /100ml; Intermediate is 10-100 *E.coli* /100ml; High is >100 *E.coli* /100ml.

| | |
|---|---|
| ***Sampling Procedure*** | 1. Test for presence of chlorine residual in stored water while at the household if chlorine treatment is claimed. |
| | 2. Take a sample of treated water from the storage unit for microbial analysis. Use a Sodium Thiosulphate sampling bag if transporting sample to laboratory. Keep the sample out of the sun and start microbial test within 6 hours. |

| SODIS Effective Use Monitoring Checklist | |
|---|---|
| Monitor Name: | |
| Community: | |
| Interviewee Name: | |
| Household/Code: | |
| Date and Time: | |
| GPS Coordinates: | ____________________ ____________________ |
| Notes: | |

| **Instructions:** For each observation, fill in Yes, No, or NA for observations that do not apply. Add up the total #Yes, divide by the total # of observations made, and multiply by 100 for % Observational Effective Use. | | |
|---|---|---|
| **Monitoring Observations** | **Checklist** | ( Yes/No/ NA) |
| ***Treatment*** | 1. User demonstrates knowledge of treatment and dosing as intended by manufacturer's specifications, without prompting from the monitor: | |
| | 1.1. Fill clean bottles with water and close lid tightly. | |
| | 1.2. Place the bottles on a corrugated iron sheet or on the roof, and in a place with continuous direct sunlight throughout the day | |
| | 1.3. Leave in direct sun from morning to dusk. | |
| | 1.4. If ≥50% overcast, leave out for 2 days | |
| | 5. Use of clean and clear PET bottles that are ≤5 liters in volume and not heavily scratched | |
| ***Safe Storage*** | 6. Storage bottles with treated water are stored safely and out of reach of small children. | |
| | 7. Lids are kept on tight, and only opened for addition or pouring of treated water. | |
| | 8. Secondary safe storage is not witnessed. | |
| ***Maintenance*** | 9. Bottles are clean. | |
| | 10. Soap used to clean bottles can be produced. | |
| ***Replacement Period*** | 11. Bottles are not scratched or opaque. | |
| | 12. Bottles do not leak. | |
| ***Physical Inspection*** | 13. Treated water is available. | |
| | 14. If weather conditions permit, water is currently being treated. | |
| | 15. A dedicated clean cup is associated with the safe storage unit. | |
| **Percentage of observations passed** | **= #Yes / (#Yes + #No) X 100%** | |
| **Notes:** | | |

| **Water Quality Monitoring** | | ( Yes/No/ NA) |
|---|---|---|
| *Turbidity* | If when one's hand is placed under a filled bottle laying horizontally and the fingers are still visible, then the turbidity requirement is satisfied | |
| *Microbial Testing* | Microbial testing shows <10 *E.coli* CFU/100 ml | |

**Notes:**

| Sample from Storage of Treated Water | 24 hr Colilert (Yes/No) | | 24 hr Petrifilm (Count) | | # *E.coli*/ 100ml | **Risk Level** |
|---|---|---|---|---|---|---|
| | Yellow? | Flouresces? | # Blue w/gas | # w/gas | | |
| | | | | | | |

Incubate Colilert and Petrifilm at body temperature (35°C) for 24 hours (or until results appear), then check:

**Colilert**: If tube is clear following incubation, <10 of both Total Coliform and *E.coli*/100ml are present;
If the water is yellow, >10 Total Coliform/100ml are present;
If tube is yellow and fluoresces, >10 of both Total Coliform and *E.coli*/100ml are present.

**Petrifilm:** # of colonies w/gas X 100= # of Total Coliform/100ml; # of Blue w/gas X 100= # of *E.coli*/100ml;
No Blue colonies with gas= <100 *E.coli*/100ml; No colonies with gas = <100 TotalColiform/100ml.

**Risk Level:** Low is <10 *E.coli* /100ml; Intermediate is 10-100 *E.coli* /100ml; High is >100 *E.coli* /100ml.

| | |
|---|---|
| ***Sampling Procedure*** | 1. Take a sample of the treated water from the bottles in storage for microbial analysis. Keep the sample out of the sun and start microbial test within 6 hours. |

## Cloth Filter Effective Use Monitoring Checklist

| | |
|---|---|
| Monitor Name: | |
| Community: | |
| Interviewee Name: | |
| Household/Code: | |
| Date and Time: | |
| GPS Coordinates: | ____________________ ____________________ |

Notes:

**Instructions:** For each observation, fill in Yes, No, or NA for observations that do not apply. Add up the total #Yes, divide by the total # of observations made, and multiply by 100 for % Observational Effective Use. No water sampling or testing is needed to measure Effective Use of the Cloth Filter.

| **Monitoring Observations** | **Checklist** | ( Yes/No/ NA) |
|---|---|---|
| ***Treatment*** | 1. Fastens manufactured cloth tightly to water storage vessel before adding water to maintain separation of filtered water. | |
| | 2. Always use manufactured cloth filters with the same side up | |
| | 3. Fold sari cloth at least 4 times and wrap tightly around rim of storage vessel inlet before adding. | |
| | 4. Filter all water immediately while at the source or upon returning home from the source. | |
| | 5. Use filtered water for all domestic water uses | |
| ***Storage*** | 6. Maintain separation of filtered water from non-filtered water. | |
| ***Maintenance*** | 7. Rinse off filter after each use, with a final rinse of cloth filtered water. | |
| | 8. Leave cloth in the sun for decontamination. | |
| | 9. Clean cloth filter with soap regularly (if instructed). | |
| | 10. Monitor witnesses that cloth filter is clean. | |
| | 11. Soap or detergent used to clean cloth filter can be produced by user (if applicable). | |
| ***Replacement Period*** | 12. Monitor witnesses that cloth filter has no tears or holes. | |
| ***Physical Inspection*** | 13. User stores cloth filter in a safe and accessible place | |
| | 14. User knows where to get a new cloth filter when needed (if bought or distributed). | |
| **Percentage of observations passed** | **= #Yes / (#Yes + #No) X 100%** | |

**Notes:**

| Ceramic Pot Filter Effective Use Monitoring Checklist | |
|---|---|
| Monitor Name: | |
| Community: | |
| Interviewee Name: | |
| Household/Code: | |
| Date and Time: | |
| GPS Coordinates: | ____________________ ____________________ |
| Notes: | |

**Instructions:** For each observation, fill in Yes, No, or NA for observations that do not apply. Add up the total #Yes, divide by the total # of observations made, and multiply by 100 for % Observational Effective Use.

| **Monitoring Observations** | **Checklist** | ( Yes/No/ NA) |
|---|---|---|
| ***Treatment*** | 1. Water is added to the CWP every day. | |
| | 2. Ceramic pot is frequently topped off in order to achieve faster flow rate. | |
| | 3. Ceramic pot is not overfilled. Water level is not above 3cm below the lip of the pot. | |
| | 4. Storage unit is not filled above the bottom of the ceramic pot. | |
| | 5. Lid for the CWP is kept in place except when being filled. | |
| | 6. Turbid waters undergo settling for at least one hour before ceramic filtration. | |
| | 7. CWP is raised above the ground to near table height | |
| | 8. CWP its level on a stable base. | |
| | 9. CWP located out of direct sunlight. | |
| | 10. CWP out of reach of young children and animals. | |
| ***Storage*** | 11. Pot remains in place throughout use as directed, maintaining a closed storage unit. | |
| | 12. Storage unit is clean inside and out (if accessible). | |
| | 13. Secondary safe storage is not used without chlorine disinfection. | |
| ***Maintenance*** | 14. Does the user have a good scheduling mechanism for cleanings? | |
| | 15. User correctly demonstrates scrubbing the inside of the pot with a hygienic brush and rinse with filtered or boiled, cooled water. | |
| | 16. User never uses soap or disinfectant with the ceramic pot itself. | |
| | 17. Ceramic pot, storage unit and tap are clean with no visible leaks or cracks. | |

| | | |
|---|---|---|
| ***Physical Inspection*** | 18. There is water in the storage unit. | |
| | 19. Ceramic pot is partially full or at least damp. | |
| | 20. Water bottles for use during travel or school are clean and producible to the interviewer if consistent use is claimed. | |
| | 21. User demonstrates hygienic method when asked to add or fetch water to the CWP. | |
| | 22. Instructional material is displayed with the CWP, if provided during purchase or installation. | |
| **Percentage of observations passed** | **= #Yes / (#Yes + #No) X 100%** | |
| **Notes:** | | |

| **Water Quality Monitoring** | | ( Yes/No/ NA) |
|---|---|---|
| *Turbidity* | Treated water is expected to be clear (<5NTU) unless influent is >100NTU. | |
| *Chlorine Residual* | Free available chlorine presence in secondary safe storage if chlorine treatment is claimed. | |
| *Microbial Testing* | Microbial testing shows <10 *E.coli* CFU/100 ml of treated water from storage unit(s). | |
| **Notes:** | | |

| Sample from Storage of Treated Water | 24 hr Colilert (Yes/No) | | 24 hr Petrifilm (Count) | | # *E.coli*/ 100ml | **Risk Level** |
|---|---|---|---|---|---|---|
| | Yellow? | Fluoresces? | # Blue w/gas | # w/gas | | |
| | | | | | | |

Incubate Colilert and Petrifilm at body temperature (35°C) for 24 hours (or until results appear), then check:

**Colilert**: If the water is clear: <10 Total Coliform/100ml and <10 *E.coli*/100ml
If the water is yellow: >10 Total Coliform/100ml
If the water is yellow and fluoresces: >10 Total Coliform/100ml and >10 *E.coli*/100ml

**Petrifilm:** # of colonies w/gas X 100= # of Total Coliform/100ml; # of Blue w/gas X 100= # of *E.coli*/100ml;
No Blue colonies with gas= <100 *E.coli*/100ml; No colonies with gas = <100 TotalColiform/100ml.

**Risk Level:** Low is <10 *E.coli* /100ml; Intermediate is 10-100 *E.coli* /100ml; High is >100 *E.coli* /100ml.

| | |
|---|---|
| ***Sampling Procedure*** | 1. If treated water is visibly dirty, check the turbidity if sufficient volume exists. |
| | 2. Check that the flow rate sounds like one drip a second or so. |
| | 3. Take a sample of treated water from the CWP storage unit for microbial analysis. Keep the sample out of the sun and start microbial test within 6 hours. |
| | 4. If a secondary safe storage container is used, take a sample for microbial analysis. If chlorine treatement is claimed by user, test for presence of chlorine residual while at the household and use a Sodium Thiosulphate sampling bag for transporting sample to laboratory. |

| Biosand Filter Effective Use Monitoring Checklist | | |
|---|---|---|
| Monitor Name: | | |
| Community: | | |
| Interviewee Name: | | |
| Household/Code: | | |
| Date and Time: | | |
| GPS Coordinates: | ____________________ ____________________ | |
| Notes: | | |
| **Instructions:** For each observation, fill in Yes, No, or NA for observations that do not apply. Add up the total #Yes, divide by the total # of observations made, and multiply by 100 for % Observational Effective Use. | | |

| **Monitoring Observations** | **Checklist** | (Yes/No/ NA) |
|---|---|---|
| ***Treatment*** | 1. Water is added daily to the filter. | |
| | 2. Uses separate containers to fetch/pour dirty water and store filtered water. | |
| | 3. Adds water slowly with the diffuser plate in place. | |
| | 4. Pretreatment is claimed for turbid waters (>100NTU). | |
| | 5. The spout is unobstructed and clean. | |
| | 6. Smooth and level sand bed at water depth of 4-6 cm. | |
| | 7. BSF is sitting flat on firm ground. | |
| | 8. The lid to the filter is in place and clean. | |
| | 9. System is out of direct sunlight. | |
| | 10. System is out of reach of animals. | |
| | 11. Filter has no visible leaks or cracks. | |
| | 12. Filter flowrate is ~0.6 L/min. | |
| ***Storage*** | 13. Dedicated safe storage unit is used. | |
| | 14. Design of safe storage unit incorporates a tap or a small sealable opening for pouring. | |
| | 15. The safe storage container has a lid that is kept on tight except for adding or pouring treated water. | |
| | 16. Safe storage container is located with the BSF indoors, out of the sun, off of the floor, in a stable position and out of reach of animals and small children. | |
| | 17. Safe storage unit is visibly clean. | |
| ***Maintenance*** | 18. User uses and demonstrates "swirl and dump" cleaning method: | |
| | 18.1. Adds ~4 liters of water to the top of the filter | |
| | 18.2. Scoops out dirty water with small container, levels sand and replaces diffuser plate. | |
| | 18.3. Fills with water and repeats the process if flow rate is still slow. | |
| | 21. Filter cleaning schedule is determined by significant reduction in flowrate. | |
| | 22. BSF cleaned less than once a week. | |

| | | |
|---|---|---|
| | 23. User cleans the spout and storage unit with treated water and soap or chlorine solution each week. | |
| | 24. Soap or disinfectant used to clean storage unit can be produced by user. | |
| ***Physical Inspection*** | 25. Water bottles for use during travel or school are clean and producible to the interviewer if consistent use is claimed outside the home. | |
| | 26. User demonstrates hygienic method when asked to add water to filter and fetch a glass of water. | |
| | 27. A dedicated clean drinking cup is associated with the safe storage unit. | |
| **Percentage of observations passed** | **= #Yes / (#Yes + #No) X 100%** | |
| **Notes:** | | |

| **Water Quality Monitoring** | | ( Yes/No/ NA) |
|---|---|---|
| *Turbidity* | Treated water is clear (Turbidity of <5 NTU). | |
| *Chlorine Residual* | Free available chlorine presence in safe storage if chlorine treatment is claimed | |
| *Microbial Testing* | Microbial testing shows <10 *E.coli* CFU/100 ml in water from both running spout and storage unit. | |
| **Notes:** | | |

| Sample from running spout | 24 hr Colilert (Yes/No) | | 24 hr Petrifilm (Count) | | # *E.coli*/ 100ml | **Risk Level** |
|---|---|---|---|---|---|---|
| | Yellow? | Fluoresces? | # Blue w/gas | # w/gas | | |
| | | | | | | |

| Sample from storage of treated water | 24 hr Colilert (Yes/No) | | 24 hr Petrifilm (Count) | | # *E.coli*/ 100ml | **Risk Level** |
|---|---|---|---|---|---|---|
| | Yellow? | Fluoresces? | # Blue w/gas | # w/gas | | |
| | | | | | | |

Incubate Colilert and Petrifilm at body temperature (35°C) for 24 hours (or until results appear), then check:

**Colilert**: If the water is clear: <10 Total Coliform/100ml and <10 *E.coli*/100ml
If the water is yellow: >10 Total Coliform/100ml
If the water is yellow and fluoresces: >10 Total Coliform/100ml and >10 *E.coli*/100ml

**Petrifilm:** # of colonies w/gas X 100= # of Total Coliform/100ml; # of Blue w/gas X 100= # of *E.coli*/100ml;
No Blue colonies with gas= <100 *E.coli*/100ml; No colonies with gas = <100 TotalColiform/100ml.

**Risk Level:** Low is <10 *E.coli* /100ml; Intermediate is 10-100 *E.coli* /100ml; High is >100 *E.coli* /100ml.

| | |
|---|---|
| ***Sampling Procedure*** | 1. Take a sample of treated water from the storage unit for microbial analysis (if available). If chlorine treatment is claimed in stored water, test for presence of chlorine residual while at the household and use a Sodium Thiosulphate sampling bag for transporting sample to laboratory. Keep the sample out of the sun and start microbial tests within 6 hours. |
| | 2. Fill the BSF to a consistent level (not to the top). |
| | 3. Check the turbidity of the filtering water if it is visible and sufficient volume exists. |
| | 4. While taking a sample for microbial analysis from the pouring BSF spout, take a flow rate measurement by counting seconds until 100ml is full in the Whirlpak bag. |

| PUR Effective Use Monitoring Checklist | | |
|---|---|---|
| Monitor Name: | | |
| Community: | | |
| Interviewee Name: | | |
| Household/Code: | | |
| Date and Time: | | |
| GPS Coordinates: | ____________ ____________ | |
| Notes: | | |
| **Instructions:** For each observation, fill in Yes, No, or NA for observations that do not apply. Add up the total #Yes, divide by the total # of observations made, and multiply by 100 for % Observational Effective Use. | | |
| **Monitoring Observations** | **Checklist** | ( Yes/No/ NA) |
| ***Treatment*** | User demonstrates knowledge of treatment and dosing as intended by Proctor and Gamble, without prompting from the monitor: | |
| | 1. Add: Cut open one packet and add contents to ten liters of water | |
| | 2. Mix: Stir aggressively for 5 minutes and let sit for 5 minutes; if non-flocculated after the wait, stir again until floc falls out. | |
| | 3. Filter: Poor water into clean storage container through a clean and dry cotton cloth without holes. | |
| | 4. Drink: Wait 20 minutes to drink. Do not consume if yellow. | |
| | 5. Complete consumption of the ten liters of treated water should occur within 24 hours. | |
| ***Storage*** | 6. Two separate, dedicated 10 liter containers for fetching/flocculation and disinfection/storage are used. | |
| | 7. The volume for treatment as specified on the hypochlorite product is easily measurable in the safe storage container. | |
| | 8. Design of safe storage unit has a tap or a small sealable opening for pouring. | |
| | 9. Safe storage container is clean, and has no leaks. | |
| | 10. Safe storage container is out of the sun. | |
| | 11. Safe storage container is indoors. | |
| | 12. Safe storage container is raised off the floor and stably situated. | |
| | 13. Safe storage container is out of reach of animals and small children. | |
| | 14. Lids are kept on tight, and only opened for addition or pouring of treated water. | |

| | | |
|---|---|---|
| ***Maintenance*** | 15. Rinse off the cloth filter after each use, with a final rinse of cloth filtered water. | |
| | 16. Leave cloth in the sun for decontamination. | |
| | 17. Regular cleaning of cloth filter with soap. | |
| | 18. Regular cleaning of the treatment and storage containers with soap or disinfectant. | |
| | 19. Soap or disinfectant used to clean storage unit and cloth filter can be produced by user. | |
| ***Replacement Period*** | 20. User knows that product expires 3 years after date of manufacture, as is printed on sachet. | |
| ***Physical Inspection*** | 21. Water bottles for use during travel or school are clean and producible to the interviewer if consistent use is claimed outside the home. | |
| | 22. The household contains a supply of unexpired sachets for consistent use. | |
| | 23. A dedicated clean cup is associated with the safe storage unit. | |
| **Percentage of observations passed** | **= #Yes / (#Yes + #No) X 100%** | |
| **Notes:** | | |

| **Water Quality Monitoring** | | ( Yes/No/ NA) |
|---|---|---|
| *Turbidity* | Treated water is clear (Turbidity of <5 NTU) | |
| *Chlorine Residual* | Free available chlorine presence is shown if treatment is claimed. | |
| *Microbial Testing* | Microbial testing shows <10 *E.coli* CFU/100 ml. | |
| **Notes:** | | |

| Sample from Storage of Treated Water | 24 hr Colilert (Yes/No) | | 24 hr Petrifilm (Count) | | # *E.coli*/ 100ml | **Risk Level** |
|---|---|---|---|---|---|---|
| | Yellow? | Fluoresces? | # Blue w/gas | # w/gas | | |
| | | | | | | |

Incubate Colilert and Petrifilm at body temperature (35°C) for 24 hours (or until results appear), then check:

**Colilert**: If the water is clear: <10 Total Coliform/100ml and <10 *E.coli*/100ml
If the water is yellow: >10 Total Coliform/100ml
If the water is yellow and fluoresces: >10 Total Coliform/100ml and >10 *E.coli*/100ml

**Petrifilm:** # of colonies w/gas X 100= # of Total Coliform/100ml; # of Blue w/gas X 100= # of *E.coli*/100ml;
No Blue colonies with gas= <100 *E.coli*/100ml; No colonies with gas = <100 TotalColiform/100ml.

**Risk Level:** Low is <10 *E.coli* /100ml; Intermediate is 10-100 *E.coli* /100ml; High is >100 *E.coli* /100ml.

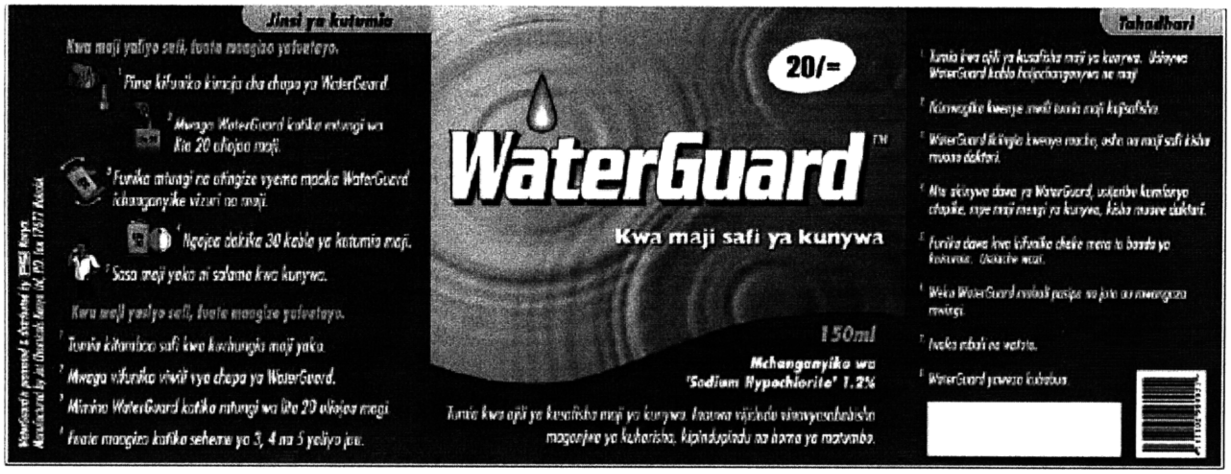
| | |
|---|---|
| ***Sampling Procedure*** | 1. Test for presence of chlorine residual in stored water while at household if chlorine treatment is claimed. |
| | 2. Take a sample of treated water from the storage unit for microbial analysis. Use a Sodium Thiosulphate sampling bag if transporting sample to laboratory. Keep the sample out of the sun and start microbial test within 6 hours. |

## *Appendix F: Usage Instructions per Technology*

Sodium Hypochlorite Solution
Aquatabs
SODIS
Cloth Filter
Ceramic Pot Filter
Biosand Filter
PUR

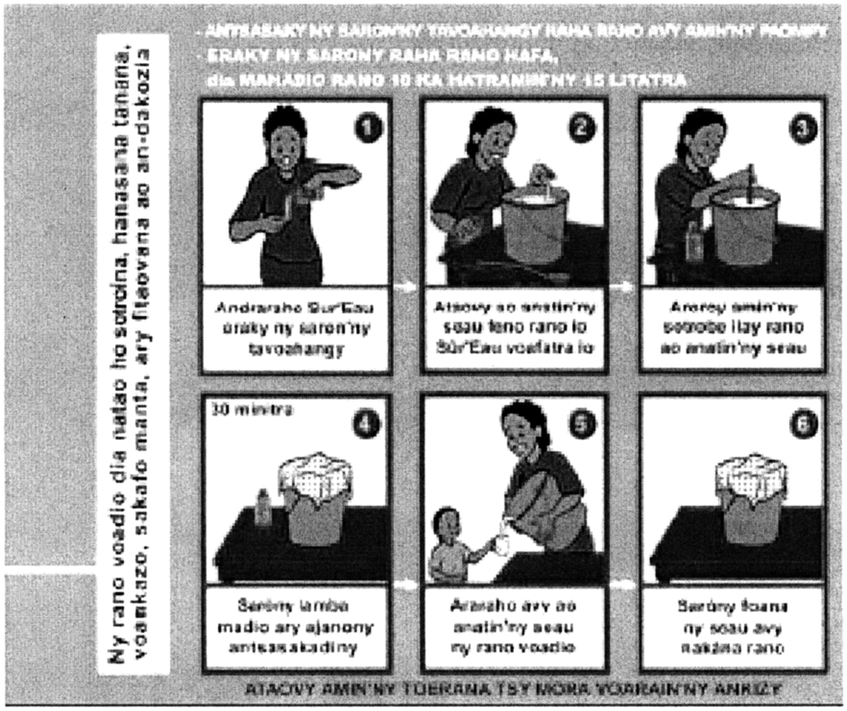
**Sodium Hypochlorite Solution Usage Instructions**

PSI, Kenya. Printed in Kiswahili, this label is well suited to Kenya's highly literate population.




(POUZN, 2007)

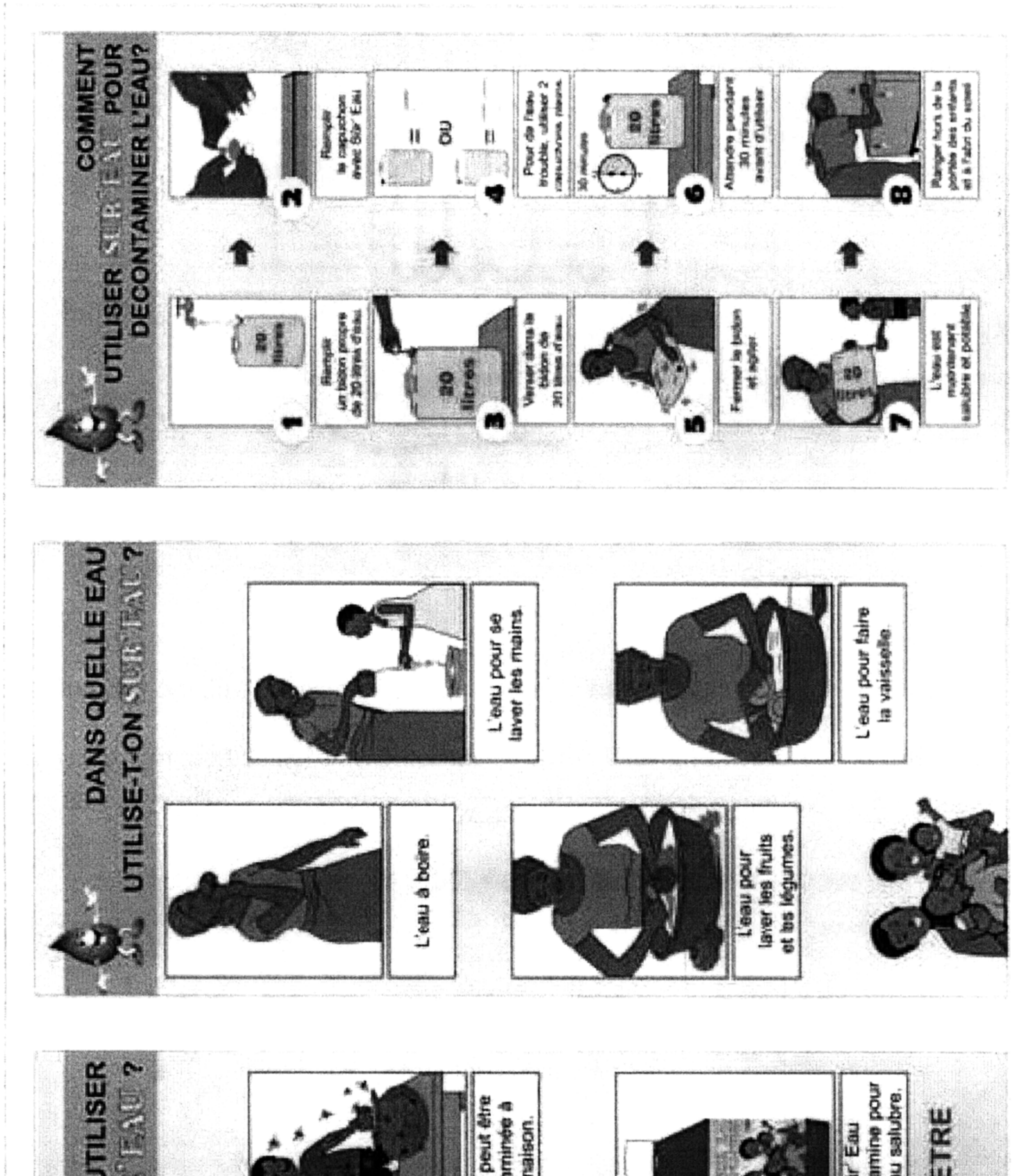
PSI, Madagascar. This label is well suited for both literate and non-literate users.




(POUZN, 2007)

PSI, Ethiopia. 150ml WahuAgar (Waterguard) product, Printed in Amharic without pictorial representations (Left).
CAWST Disinfection Black English 27 maintenance poster as handed out to users (right)


PSI Guinea Educational Materials (Lantagne, 2008)



**Aquatabs Usage Instructions**

**From Aquatabs Sleeve of Precision dx Ltd.**, Accra, Ghana. All information is printed for every two tabs on the ten-tab sleeve:

NaDCC 67mg
Use one tab to treat 20 litres of clear water in a jerrycan. If the water is dirty, filter it first with cloth then treat with two tabs. Close your jerrycan and wait for 30 minutes before use. Do not swallow the tablet. Medentech, Ireland. Distributed by Precision dx Ltd.

On the reverse side, bin number and expiration date are listed.

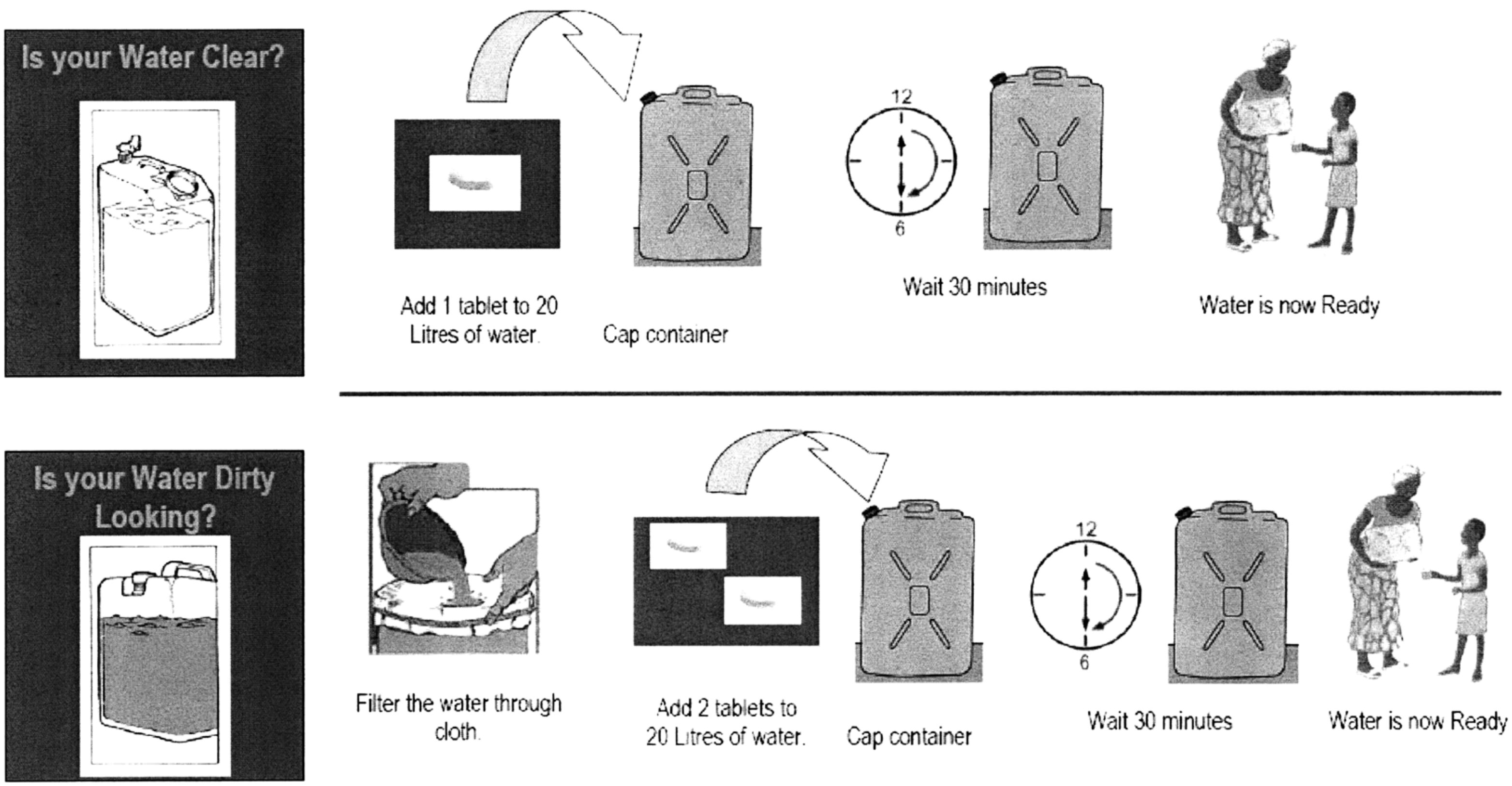
Additional information from Medentech Website:

How do I Use Aquatabs?

- The tablet is added to the appropriate volume of water. Wait at least 30 minutes before using the water. The tablets do not need to be crushed; they will self-dissolve to give clear solutions.
- No stirring or shaking is necessary for the smaller, strip-packed tablets.
- For larger volumes of water (200 litres and above) the water should be mixed, for example by re-circulation, to ensure an even distribution of the chlorine.
- Where the water is very turbid, for example greater than approximately 80 NTU, then it should be filtered to reduce the turbidity before adding the Aquatabs

from Medentech's AquatabTechnical Report 06:

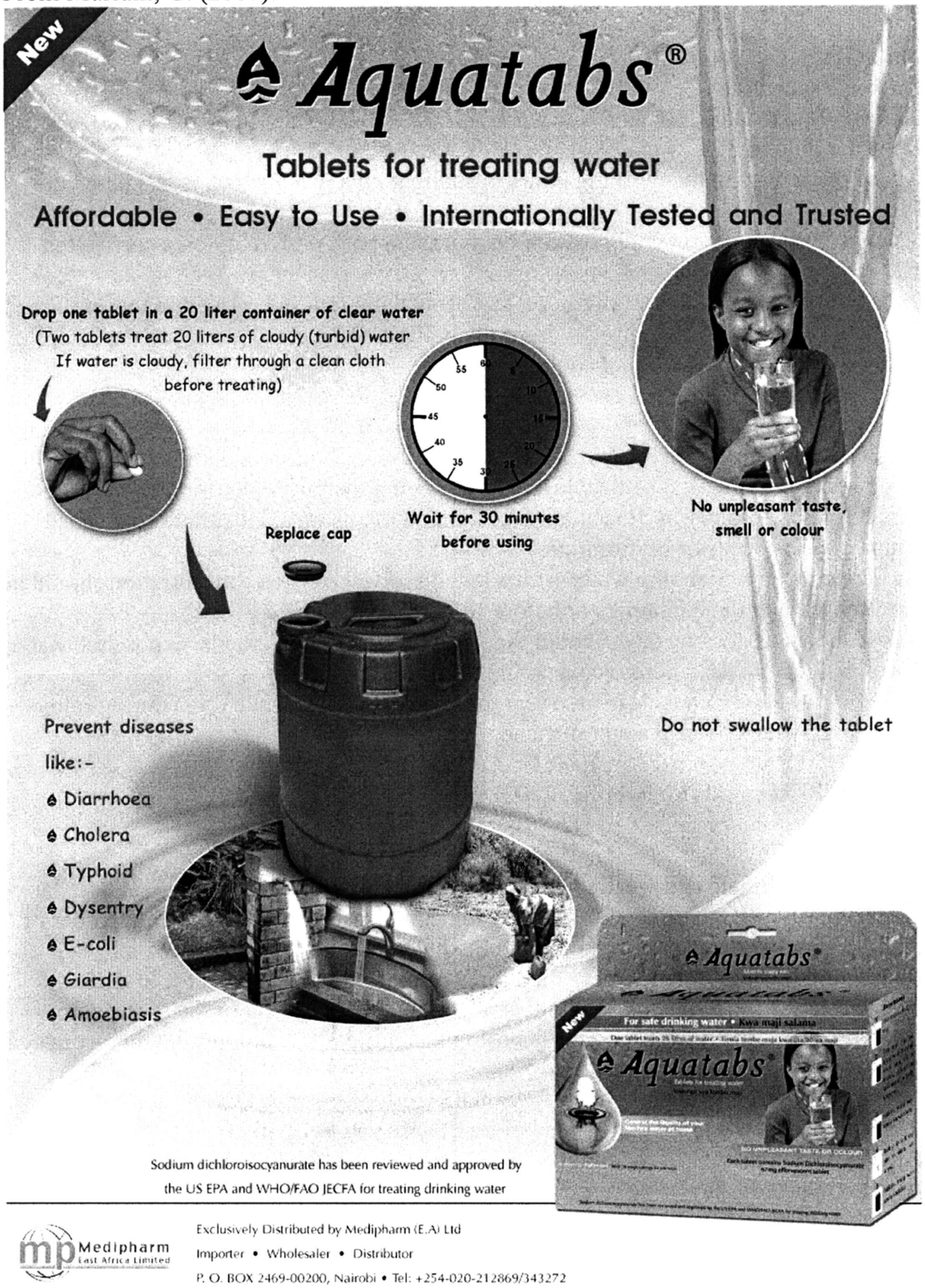
# Aquatabs® 67mg Instructions




**Remember: Do not swallow tablets and always keep your water container tightly closed**

Instructions & Pictures compiled with thanks to CDC (Centers for Disease Control and Prevention) and PSI (Population Services International)
Medentech Ltd., Co. Wexford, Ireland Tel: + 353 53 9160040 Fax: + 353 53 9141271 E-mail : enquiry@medentech.com Web: www.medentech.com

From Muriuki, G. (2007):



**SODIS Usage Instructions**

**From SODIS Tech Note 13**
**Exposing Procedure**
• Fill the bottles completely with raw water
• Screw the plug tightly
• Expose the bottles in the morning hours to sunlight on a place which is irradiated the full day
• Place the bottles in horizontal position on a firm support, preferably on a corrugated iron sheet/roof or on a tile roof
• Collect the bottles in the late afternoon and bring them to a safe place for cooling
• Consume the treated water directly from the bottle using a clean glass or a cup, store it possibly overnight for additional cooling

**Additional Prescriptions**
• Use clean water free of settleable solids and of a low turbidity (maximum turbidity 30 NTU). Separate coarse and settleable solids by storing the raw water for one day and reduce turbidity possibly by flocculation/sedimentation using alum sulfate or crushed Moringa oleifera seeds or by filtration.
• Use aerated water. Standing water with a low dissolved oxygen concentration should be aerated by shaking the containers or before filling the containers.
• Expose the water for one day. Should the sky be covered with clouds, expose the water for two consecutive days before consuming it.
• Collect rain water from a clean area (e.g. from a corrugated or tile roof) during rainy days to cover your drinking water demand.

**From SODIS Manual** (Meierhofer, 2002)
*Application Procedure*
**Preparation**
1. Check if the climate and weather conditions are suitable for SODIS.
2. Collect plastic PET-bottles of 1-2 litre volume. At least 2 bottles for each member of the family should be exposed to the sun while the other 2 bottles are ready for consumption. Each family member therefore requires 4 plastic bottles for SODIS.
3. Check the water tightness of the bottles, including the condition of the screw cap.
4. Choose a suitable underground for exposing the bottle, for example a CGI (corrugated iron) sheet.
5. Check if the water is clear enough for SODIS (turbidity <30 NTU). Water with a higher turbidity needs to be pretreated before SODIS can be applied.
6. At least two members of the family should be trained in the SODIS application.
7. A specific person should be responsible for exposing the SODIS bottles to the sun.
8. Replace old and scratched bottles.

**From** KWAHO (2005) Promotional Poster
**How to use SODIS**
1. Wash the bottle well before the first time you use it.

2. Use the cleanest water you can get. If your water is dirty leave it in your bucket for some time to settle it down. Use a clean cup to fill your SODIS-bottle and leave the residue at the bottom.
3. Fill the bottle ¾ full with water.
4. Shake the bottle for 20 seconds.
5. Fill up your SODIS-bottle completely with water and close it. Only a small air bubble should be seen after turning around the bottle.
6. Lay down your SODIS-bottle in the sun, e.g. on your roof.
7. Leave your SODIS-bottle for at least 6 hours from morning till evening in the sun. If it is cloudy, expose your SODIS-bottle at least 2 days to the sun.
8. The water is now ready for drinking.

Keep your SODIS-bottle clean. Replace your bottle when it got too many scratches and is not clear any more.

**Sun Water GRI framework**:
To use the sun to purify water, put water in clean and clear or slightly blue plastic or glass bottles with tops. Remove bottles. Use 1 or 2 liter bottles.

- Leave one inch of air at the top of each bottle. Shake for 15 seconds.
- The water cannot be too cloudy. Large printed letters should be visible through the bottle. If necessary, filter water through clean sand or several layers of cloth before putting it in bottles.

Place the bottles outdoors in the sun for 5 hours or for a full day in cloudy weather. Put them in a clean place away from animals and not in the shade. It is best if the bottles are inclined so they receive the most sunlight and placed on a black surface in order to warm them.

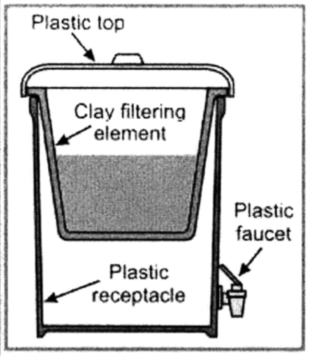
This process produces clean drinking water that is safe from bacteria and viruses. However, clean water is not medicine. It will not protect you if you also drink unclean water.

This process does NOT remove chemicals, pesticides, worms, or cysts.

## Ceramic Pot Filter Usage Instructions

Instructions for Use of Ceramic filter (PFP, 2007) from (Swanton, 2008)

# HOW TO USE YOUR FILTRON




**1. Washing the RECEPTACLE**

Wash your hands with soap .
Attach the spigot (faucet) to the plastic receptacle.
Fill the receptacle one quarter full with water and add two tablespoons of chlorine bleach.
Leave this for thirty minutes to disinfect the plastic receptacle.
Use this water to wash the entire inside of the plastic receptacle and the lid with a brush or cloth.
Drain the water out through the spigot to disinfect.
If you do not have bleach, wash the receptacle and lid with soap and water as described above.
You can use either filtered or boiled water to rinse.

2) Place the plastic receptacle in a location that is stable and out of the way of activity.

Using both hands on the edge of the clay filter, place it on the mouth of the receptacle.

3) To get rid of the clay taste of the new filter, fill it with water and drain through the spigot. Repeat until all taste is gone.

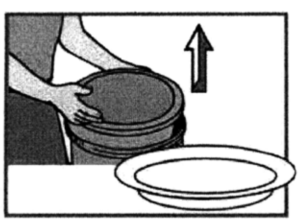
4) If your water is turbid, strain it through a clean piece of fine cloth. Tie the cloth in place around the outside of the plastic receptacle.

5) **Keep your filter filled and covered at all times.**

The filter will flow more rapidly (one to two liters per hour) if it is kept full.

Remember: Before serving water wash your hands and cups with soap.

# HOW TO CLEAN YOUR FILTRON

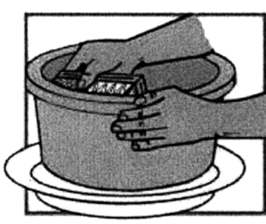


**Cleaning your CLAY FILTER**

1) When the flow rate decreases, it is a signal that the pores of the clay filter are clogged.

To wash:

- **Do not lift the clay filter when it is full of water.** Wait until the clay filter is empty and there is filtered water in the plastic receptacle.
- Wash your hands with soap.
- Remove the clay filter from the plastic receptacle and put it on a plate that has been washed with filtered water.



- Pour a few inches of filtered water back into the filter.
- Scrub the filter with a stiff laundry brush on the inside and outside to remove any debris or particles.
- Do not worry if some of the clay comes off. It means you are scrubbing well.
- Rinse with filtered water until the water is clear.

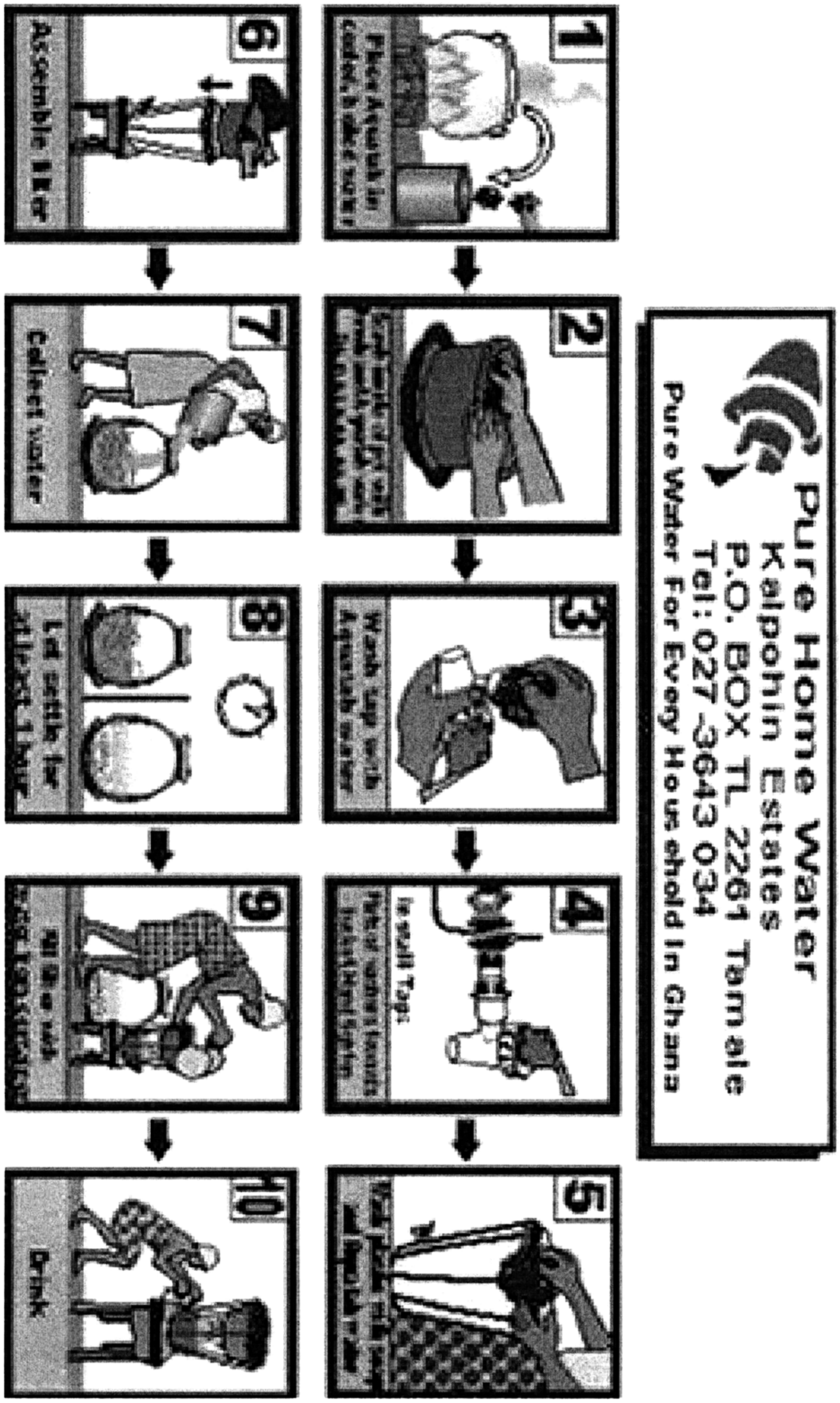
**Attention! Never use chlorinated water or soap to wash the clay filter.**

3) **Washing the PLASTIC RECEPTACLE**

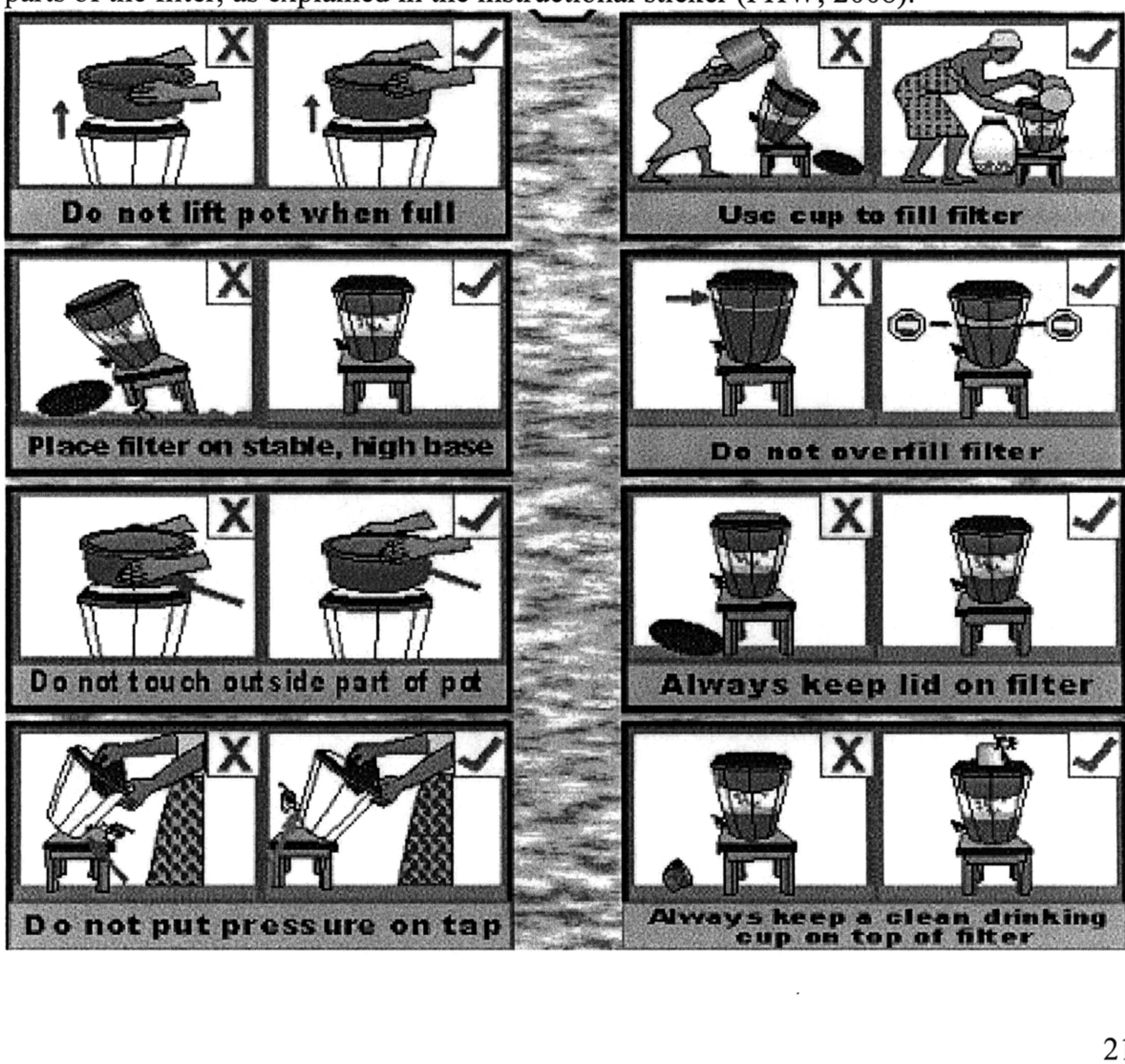
Wash the plastic receptacle each month with chlorinated water or with soap as explained in part 1. Once you have finished washing, return the clay filter to the plastic receptacle to begin use.

**Attention: The Filtron filter generally functions well for a year and a half or more. If you have problems, contact the organization that distributed your filter for advice on what to do.**

Pure Home Water Usage Poster (PHW, 2008)



The Instructional Sheet or Sticker pictorially shows users how to assemble, set-up and operate and maintain their *Kosim* filter. It also shows a STOP line, indicating to users the acceptable level of water in the safe storage container. The sticker is placed on the storage unit such that the Stop line is below the bottom of the ceramic pot, preventing back flow into the filter from overfilling. Finally the sticker shows "Do's and Don'ts" which are some of the common mistakes made by users in their operation and maintenance of the Kosim filter and the manner by which to correct each error. The Tap Installation Sheet shows the correct position of the washers and nut when installing the tap. Additionally, each filter sold by Pure Home Water includes one Aquatab, a chlorine tablet made by Medentech. This Aquatab is to be used in the first cleaning of the plastic parts of the filter, as explained in the instructional sticker (PHW, 2008).




B

**Biosand Filter Usage Instructions**

**Samaritan's Purse "Biosand Water Filter: User Instructions" (2001)**
(As used by Kale Hewyet Church, Ethiopia)
1. ONLY pour water in the filter with the diffuser basin in place - failing to do this will damage the filter.
2. ALWAYS use two buckets: one to pour in dirty water and one to collect filtered water. If only one bucket is used, the dirty bucket will contaminate the filtered water.
3. NEVER attach anything to the tap, such as a longer pipe, a hose or a valve.
4. ALWAYS use filtered water for as many tasks as possible: drinking, cooking, cleaning food, cleaning clothes, washing children, and feeding animals. Using the filter for all your water needs will contribute to better health.
5. NEVER put bleach in the water before pouring it into the filter and NEVER pour bleach directly into the filter - this will damage the filter.
6. ALWAYS pour the water into your filter SLOWLY.
7. NEVER move the filter once it has been installed - unless it is an emergency. Moving the filter will cause water to come out more slowly. If moved, the filter must be placed in a level position before using.
8. ALWAYS keep the lid on the filter when not in use.
9. DO NOT touch the tap of the filter unless cleaning it - keep animals and children away.
10. MAINTENANCE:

a) CLEAN tap once each week with a diluted bleach solution or soap.

b) When the flow of water out of the filter becomes much, much slower than its original flow—this will be a slight trickle, almost dripping rather than flowing in a stream—it is time to maintain the sand. At this point there will be a visible, thick layer on top of the sand either brown or green in color. To maintain the filter, put your hand or a spoon in the filter and down into top 2-3cm of sand. Stir in a circle until the water becomes dark and then scoop this water out with a cup. Continue to stir and scoop water out until all the water is gone above the sand. Be careful not to scoop out sand. Add water to the filter and repeat this process until the water is clear. Then level the sand, replace the diffuser basin and pour water back into the filter. Do not take sand out of the filter. Finally, always check the level of water above the sand once you are finished. it should be 5cm or the second finger joint.
(Samaritan's Purse, 2001)

**Samaritan's Purse recommended maintenance procedures**
(As used by Kale Hewyet Church, Ethiopia. Taken from *Appendix 6* of Earwaker, 2006)

**Used during Phase 1, pilot implementation**

- Remove the filter cover and diffuser plate
- Lower the water level in the filter by scooping out water from the top of the filter with a small cup.
- Remove approximately 2.5-5cm of sand which should be discarded or washed and reused.

- Add water to the filter until it begins to drain. Sand should always be added to water.
- Add fresh or washed sand such that the sand surface is 5cm below the water level.
- Level the surface of the sand.
- Replace the diffuser plate and lid.
- The diffuser plate should not touch the surface of the standing water.

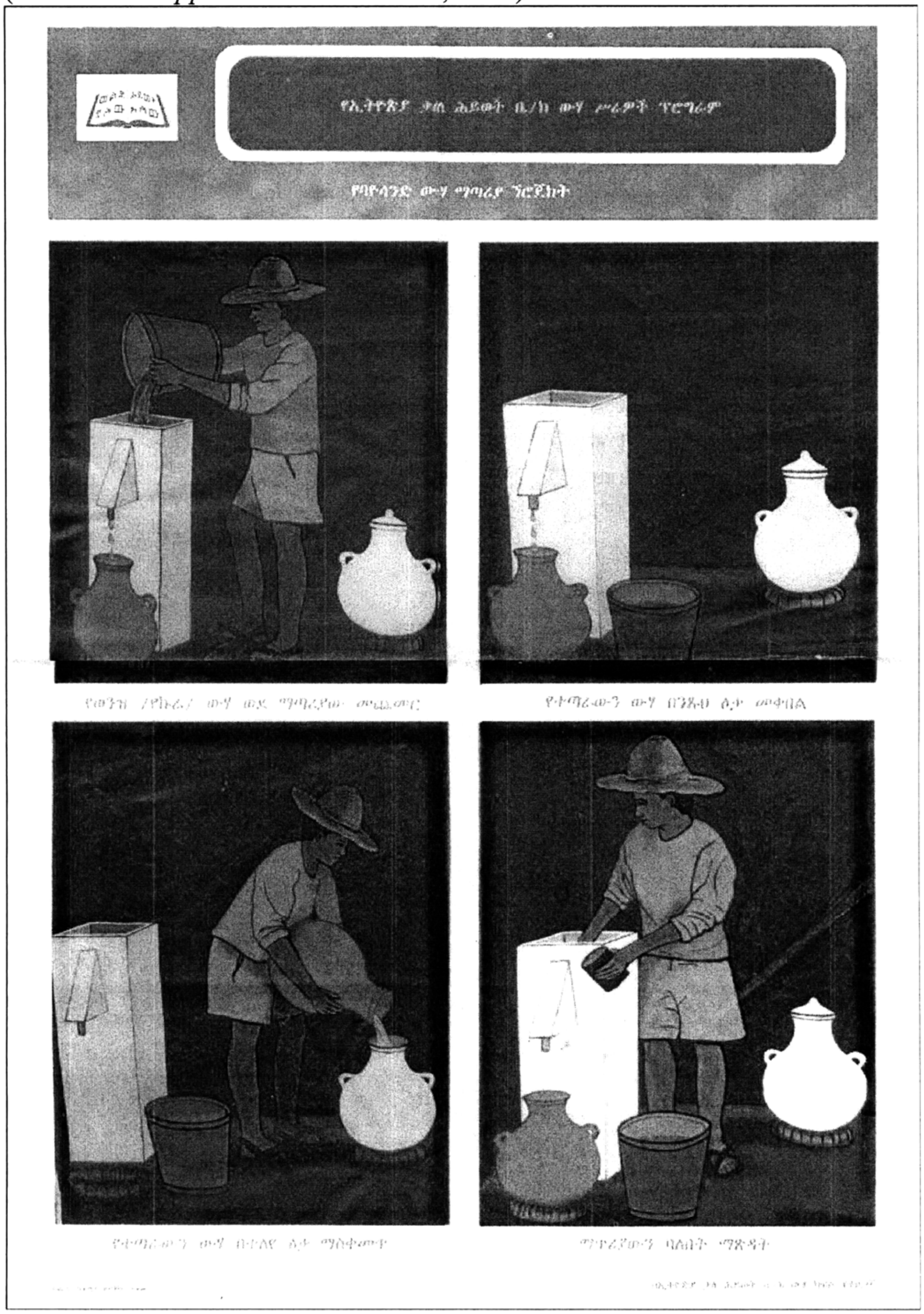
(Dejachew, 2002)

**Used during Phase 2, scale-up**

- Remove the diffuser plate and lid.
- Put your hand or a spoon in the filter and down into top 2-3cm of sand. Stir in a circle until the water becomes dark and then scoop this water out with a cup. Continue to stir and scoop water out until all the water is gone above the sand. Be careful not to scoop out the sand. Add water to the filter and repeat this process until the water is clear.
- Level the sand, replace the diffuser basin and pour water back into the filter. Do not take sand out of the filter. Finally, always check the level of water above the sand once you are finished. It should be 5cm or the second finger joint.
- Pour water into the filter until it begins to drain.
- The diffuser plate should not touch the surface of the water.

(Samaritan's Purse, 2001)

**Posters** distributed by the Kale Hewyet Church for their work in Ethiopia. (Taken from *Appendix 3* of Earwaker, 2006).



A plastic safe storage container was included in the update of this poster (not shown) as handed out among their second intervention to ~10,000 households.

**CAWST Latin America English 21 poster**, similar to that distributed to users by the International Aid implementation in partnership with Watersites Int., Tamale, Ghana.


**From:**
**CAWST "Installation Operation & Maintenance Manual: Biosand Water Filter." Version 2007-01**

**DAILY USE**

Educate all of the users, including children, on how and why the filter works and on the correct operation and maintenance. Children are frequently the main users of the filter.

- Slowly pour raw (untreated) water into the filter daily (at least 20 litres, twice per day)
- Using the same source of water every day will improve the filter effectiveness
- Use the best source of water (least contaminated) available – the better the raw water is, the better the treated water will be
- Pre-filter or settle raw water if not relatively clear – less than 50 NTU

Tip: A simple test to measure the turbidity is to fill a 2 litre clear plastic soft drink bottle with raw water. Place the bottle on top of large print such as the CAWST logo on this manual. If you can see the logo, the water probably has a turbidity of less than 50 NTU.

- The diffuser must always be in place when pouring water into the filter – never pour water directly onto the sand layer
- The lid should always be kept on the filter
- Use a designated bucket for fetching raw water
- Use a designated safe storage container to hold the treated water which has:

○ a small opening to prevent recontamination due to dipping with cups or hands
○ a tap or spigot

• Place the receiving container as close to the spout as possible (i.e. place it on a block) to reduce dripping noise and prevent recontamination

Note: The dripping noise can be irritating. The closer you place the container to the spout, the less dripping noise there is. A container with a small opening also reduces dripping noise.

• Water must always be allowed to flow freely from the filter – never plug the spout or connect a hose to it

Note: Plugging the spout could increase the water level in the filter, which could kill the biolayer due to lack of oxygen. Putting a hose or other device on the spout can siphon or drain the water in the filter, dropping the water level below the sand layer.

• No food should be stored inside the filter

Note: Some users want to store their food on the diffuser plate because it is a cool location. The water in the top of the filter is contaminated, so it will contaminate the food. Also, the food attracts insects to the filter.

• The treated water should be chlorinated after it passes through the filter to ensure the highest quality of water and to prevent recontamination (1-5 drops/litre or up to 1 teaspoon/gallon)

**How to Use and Take Care of The Biosand Filter**

**How to Use:**

1. Use the filter daily - this will maintain the water level 5 cm above the sand (measured during the pause period) and keep the bio- layer alive.
2. Ensure water quality is from the best possible source. Always use the same source if possible. If water is very dirty allow the water to settle for 24 hours then pour the clear water through a fine woven-cloth (folded many times).
3. Use two separate containers; one container should be used as a receiving container to properly store and disinfect water from the filter, a second container should be used as a source container to collect the water from the water source. Ensure both containers are kept clean.
4. Typically, add between 1 to 5 drops of bleach for each litre (or up to 1 teaspoon per gallon) to the empty receiving container - for example, if the container is 20 litres then add at least 20 drops.
5. Remove the filter lid
6. Slowly pour contents of the source container into the filter, without letting the sediments enter the filter, and then replace the lid. As the water fills the receiving container, it mixes and reacts with the chlorine to treat any remaining bacteria.
7. Remove the filter lid.
8. When filtration is complete, cover receiving container.
9. Repeat process at least once a day.
10. Clean the spout daily.
11. Do not store food on the diffuser plate.
12. Keeps animals away from the spout and filtered water.

**How to Take Care of:**

- **Location** - Protected from the weather (dust & wind), birds, animal, mosquitoes and insects. Placing the filter indoors is preferred.
- **Level** - Filter placed on a level spot- even floor, not slanted, no bumps.
- **Leaks or Cracks** - Drips of water or wet spots under the filter will indicate a leak in the concrete box.
- **Lid** - Clean on the outside and inside; no rotting wood parts; tight fitting but not sealed.
- **Diffuser** - Clean regularly; sand under diffuser should be level and smooth; rotten wood should be replaced; diffuser should rest securely on the lip. This should be approximately 5 cm ( 2") above water level.
- **Sand Level** - The surface of the sand should be 5 cm (2") below the water level. Contact your technician to add (or remove) sand if this dimension is not correct; the sand should be smooth and level.
- **Spout** - Clean daily; eliminate any direct human and animal contact with spout and filtered water.
- **Receiving Container** - 5-10 cm (2" - 4") – a small opening will prevent contaminants from entering the container that now hold treated water. Sanitize the container frequently (every second day) by washing it with soap and water or with a chlorine cleaning solution. Ensure the container has a lid. Do not scoop water out of receiving container. It is best to pour the water out.
- **Flow Rate** - Measure the outlet flow rate from the spout when filter reservoir has just been filled with water; 0.6 litre/minute (100 seconds per liter)is the design rate for the standard concrete filter; if the flow rate is less than about 0.3 litre/minute (1/3 quart/min), clean the sand in the filter by using the "swirl and dump" technique.

**Swirl and Dump**

- Remove the lid to the filter; remove the diffuser
- "Swirl" your hand,(up to the first knuckle), or an appropriate tool, (2 cm deep), around in the water at least 5 times. You will disturb the surface of the sand but don't mix the surface layer below the top 5 cm of sand. The water above the sand will become dirty.
- Scoop out dirty water with small container (i.e. cup or cut open plastic pop bottle) Avoid scooping out sand.
- Throw out dirty water outside the house in an appropriate location
- Repeat this until all the water has been removed from the filter
- Replace diffuser
- Add 20 litres or 5 gallons of water- replace lid
- Check flow rate
- Repeat if flow rate is still low

**PUR™ Usage information**:

From Aquaya *Standard Operating Procedure for the Deployment of Procter & Gamble's PUR™ PuRifier of Water in Emergency Response Settings.* http://www.psi.org/Pur-emergency-relief/resources/aquayaSOP.pdf Accessed May 22, 2008.

**Supplies needed to use PUR:**
PUR requires only a few simple tools that most target beneficiaries of disaster assistance should have at their disposal:
• a scissor or knife to open the sachet,
• a spoon or other implement to stir the water,
• a cloth fabric to filter the treated water, and
• two vessels (i.e. buckets) with volume capacity of 10 liters or more – the first to be used for the treatment process and the second to be used for storing the treated water.

**How to use PUR:**
The treatment procedure is as follows:
1. Open a PUR sachet using a pair of scissors. Add the contents of the sachet to a vessel containing 10 liters (2.5 gallons) of contaminated water. One simple way to measure a 10 liter volume is to use a 2-liter bottle five times. Extreme precision is unnecessary: if there are slightly more or less than 10 liters, the treatment procedure will still be effective.
2. Stir the powder steadily and vigorously in the water for five minutes. After adding the powder to the water, the water will become temporarily colored, and after a minute or two, large particles or "floc" will begin to form, with the water becoming clear in the process. At the end of five minutes, stop stirring and let the floc settle to the bottom of the container. If the water is still colored, it can be mixed again and left to rest for another few minutes.
3. Once the water looks clear, and the floc, or precipitated material, is at the bottom of the bucket, filter the water through a clean cloth into a clean storage container. The filter must be a cotton cloth that prevents the floc particles from passing through.
4. Wait 20 minutes before drinking the water. This is an important step, because it is during this time that remaining pathogenic bacteria are killed. The water should be stored in a container with a lid if available to keep it safe from recontamination.
- Roughly a single sachet per household per day for emergency use is an appropriate amount for distribution. Two 12-sachet strips will treat 240 liters of water, and should be sufficient to support a household for three weeks.
- It is important to stir the water vigorously for the floc to form properly. This visual sign is the signal that the product is working properly. The floc will form even if PUR is added to clear water.
- The floc from the water treatment process should be disposed of in the latrine or on the ground away from children and animals.
- Water that is still colored or cloudy after treatment should not be drunk.

If floc accidentally gets into the treated water (by accidentally dropping the filter cloth into the water, for example), then another cloth should be used to refilter the treated water into a clean container.
- The chlorine in the water gradually disappears, and after 24 hours it will not be present in sufficient concentration to remove microbes. It is important to store and dispense drinking water so as to avoid recontaminated.
- Water from the storage container should always be dispensed into another container, such as a cup or glass for drinking. Unwashed hands and utensils should never be dipped into the treated water because this is how treated water becomes re-contaminated. A solid cover on the treated water is preferred. If a lid is not available, a large plate or a towel may be used.
- A simple test to determine whether the cloth is adequate is to use it to filter the water. If the "floc" does not pass through the cloth then it is working correctly. A cotton cloth works best and you should not be able to see through the cloth. On the other hand, the cloth should not be so thick that it takes a prohibitively long time to filter the water.

From **PUR Usage Instructions in 4 Languages, from the PSI website**:
1. Open a sachet using a pair of scissors.
2. Add the contents of the sachet to a clean mixing vessel containing 10 liters of water.
3. Agitate the powder vigorously in the water for 5 minutes. Be sure a vortex is created when mixing. Then, let the water stand until it clarifies.
4. After adding the powder to the water, the water will become colored. The color indicates that the product is working. When the process is finished, the water will be crystal clear.
5. If you see the water is still colored, you can mix again and let it rest for another few minutes.
6. Once the water looks clear, and the floc is at the bottom of the bucket, filter the water through a clean cloth filter into a storage container and cover with a lid.
7. The filter must be a cotton cloth that prevents floc from passing through.
8. Wait **20 minutes** before drinking the water.
9. Do not drink the water if it is colored or cloudy after treatment. If the floc accidentally gets into the treated water, use another cloth to filter the floc out of the treated water. The water is still good to drink.
10. The treated water should be preferably consumed within 24 hours after its preparation. Water that is left over should be used for cooking, washing, watering animals, or otherwise discarded.
11. **Always** dispense the water from storage container into another container, such as a cup or glass for drinking.
12. Discard the floc from the water treatment process in the latrine, or on the ground away from children and animals.

Do not ingest the powder; Maintain out of children's reach.
Contents: $Fe_2(SO_4)_3$: 352 mg Fe(III); $Ca(OCl)_2$
Also translated into Spanish, French and Arabic

# *Appendix G: PSI Participatory Hygiene and Sanitation Training Materials for use with Waterguard Sodium Hypochlorite Solution*

Population Services International, Addis Ababa Office[6]

When dealing with emergency situations, training of correct dosing is important to encourage product use and hygiene as well as to prevent improper dosing. Included in *Appendix G* are the posters used by PSI Ethiopia in community trainings when supplying WuhaAgar (Waterguard) in acute watery diarrhea (cholera) outbreaks, as paid for by various international aid organizations.

The writing on the back of each poster is broken into three segments. The first section concerns a story that highlights the subject of the picture. The second section lays out specific questions which, if they are not brought to bear in the ensuing discussion among the meeting's participants, should be raised directly by the community educator leading the discussion. The third section succinctly restates the main points of the poster and discussion therein.

[6] PHAST (Participatory Hygiene And Sanitation Training) posters provided by Henock Gezahegn of PSI Ethiopia. Translation from Amharic to English done by Bete, a friend and student at UMass Boston and recorded by Matt Stevenson on March 24, 2008. These pictures and stories are also translated into a culturally relevant Somali version for PSI's work in the Somali State (not included here).

**Poster 1: "Basic Health Protection through Washing Hands"**


Marta is a young woman who has completed the tenth grade in school, and is on her annual summer visit to her rural home to spend time with family. As she serves lunch, she brings water and soap for hand washing. Her mother tells her to leave her alone and let her eat in peace. To this, Marta replies "Mamma, you must wash hands each time you eat, cook, or use the bathroom to protect from diarrhea and germs."

??? Questions:

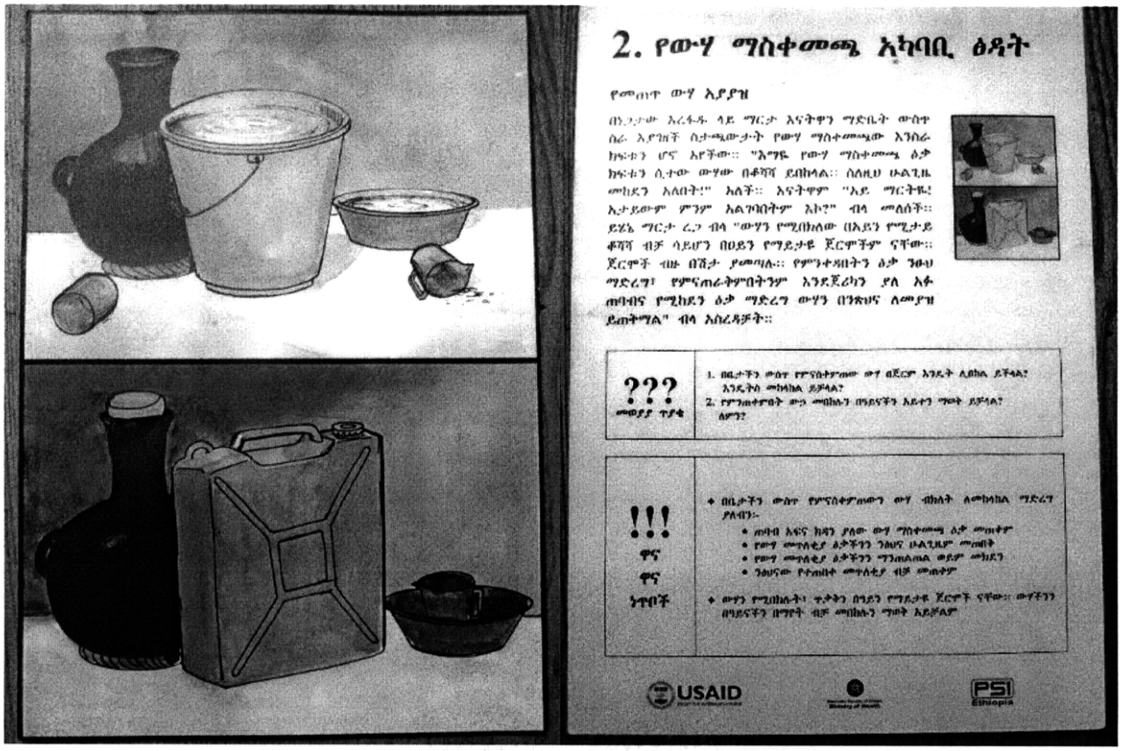
1. What's the main point?
2. Who was the main character?
3. What was her education trying to teach them?
4. In the story, what's the cause of diarrhea?
5. When and where does she recommend washing?

!!! Main points/ideas:

*The main cause of diarrhea is bacteria in improperly cleaned water
*Use soap when washing, or soda ash, or whatever is available
*In order to protect, one must wash before:

- eating
- cooking
- feeding children
- using the bathroom
- cleaning infant and kids
- handling animals

**Poster 2: "How to clean the water area"**




Marta is trying to teach her mother, saying "Don't leave the pot open because germs can get in there. They're invisible and they can cause lots of pain and diarrhea. You must always keep the top on the pot."

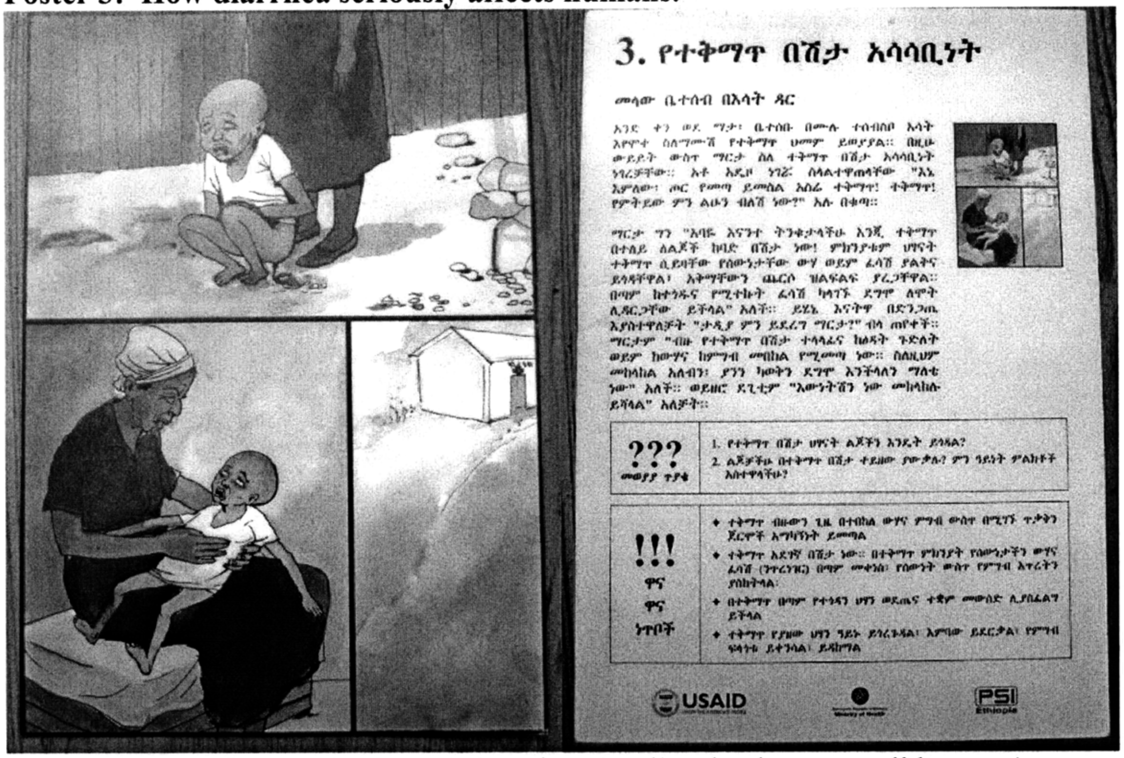
???

1. In your house, how can germs affect you from your water?
2. Can we see the germs and know if it is clean?

!!!

*You can not see the germs.
*You must always cover the pot.
*Keep a separate drinking glass.

**Poster 3: How diarrhea seriously affects humans.**




"All the families behind the fire." (n.b., adage implies the danger to all humans)

While people were discussing the baby's sickness, Marta brought up how serious the diarrhea is. Adessa (the father) did not want to listen to Marta's "diarrhea talk," and was angry with her. She replied "You may not think that it is serious, but kids with diarrhea are losing water, and will not resist death." Her mother's reply was that she did not know this, and wanted to know what she can do…? Marta: "Diarrhea comes from water and food germs, so you must wash and cover pots for water." Mom: "I can do this in the future."

???

1. How does diarrhea affect the body?
2. Have your kids had diarrhea? What was the cause/visible symptoms?

!!!

*Affected water's germs and bacteria cause diarrhea.
*diarrhea is a very dangerous pain with which we can lose the minerals from the water.
*kids with diarrhea must go to the hospital
*there are many signs: loss of appetite, sunken eyes

**Poster 4: "Wuha agar"**


"After Shopping"

Marta told her father that she went to the store to buy WuhaAgar. Adessa (her father): "What does Wuhaagar mean?" Marta, who works for Wuhaagar, explains that she brings chlorine to people to put in the pot to protect from diarrhea and typhoid by killing germs. Drinking this clean water prevents diarrhea. Adessa: "Maybe this is expensive?" Marta: "Baba, it is easy and cheap. Wuhaagar especially protects the children under five years old, which is important. Especially for treating river water, they can be treated." Adessa: "I did not know about it, let's use it."

???

1. What's the benefit of Wuha'agar?
2. When we use Wuha'agar, which water can we use?
3. Whose health benefits from using Wuha'agar and why?

!!!

- Wuha'agar is a chemical which cleans water
- Wuha'agar kills bacteria and germs, typhoid and diarrhea, etc.
- Wuha'agar is very cheap, easy to use.
- Especially when taking water from the river, it is very useful.
- Wuha'agar is very important for families, especially those with children under five years of age

**Poster 5: How to use Wuha'agar**

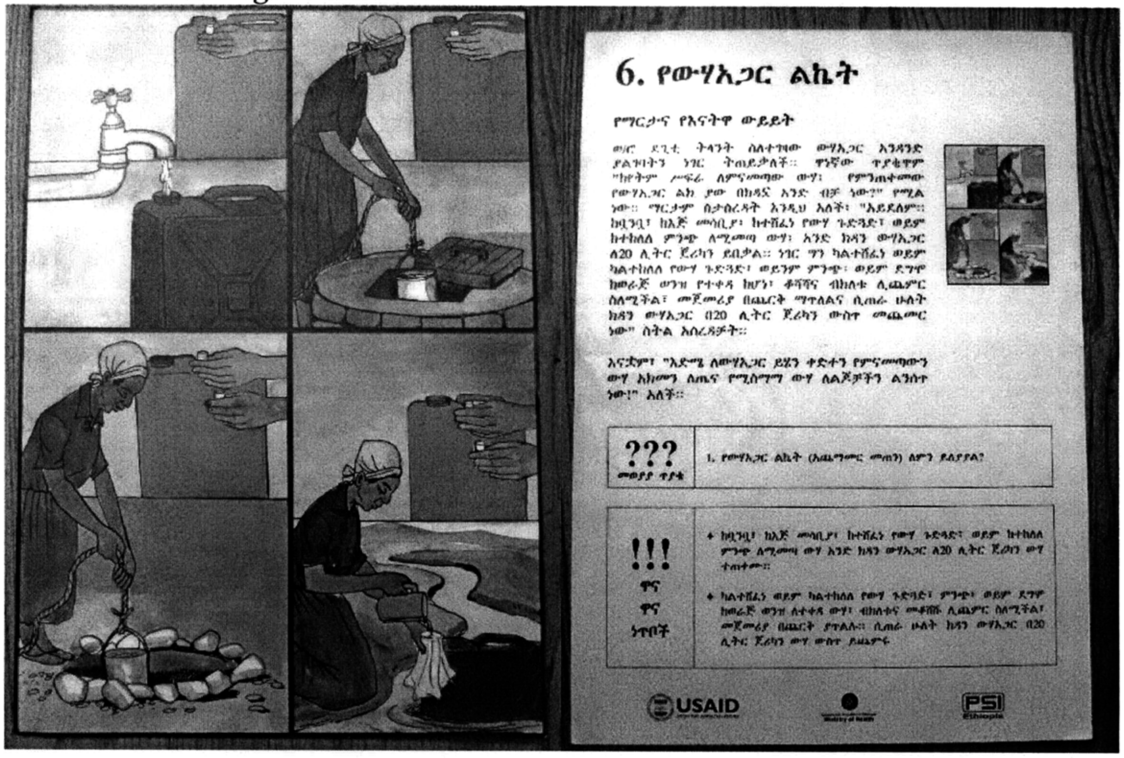

"Family and Wuha'agar"
When Marta brings Wuha'agar to her family, they are originally surprised and do not know what it is. Marta: "Do you know how to use it?" Mom: "Yes, you have to measure it, because we already know its benefits." Marta: "For 20 liters, one cap. Shake it, leave it for 30 minutes. You can drink it from a cup after this. That is how to use it." Dad: "You have to be cautious, because children are not supposed to get chemicals." Marta is very pleased because they have learned and understand.

???
1. Discuss about the steps for using Wuha'agar

!!!

- 20L=1 cap
- Shake it, leave it for 30 minutes. After this, you can transfer to other containers
- Don't touch containers with dirty hands!
- Missing some rules here, as the line is long on the poster

**Poster 6: Wuha'agar measurements**




"Discussion between Martha and her Mother"
Mom asks: "If water is from anywhere, does it matter how much Wuha'agar we add?" Marta: "One cap= 20L only, for water which is clean (pipe borne, for example). For river water, must cloth filter, then use 2 capfuls of Wuha'agar." Momma: "Wuha'agar is good, it will keep us clean and healthy."

???
How do measure Wuha'agar? What's the difference when using tap and river water?

!!!
Tap = 1 cap/20L
Non-tap ("river")= pre-filter, then 2 caps/20L