# An Evaluation of Student Implemented Clean Water Programs in Ecuador

Submitted By
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# Abstract

Engineers Without Borders (EWB-USA) is a non-profit, non-competitive, humanitarian organization established to partner with developing communities worldwide in order to improve their quality of life, while training internationally responsible professionals and students. This research evaluates case study Programs completed by two student EWB-USA Chapters in Ecuador; to inform about monitoring and evaluation which currently receives minimal support from the EWB-USA Project Process.

Project sites were visited for an evaluation, at which point, water quality testing, household surveys, and key informant interviews were conducted. Although the Programs varied by community, goals, project type, implementation strategy, and evaluative metrics, a common narrative was found between the student Programs. These commonalities were used to develop recommendations on the Project process such as identification of measurable metrics, enhancement of the EWB-USA Technical Advisory Committee, creation of an open source network for intra-Chapter knowledge sharing, and creation of an online file-sharing and database for Programs.

# Acknowledgements

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This thesis is dedicated to the generations of students who devoted their time and efforts into making these projects a reality.

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# Abbreviations List

| | |
|---|---|
| ASCE | American Society of Civil Engineers |
| ASME | American Society of Mechanical Engineers |
| CDC | Centers for Disease Control and Prevention |
| CF | Ceramic Filter |
| CFU | Colony Forming Units |
| DROPS | Developing Rurally Optimized Projects for Sustainability |
| EWB | Engineers Without Borders |
| EWB-USA | National Organization of Engineers Without Borders |
| FBU | Fundacion Brethren y Unida |
| FCR | Free Chlorine Residual |
| HdC | Hogar de Cristo |
| HWTS | Household Water Treatment and Storage |
| MF | Membrane Filtration |
| MIDUVI | Ministry of Urban Development and Housing, Ecuador |
| NGO | Non-governmental Organization |
| NSF | National Science Foundation |
| NTU | Nephelometric Turbidity Units |
| PFP | Potters for Peace |
| PoU | Point of Use |
| SODIS | Solar Disinfection |
| SSF | Slow Sand Filter |
| WHO | World Health Organization |
| WQ | Water Quality |

# Introduction

*The Global Water Challenge*

The UN Millennium Development Goal to halve the proportion of the population that does not have access to an improved source of drinking water was met in 2010, with 89% of the world achieving this standard. This number, however, does not reflect access to safe water, as there are no global indicators for water quality, reliability and sustainability. [**1**] Furthermore, sanitation is not on track to meet the Millennium Development Goal by 2015. [**2**] In Ecuador, it is reported that 96% of the country has access to drinking water. [**2**] The clean water problem is exacerbated in marginalized rural areas in particular by the global trend towards urbanization as funding and support go towards large-scale urban systems. [**1**] In 2010, a WHO report determined that Ecuador has only an 89% access to improved water supply in rural areas, with death due to diarrhea at 6% of the under-five population. [**3**]

Lack of access to improved sanitation and lack of a safe drinking water supply contribute to the environmental disease burden that many developing countries face. There are several interventions in environmental health shown to reduce this burden, including improved water supply, improved water quality, sanitation, and hygiene promotion. However, much debate still surrounds which option has the potential to be the most effective. [**4**,**5**,**6**,**7**] The meta-analysis by Fewtrell and Colford in particular found that water quality improvements could reduce incidence of diarrhea by 39%. [**8**] While the data in these studies are aggregates and based upon location-specific projects, they do provide an indication of the abatement capacity of specific interventions in developing countries.

In general, there are two types of water treatment in common practice in the developing world: community scale systems and household water treatment and safe storage (HWTS). Small, rural community water supplies worldwide are more frequently subjected to severe contamination, are more likely to operate discontinuously or intermittently, and are more frequently subject to breakdown and failure. [**9**] An evaluation of small water supplies concluded that key indicators for assessment are: service level/means of provision, continuity of supply, susceptibility of supply system to contamination, and the presence of fecal contamination. [**10**] The presence of locally trained monitors on community supply systems drastically decreased waterborne illnesses in a longitudinal study in Ecuador where communities had continual access to technical support. [**11**] An outcome of monitoring activities in another program in the Andes found that sustainable community systems were those with sound management schemes and financial support. [**12**]

Much debate exists in the development context over the role of HWTS as a long-term sustainable solution. Regardless, these options have been proven to improve the microbiological quality of water and reduce diarrheal disease, and are therefore endorsed by the WHO and UNICEF. [**13**] Although boiling is one of the most common HWTS practices, it has never been evaluated for its health impact. [**14**] Other HWTS methods including biosand filtration, ceramic filtration, solar disinfection, flocculation/disinfection sachets, and chlorination have shown a health impact. [**15**,**8**,**16**] In HWTS practices, education and appropriateness of the system are key factors to both uptake and sustainability of use. [**17**]

*At the Student Level*

Engineers Without Borders (EWB-USA) is a non-profit, non-competitive, humanitarian organization established to partner with developing communities worldwide in order to improve their quality of life. This partnership involves the implementation of sustainable engineering projects, while training internationally responsible professionals and students. However, only limited research has been conducted to determine the long-term effects of these projects in the communities they serve.

Sigmon produced a master's report in 2011 investigating six different EWB programs in Peru to determine how they were functioning and what lessons were learned from those projects for application to a current EWB program in Peru at the University of Colorado. His evaluation concluded that the following factors played a role in Peru programs: partnership with a local organization, involvement of the local government, agreed-upon rules and regulations, communication, community motivation, and choice of metrics. [**18**]

In a paper written at the conclusion of a Tufts University EWB project in El Salvador, the authors pointed to three components as key factors for sustained success on a small scale project: existence of a Water Board, partnership with a local NGO, and strong personal relationships with community members. [**19**] Project advisors at Tufts also sited the need for multi-disciplinary teams that have prior experience working together. [**20**]

Other papers published by the Tufts University EWB chapter identify additional items for project success. Swan et al. describe critical steps for sustainability in an EWB project as: education of key stakeholders on technology options and trade-offs and information transfer between EWB and the community based on mutual trust. They argue that this aids in the development of collective goals between the student team and the partnering community. [**21**] Wright et al. and Matson et al. ascertain five key aspects for gaining community trust in projects: community introduction, community mapping, health surveys, water quality sampling, and community feedback. Also noted is the characterization of successful collaboration: effective two-way education, the establishment of local management controls, financial stability, and the development of proper operation and maintenance procedures. [**22**,**23**]

This thesis investigates two EWB student programs conducted in Ecuador, one from Tufts University and one from Clarkson University. These Programs were chosen because the researcher had been involved with both at one point in time and was granted permission by the two Chapters to conduct an evaluation of each. An intentional design of the EWB student Programs at Tufts and Clarkson is that they are predominately student run and student driven. Both are structured as official student organizations recognized by their respective universities. Part of this classification means that students hold positions of leadership, set goals, conduct projects, plan the programs, fundraise for the projects, and determine the direction of the organizations with advice from the faculty advisor. [**20**] This affords students the opportunity to develop leadership experience and to grow into roles as professionals and global citizens.

Factors that are critical to remember when evaluating these programs are: most students do not receive formal training on how to conduct an international development project, EWB is typically one of many commitments on a student schedule, commitment waxes and wanes with availability, and there is a high turnover rate of students. Within the realm of engineering, much work is being done to determine the impacts of involvement in service-learning projects, such as EWB, on the creative, practical, and analytic skill set of the next generation of engineers. [**24**,**25**,**26**] Ensuring that EWB style projects are conducted appropriately strengthens the goals of analyzing impact of service-learning on engineers.

This thesis contains many sections detailing the background of the Programs evaluated. For an overarching view of the key points of this work please read the background on EWB-USA, followed by the introduction and summaries to each of the case studies, and the conclusions section. More in-depth understanding of the Programs is provided in other sections.

# Background

This section is comprised of two main components, background information on water treatment technologies that are specific to the programs evaluated in this study and the background of Engineers Without Borders programming at the National and student level.

## Water Treatment Methods

### *Slow-Sand Filtration (SSF)*

James Simpson, at the Chelsea Water Works Company in London, first developed slow-sand filter technology in 1829. However, efficacy of slow-sand filters for bacterial removal was not documented until 1886 when Percy Frankland was able to report that using Robert Koch's bacterial culturing method SSF removed approximately 98% of bacteria from Thames River Water. [**27**] In 1892 Altona drew water from the River Elbe downstream of the stage outfalls of the city of Hamburg, Germany. He was able to prove the efficacy of SSF for prevention of waterborne disease of bacterial origin. [**28**] A historical look at typhoid fever death rates in the USA saw a significant reduction with the installation of SSF. [**29**] SSF experienced resurgence within the USA as a popular form of treatment during the 1960s and 1970s because of Giardia outbreaks associated with high turbidity waters and treatment without disinfection.

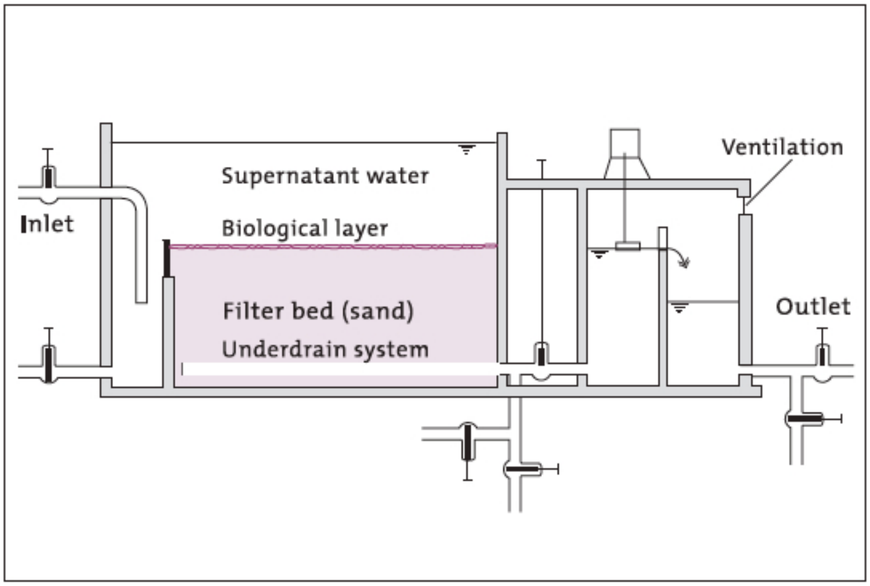


**Figure 1: Typical SSF design for water treatment [30]**

An example of a SSF setup is demonstrated in Figure 1. Inflow water may have undergone some sort of pre-filtering or aeration process before reaching the SSF stage. To be an effective choice for treatment, influent water should have a turbidity of >10 NTU and contain no significant algal growth or inorganic/organic chemicals. A SSF's bed will contain levels of fine sand, coarse sand, and gravel that the water passes through before collecting in the under-drain system. There are three main mechanisms for microbial removal within the filter: physical filtration, biological filtration via the schumutzdecke, and biological filtration via predation. Viruses and protozoa are also removed via physical filtration and post-filtration disinfection.

Physical filtration relies on particle transport governed by Brownian motion, sedimentation, and interception to provide collision opportunities for particle-to-sand contact. A slow sand filter should remove particles from water at a reduction factor of approximately 20 times the initial particulate load. [**31**] The biolayer, known as the schmutzdecke, grows several centimeters into the top layer of the fine sand and assists in the removal of microbes and particulates. [**32**] [**33**] This layer takes up to 28 days to regrow when a filter is dried out. [**34**] The schmutzdecke biologically breaks down organic matter and some suspended particles. [**35**] It was also discovered that within the top 10 cm of the fine sand layer there exists protozoa, aquatic worms, and other prey that eat smaller organisms in the influent water. During the cleaning process, both the predation organisms and the schmutzdecke may be damaged or removed, therefore reducing the effectiveness of the filter. [**36**] In order to protect the ecology of the filter, they should be out of commission for no more than a day during the cleaning process. [**37**]

***Ceramic Filters***

Ceramic filters are a common point-of-use (PoU) water treatment option throughout the world, with many current designs based upon the work of Dr. Fenando Mazariegos in Guatemala in 1981. The original conception behind ceramic filters was to utilize native artisanal skills for the local production of a PoU water treatment system. **[**38**]** In the mid-1990's Potters for Peace (PFP), a U.S. based NGO, redesigned the ceramic filtration manufacturing process and has been a promoter for the system in numerous countries. By 2011, PFP had provided assistance to 37 factories in 25 countries throughout the world and more than 40 university studies had confirmed that the filters reduced bacteriological contamination by 98-99.98%. **[**39**]** **Figure 2** is a depiction of an example PFP ceramic filtration system.

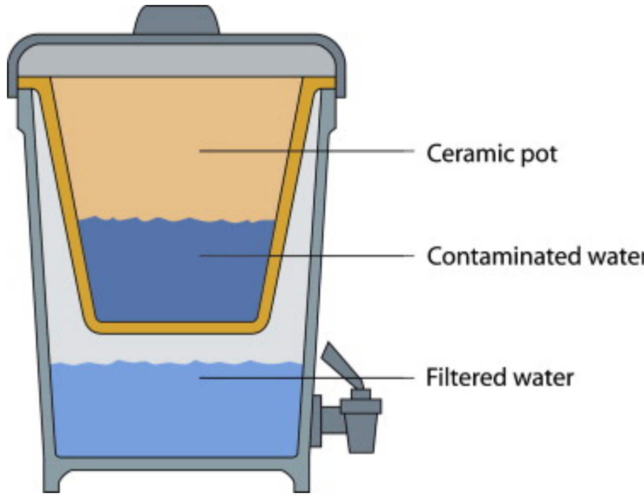

**Figure 2: Ceramic pot filtration system** [39]

Mixing clay with a burnout material, such as sawdust or ground rice husks, is the basis of filter production. During the firing process, the combustible material burns out leaving behind microscopic pores at the completion of firing. These microscopic pores are the first inhibitor to solids, bacteria, protozoa, and helminthes that may be present in contaminated water. The second inhibitor is the jagged cracks that connect the pores to each other. After the filters have been produced they must provide, at a minimum, 2-log reduction in bacteria, which means the effluent contains $1/100^{th}$ of the influent water concentration of colony forming units (CFU) of coliforms. [**38**] If a batch passes this test, the filters are painted inside and out with a form of colloidal silver. The silver provides the third barrier to contamination of the treated water and prevents bacterial regrowth in the walls of the filter. [**39**] Filters are then seated on the lip of a bucket with a tap and lid. Untreated water is poured into the pot and allowed to filter into the bucket, where it is drawn from the tap for use. If properly maintained, this system provides both PoU water treatment and safe storage. Ceramic filters needed to be cleaned by the user on a regular basis. Cleaning of the filter includes lightly scrubbing out the inside of the pot with a brush to remove particulate buildup. Scrubbing and rinsing the collection bucket and the tap are also critical to maintaining a functional system. A ceramic filter is approximated to have a lifetime of 3 years, but this is highly contingent upon maintenance and quality of the source water. [**38**]

## Engineers Without Borders Programs

### *EWB-USA Overview*

Bernard Amadei, a Professor of Civil Engineering at the University of Colorado at Boulder, founded EWB-USA in 2002 after he and a team of eight students completed a clean water project in Belize for a friend. Dr. Amadei started the organization after seeing the power students had to make a significant difference to a developing community with low-tech solutions. It was also the perfect opportunity for students to experience hands on engineering outside of a classroom. EWB has seen rapid growth in its first 10 years. In 2003 there were 4 professional chapters and 24 student chapters. In 2012 there were 93 professional chapters and 201 student chapters. [**40**] The organization has grown to include over 12,000 students, faculty, and professional members. [**41**]

EWB-USA states: “Our vision is a world in which the communities we serve have the capacity to sustainably meet their basic human needs, and that our members have enriched global perspectives through the innovative professional education opportunities that the EWB-USA program provides.” [**42**]

Additionally, EWB-USA’s mission is to: “support community-driven development programs worldwide by collaborating with local partners to design and implement sustainable engineering projects, while creating transformative experiences and responsible leaders.” [**42**]

The organization has an extensive procedure for Chapter and Project processes. Criteria used in evaluating an application to start a university chapter include: broad membership base, continuity and longevity of potential chapter, diversity of experience, fundraising capabilities, mentorship, university-wide commitment, and a quality control/quality assurance process. [**43**] Once a Chapter becomes established under the national organization, it is able to open a Program. A Program is a 5-year partnership with a specific community and an accompanying local NGO partner. [**44**] In order for a Program to be approved by National it must demonstrate the following elements of a successful partnership [**45**]:

1. Community-driven approach;
2. Community ownership of projects;
3. Long-term sustainability; and
4. Community organization and involvement.

A Memorandum of Understanding must be signed by all parties to legitimize a partnership. Within a Program there are Projects. Projects may be shorter than the overall Program and are focused on solving a specific challenge with the community. Figure 3 is a depiction of a hypothetical Chapter and Program structure. The Project process is comprised of different phases and their accompanying reports to National. An overview of the reporting process is included in Table 1.

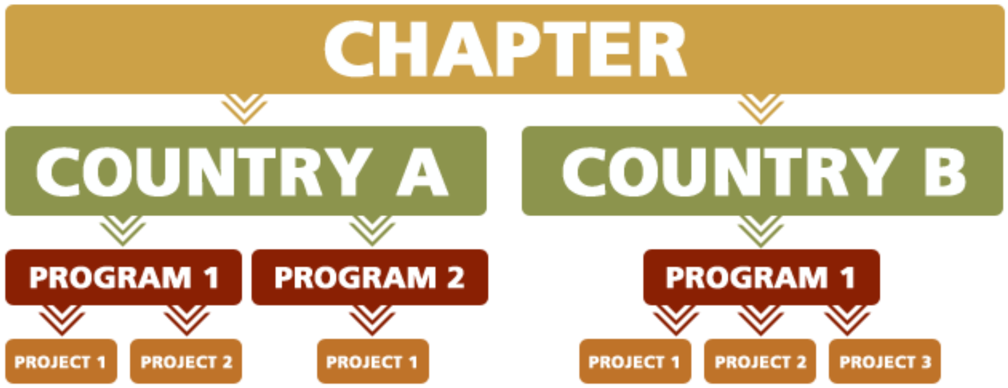


**Figure 3: Theoretical EWB-USA program and project structure** [44]

A Monitoring and Evaluation form was added to the reporting cycle of documents in September 2010. Detailed instructions from EWB-USA for the Monitoring and Evaluation post-trip report are included in Appendix A for reference. The document requires that chapters state the three metrics by which they measure the impact of their projects, which would have been determined prior to the trip, and include all data in support of those metrics. Additionally, EWB-USA asks Chapters to evaluate their projects from the standpoints of [**46**]

1. "Functionality status of system;
2. Supporting information demonstrating periodic maintenance;
3. Demonstration of knowledge transfer;
4. Resolution of technical issues; and
5. Capacity and financial assessment."

**Table 1: Reports to EWB-USA**

| Submittal | Report No. | Purpose of Report |
|---|---|---|
| New Project within an Existing Program | 501B | This document is an application for a new project to be completed under an existing program. For example, if a chapter had completed a water supply project with a community and now wanted to start a sanitation project, a 501B would be used to apply for the sanitation project. This document can also be used for chapters that would like to expand the program to another community. If the chapter wishes to extend the program to a new community, see the EWB-USA website for the strict requirements that must be met. |
| Pre-Assessment Report | 521 | To serve as a planning document for each assessment trip. Proper trip planning is needed to ensure that the team is safe and has sufficient time to accomplish all of the objectives of the assessment trip which include establishing relationships, verifying community priorities, assessing overall project feasibility, and collecting sufficient technical data to support the design of a sustainable engineering project. |
| Post-Assessment Report | 522 | To present, summarize, and document the data and information collected during the assessment trip. |
| Alternatives Analysis | 523 | To document the thought process that the chapter should go through to determine which alternative solution is best for a given situation. For example, if there are a number of different water sources that may be used for a water supply, the alternatives analysis would describe how the preferred source was chosen. There is no prescribed methodology for carrying out this analysis. |
| Preliminary Design Report | 524 | This document presents a complete design that will be reviewed by the EWB-USA headquarters Project Managers. The intent is to provide review comments to the chapter that they can improve the project prior to submitting the 525 pre-implementation document for TAC review. |
| Pre-Implementation Report (Final Design) | 525 | To present the final design of the project and the details of the proposed implementation trip. The document should be sufficiently detailed that someone with no background with the project would be able to use the document to construct all the proposed facilities. The document should be of the quality that would be sealed by a professional engineer for a project in the US. |
| Pre-Implementation Short Form Report | 525B | This report requests permission to travel on an implementation trip that has already been approved by the TAC. Examples where this document should be used are: a) the construction will be phased over more than one trip but the entire design and construction has been approved by the TAC, b) difficulties during a trip resulted in construction not being completed and the chapter must return to finish the construction or c) the chapter had to postpone an implementation trip that had been approved by TAC. |
| Post-Implementation Report | 526 | To present, summarize, and document the activities and results of the implementation trip. This report also provides an opportunity to propose and describe future program activities such as continued construction activities, monitoring and evaluation of the implemented project, or assessment of future projects. |
| Program Closeout | 527 | To ensure that the projects are functioning properly and that the community is properly prepared to take over responsibility and ownership of the projects that were implemented under the Program. Chapters must perform a monitoring trip at least one year after the final implementation before closing out a program. |
| Pre-Monitoring Report | 530 | For planning a monitoring-only trip. Proper trip planning is needed to ensure that the team is safe and has sufficient time to accomplish all of the objectives of the monitoring trip which include identifying any issues post-construction, gather technical data for purposes of determining project success, and establishing the community's financial and operational capacity to maintain the project. |
| Post-Monitoring Report | 531 | To present, summarize, and document the data and information collected during the monitoring trip. |

In 2011, the total support for EWB-USA from all contributing sources totaled $7,921,717 USD. [**42**] This was down slightly from the first public reporting of income in 2008, which totaled $8,152,870 USD. [**47**] This has helped EWB extend their impact to a broader scale. An overview of EWB-USA's reach both by country and by project type is illustrated in Figure 4 and Figure 5.

**Figure 4: Locations of Programs in EWB-USA's first 10 years highlighted in blue** [40]

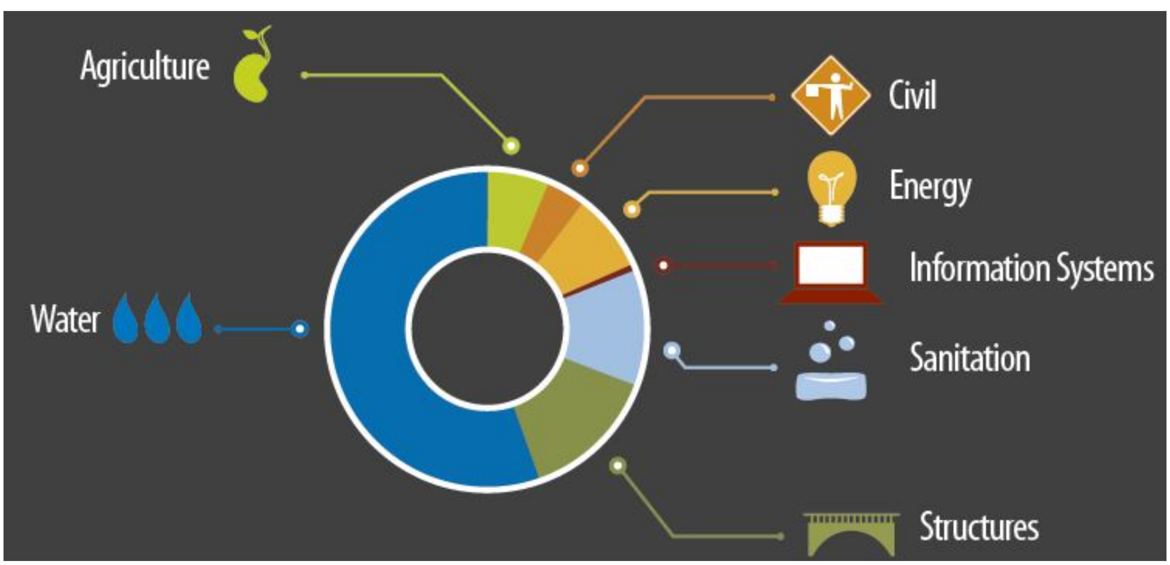


**Figure 5: Types of EWB-USA Projects open or completed during first 10 years** [40]

By 2009, based on survey feedback and tracking the state of programs, EWB had identified that strengthening the infrastructure of EWB-USA and focusing on the quality and effectiveness of the community programs and the corresponding education of its members was needed. At this time, EWB-USA curtailed the growth of both Programs and Chapters in an effort to develop an improved Operating Model. In March of 2010, after experimenting with a number of restructuring models throughout the years, EWB-USA released their Strategic Plan. In this they introduced the current mission and vision statements of the organization (presented previously) as well as developed their Core Values of integrity, service, collaboration, ingenuity, leadership, and safety. [**48**] Under the Strategic Plan, EWB-USA also defined their Guiding Principles, which are:

1. "Deliver sustainable and appropriate community projects;
2. Provide transformational education; and
3. Provide opportunities for constant networking and communication between invested parties as a means for sharing best practices."

In order to meet the goals of the Guiding Principles, EWB-USA identified its four Operational Strategies that it was adopting for success at an organizational level:

1. "Build and deliver an effective and efficient infrastructure to support EWB-USA's mission;
2. Recruit and retain the right people;
3. Build sustainable financial strength; and
4. Attract and foster effective partnerships."

**Table 2: Specific objectives of EWB-USA and their accompanying tactics and metrics as related to Strategy 1 [48]**

| Objective | Tactics | Metrics |
|---|---|---|
| Build and strengthen the project delivery system through a focus on project quality | Maintain and enhance the Technical Advisory Committee and its operation. | - Rate of project approval without major revisions |
| | Create a framework for long-term community plans for future sustainable development. | - Annual number of projects successfully implemented and transitioned into sustainment<br>- Benchmark increase in number of satisfied communities and plans to begin another project |
| Ensure that the technologies and project delivery systems are appropriate and sustainable to the communities | Implementation of a Monitoring and Evaluation Program | - Benchmark increase in the number of projects maintained by community<br>- Benchmark increase in the number of projects done by the community that replicate the EWB-USA project |
| Improve the sills and qualifications of EWB-USA members through a multi-platform educational program | Implementation of a EWB-USA curriculum through a webinar series | - Benchmark increase in number of webinars held<br>- Benchmark increase in number of webinar participants |
| | Implementation of a certification system to ensure that 100% of EWB-USA mentors are appropriate | - Benchmark increase in number of mentors certified |
| Build and education program to facilitate the development, dissemination, and application of knowledge and resources throughout EWB-USA | Implementation of web-based forums for country and technology sharing | - Benchmark increase in number of web-based forums |
| | Provision of resources for Faculty Advisors | - Benchmark increase in number of resources |
| | Identification and approval of training partners | - Benchmark increase in number of approved partners |
| Create fully integrated software systems which allow for accumulation, storage and sharing of EWB-USA information | Implementation of a fully integrated system to accurately track and maintain information on projects | - Deployment of project record system |
| | Enhancement of existing website to provide additional user requests such as forums, etc | - Benchmark increase in number of forums<br>- Benchmark increase in number of user requests |

Under each Strategy they identified specific objectives and the corresponding tactics and metrics to meet those objectives. [**48**] Table 2 is a listing of tactics and metrics teased out of the Strategic Plan that relate to either monitoring and evaluation of Projects or relate to student chapters.

EWB-USA also identified their internal strengths and weaknesses and the external opportunities and "threats to the organization". Among their strengths they listed "direct positive impact on developing communities" and "long-term relationship building." Weaknesses listed were: [**48**]

1. "Communication is difficult with communities until cultural and common understanding is reached;
2. Effective communication is difficult to maintain with remote communities;
3. Lack of long-term implications and ability to measure program effectiveness (M&E);
4. Traveling teams often do not have adequate cultural context;
5. Students do not have directly related experience (either technology or international development); and
6. Inadequate training program to support unqualified volunteer base."

Several "threats" to the national organization were also identified as: [**48**]

1. "Chapter attitude that national office is not necessary; and
2. General lack of understanding within universities regarding what international community development is and how it works."

A goal of the Strategic Plan is to monitor and evaluate EWB-USA's progress on its own processes; at this time there has not been a report released detailing this information. There are several changes that have been made in the Project process of note to student chapters. The first is the increase in both webinars and technical documents for Chapters to use as a springboard for building up a project. Some of the webinars are now mandatory for Chapters to watch, which require an attendance report to National. [**49**] National has also instituted a Corrective Actions Process that chapters must go through if they have violated EWB-USA's policies and procedures. [**50**]

Another requirement of new programs is the partnership with a local NGO/local government to ensure both in country program sustainability and to improve communication between the chapter and their partner community. The 2012 Fall State of EWB Report indicated that an "Organizational Monitoring, Evaluation, and Impact System" is under design and expected to be completed during the first half of 2013. [**40**] As part of this system, they will be rolling out a series of five courses on proficiency and competency beginning January 1, 2013.

### ***Tufts University Chapter History***

The Tufts University chapter of EWB was founded in 2004 within the School of Engineering. Currently, Tufts EWB maintains two Programs, one in El Salvador and one in Uganda. Since its founding eight years ago, the chapter has completed three other Programs (Table 3). Additionally, the chapter currently boasts 32 active members, 4 faculty advisors, and 3 community health faculty advisors. [**51**]

**Table 3: Summary of Tufts University EWB Programs**

| Project Location | Project Type | Start Date | End Date |
|---|---|---|---|
| Gyapthang, Tibet | Composting Toilets and Solar Cooker | 2004 | 2005 |
| El Cristal, Ecuador | Potable Water | 2006 | 2011 |
| Arada Vieja, El Salvador | Water Supply and Potable Water | 2006 | 2010 |
| Shilongo Village, Uganda | Water Supply | 2009 | -- |
| Porvenir, El Salvador | Water Supply and Distribution | 2009 | -- |

As a newly formed organization in 2004, Tufts EWB set about locating their first Program, and had success in forming a partnership with the Tibetan community of Gyapthang. Over the course of 10 days a travel team implemented a solar cooker and built a composting toilet facility in the town. [**52**] Lasting for only the first year, the Tibet Program was then closed due to the difficulty of completing a Project in this region.

In 2006, the Chapter started two new partnerships. 1) The first was with an NGO in Ecuador known as Fundacion Brethren Y Unida (FBU) that later segued into a partnership with the community of El Cristal. This Program will be discussed in detail in later chapters. 2) The second was through the NGO Epilogos Charities that connected the team to the community of Arada Vieja, El Salvador.

The scope of the first El Salvador Program included Projects involving the protection of the existing spring source, effective filtration of source water, system maintenance, and community education. [**53**] In 2007, Tufts EWB constructed slow sand filters, a freshwater storage tank, aided the organization of a Water Committee, installed a hydraulic ram pump, and conducted preliminary water quality surveys. [**54**] [**55**] By 2008, the team had reconstructed a spring box, conducted in-depth health surveys, and carried out formal community education and training. [**56**] [**57**] In 2010, it was clear from continued water quality monitoring that the filter system was functioning well. Natural disasters had damaged part of the water delivery system and it was found that the community had come together to repair it on their own. Due to community initiation in maintenance and signs of system sustainability, the Program was officially closed in 2010. [**58**]

In March 2013, while the travel team was conducting its fourth assessment trip for the Porvenir El Salvador Program the group spent two days monitoring the former Projects completed in Arada Vieja. They found that the hydraulic ram pump and tanks were still in operation as installed in 2007. However, the community was bypassing the slow-sand filters, citing that they felt their water was clean enough without filtration. The community offered to help fix the filters if the travel team felt it was necessary. The next day the travel team and community members cleaned the filters and helped begin construction of a new shelter around the system. The team left El Salvador before the construction had been completed, and thus the status of the system is currently unknown. [**59**]

In the winter of 2009, Epilogos Charities introduced the Tufts EWB group to another community, Porvenir, also located in El Salvador. This Program has been a challenging one for the organization to undertake, as its scope involves Projects in both water supply and distribution. The first year of the Program was spent primarily in assessing health needs, topography of the community, the quality of existing water, and learning about the feasibility and sustainability of drilling a well in the community. [**60**] [**61**] In 2010, the assessment travel team assessed the possibilities of piping water from an existing source and conducted in-depth health and water use surveying. [**62**] Due to internal and community communication issues, the Projects were stalled until January

2012. On their latest assessment trip in March 2013, Tufts EWB again completed extensive surveying and testing of water sources and community needs. Additionally, the team visited other local communities looking for possible future partner communities. [**63**] To date, the Tufts EWB team has conducted only assessment trips to this community. This project remains an ongoing effort of Tufts University EWB.

During the 2009-2010 academic year Tufts EWB began another Program in Shilongo Village in Uganda via a partnership with the Foundation for the Development of Needy Communities. The goal of the first Project is to provide the community with access to clean water. During the summer of 2010 an assessment trip was made to determine the feasibility of water storage and access within the community, conduct health surveys, map the community and establish a relationship with the community leaders. [**64**] In the summer of 2011, a Tufts EWB travel team returned to the community to implement both a bicycle pump on an existing borehole and a water storage tank. Community health workshops and children's educational programming were also conducted. Tufts EWB received word that the pump was no longer working in 2012 and they realized that their solution was not technically feasible or culturally appropriate. This Program is still ongoing with the Tufts EWB chapter as the group works toward improved bicycle pump designs and water filtration and treatment options. [**65**]

***Clarkson University Chapter History***

The Clarkson University chapter of Engineers Without Borders was founded in 2005, at which time a graduate student expressed interest to start a program in his native country of Ecuador. However, under EWB-USA's new guidelines, the chapter was required to successfully complete a local program before an international one could be opened (Table 4). The Clarkson University Chapter of EWB currently runs multiple Projects in Ecuador under one program heading. The chapter boasts 41 members and 1 faculty advisor as well as partnerships with Potters for Peace and Potters Without Borders. [**66**]

**Table 4: Summary of Clarkson University EWB Programs**

| Project Location | Project Type | Start Date | End Date |
|---|---|---|---|
| Akwesasne, New York | Biodiesel for Vehicle Use | 2005 | 2010 |
| La Margarita, Ecuador | Potable Water and Sanitation | 2007 | -- |

Clarkson EWB formed a partnership with the St. Regis Mohawk tribe, known as the Akwesasne, located in Northern New York. The goal of the first Project was to build and operate a biodiesel plant on the reservation to convert vegetable oil from the Akwesasne Mohawk Casino to biodiesel to power the tribe's maintenance trucks. [**67**] Although started with the best of intentions, the Project experienced many difficulties along the way. The initial plan of building a biodiesel plant was abandoned when it was discovered that used vegetable oil estimates from the casino were off by more than an order of magnitude. Clarkson EWB reconfigured the Project to involve creating a blended vegetable and diesel oil.

After initial success it was found that casino kitchen workers refused to filter the waste oil and allowed water into the holding tanks. There was later evidence that the system that Clarkson EWB built was sabotaged, and larger issues outside the scope of the Project were uncovered. [**68**] The St. Regis Mohawk Tribe Environment Division eventually abandoned the Project citing a number of constraints. [**69**] Clarkson EWB's first Program did not end in total failure, however. The National Science Foundation

(NSF) and American Society of Mechanical Engineers (ASME) produced a documentary of the group's Project as part of an alternative fuels curriculum to be shown in high school classrooms. Also developed in coordination with the American Society of Civil Engineers (ASCE), EWB-USA, ASME, and NSF was an in-depth curriculum to be used in high school and middle school classrooms. [**70**] The Akwesasne Program was officially closed in January of 2010 with EWB-USA, although Clarkson EWB stopped working on the Project in late 2008.

In the fall of 2007, a small team of students began the process of starting an international project for Clarkson EWB. Despite the failures of the first Program, EWB-USA approved the opening of the Ecuador Program. More information on this Program is detailed in later chapters.

# Methodology

This chapter is comprised of four main sections. The first is a literature review of the projects followed by the methods for the water quality testing. The third section is the theory and methods behind the surveys. The last section is an overview of the statistics used to analyze the results.

## Literature Review

The first task in conducting this research was to obtain all information related to the two case studies. Not only was this critical in informing the directions of this research, it also represented the first time the histories of the Programs were pulled together. Neither Chapter had a complete record of the Projects readily available. Therefore, former students were contacted and asked to provide any written documentation from prior years of the Programs if available. Unfortunately, many reports were lost, and missing data is as follows:

1. Tufts EWB Ecuador Program: Memorandum of Understanding, 2007 Pre-Trip Report, 2008 Post Trip Report, 2008 Health Surveys
2. Clarkson EWB Ecuador Program: Memorandum of Understanding, 2008 Post-Trip Report, 2008 Health Surveys, 2011 Pre-Trip Report, 2011 Post-Trip Report

Many of the reports available from the Tufts EWB Ecuador Program were unfinished. The Clarkson EWB Ecuador Program hard drive that contained many of the reports in their finalized version became corrupted, therefore the remaining available reports were about 90% complete.

In addition to gathering the reports to learn about the Project goals, decisions, community relations, and accomplishments, the historical information was used to determine what data had been collected in the past. Learning what metrics were being assessed in the past was important in establishing metrics and methods for this research thesis.

## Water Quality Testing

Provided in Table 5 is an overview of the different water quality testing methods used in this research.

**Table 5: Summary of Tests by Project**

| Water Quality Test | Test Method | Program |
|---|---|---|
| Microbiological | Membrane Filtration | Tufts & Clarkson EWB |
| Free Chlorine Residual | Hach Color Wheel | Tufts EWB |
| | Hach Digital Colorimeter | Clarkson EWB |
| Turbidity | Lamotte Turbidity Kit | Tufts EWB |
| | Hach Digital Colorimeter | Clarkson EWB |
| Nitrates | Hach Digital Colorimeter | Clarkson EWB |
| Temperature, pH, Electrical Conductivity | Hach Probe | Clarkson EWB |

### *Microbiological Testing*

Microbiological testing is conducted to test for indicator organisms in the water that may cause diarrheal disease. There are four types of microbiological indicators that have been used in water quality testing: total coliform, thermotolerant coliform, *E. Coli*, and production of hydrogen sulfide. The two indicator bacteria used in this study are described in more detail.

*Total Coliform Bacteria*

Traditionally, total coliform bacteria have been the indicator of choice for assessing drinking water quality. However, they are naturally present outside of fecal matter, and thus not the best indicator. For this reason, the WHO has moved away from using this as a primary indicator. [**30**] The use of total coliform bacteria in this study was to aid in the determination of treatment efficacy. At 35°C in a membrane filtration test, they will form small colonies. These colonies are enumerated as Colony Forming Units (CFU).

*Escherichia Coli*

*E. Coli* is a bacterium found in the intestinal tract of mammals and thereby found in feces and waters with fecal contamination. Although most types are harmless, *E. Coli* O157:H7 possess virulence factors that can cause diarrhea in humans. [**71**] At 35°C in a membrane filtration test, they will form small colonies, which can be enumerated. WHO guidelines state that *E. Coli* must not be present in any 100 mL sample of water. They have developed a risk classification guideline for thermo tolerant and *E. Coli* bacteria that describe the risk to human health and are presented in Table 6.

**Table 6: Levels of risk associate with water quality [30]**

| **Number of Thermotolerant Coliforms or *E. Coli* per 100 mL sample of water** | |
|---|---|
| <1 | Conforms to WHO guidelines |
| 1-10 | Low Risk |
| 10-100 | Intermediate Risk |
| 100-1000 | High Risk |
| 1000 + | Very High Risk |

*Membrane Filtration (MF) Testing*

MF testing results in colony formation of the indicator bacteria; these are enumerated to determine their concentration in a certain volume of water. Water was collected in a sterile Whirlpak bag with a thiosulfate tablet for chlorine inactivation and stored on ice in a cooler for analysis within 8 hours of collection. MF tests were conducted using Millipore field filtration stands and equipment. A 100 mL volume of water, raw or a dilution therein, was filtered through a 0.45-micron filter. This filter was then placed on top of a media soaked pad in a plastic petri dish. The media used for this study was mColiBlue24 from Hach Company. Colony growth was either red or blue, relating to total coliforms or *E. Coli* respectively. The pre-labeled petri dishes were placed in a Hach potable incubator at 35°C for 24 hours. At the end of the incubation cycle, different color colonies were counted by hand and spot-checked by a second researcher.

Additionally, for every batch of samples prepared for analysis control samples using bottled water were prepared for quality control. In El Cristal, the Tufts EWB case study, there was enough testing equipment to prepare two petri dishes per water sample for quality assurance. The sampling and testing procedure that was adapted from the CDC Safe Water System Program and used in this study may be found in Appendix B**.**

***Chlorine Testing***

Chlorine is used as a common disinfectant for drinking water. When added to water, it reacts with organic materials and metals, thereby inactivating the chlorine. Any unreacted chlorine will be available for both further reaction with nitrates in the water and disinfection. Figure 6 is adapted from the CDC Chlorine Residual field guide and is an overview of chlorine reaction and disinfection. The amount of chlorine initially added to the water will be dependent on chlorine demand and disinfection needs for each case. The WHO recommends a free chlorine residual (FCR) of 0.5 mg/L for water from a distribution network that is coming from a flowing tap. [**30**] This was the guideline used for comparison in El Cristal. The CDC Safe Water Storage Program recommends an FCR of 0.2 mg/L – 2.0 mg/L for water that has been treated from 24 hours – 1 hour ago. The reason for this difference is due to storage. Chlorine will decay in water after 24 hours. The WHO minimum corresponds to 0.2 mg/L, but their maximum is 5.0 mg/L. The CDC recommends a lower maximum because a study in Africa and Asia indicated that the taste threshold for FCR in water was 2.0 mg/L. [**72**] In La Margarita, the Clarkson EWB case study, acceptable FCR levels were 0.2-2.0 mg/L, in combination with the time since treatment.

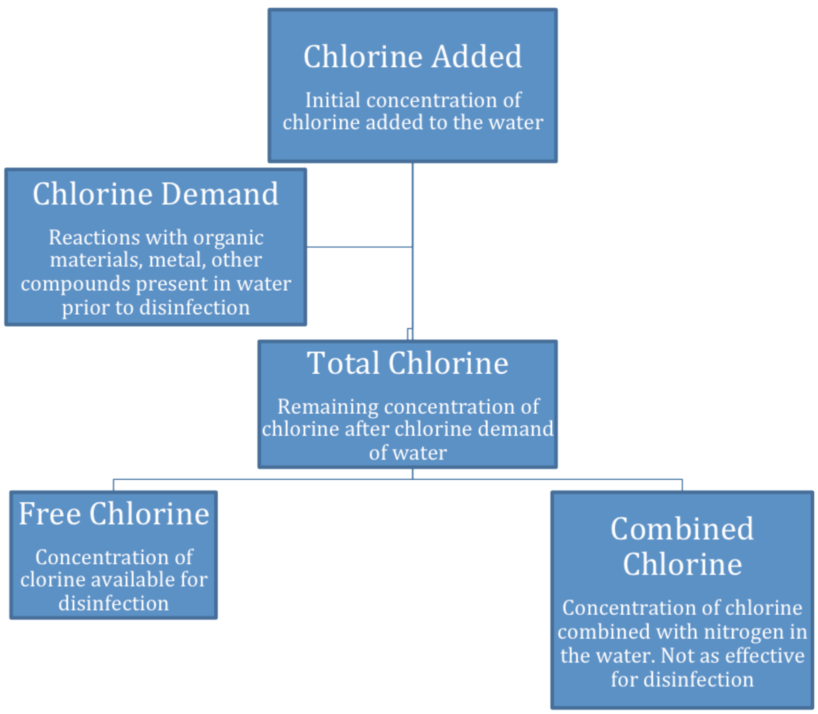


**Figure 6: An overview of chlorine reaction processes** [72]

*Field Testing FCR*

In El Cristal, a Hach Color Wheel CN-66 was used to test the FCR in residential and system waters. The color wheel test kit works by emptying a DPD powder into a premeasured volume of test water, which reacts with any free chlorine and turns a shade of pink. This tube is inserted into a viewing window alongside a calibration sample of the same water. The user rotates the color wheel until the color of the calibration tube matches the color of the sampled water. A corresponding FCR measurement is read from the wheel. Details of all chlorine testing systems are provided in Appendix C.

An additional FCR test to note is the use of a pool test kit. This is mentioned, because this is what the Operators in the El Cristal Program use to measure their treated water. A pool test kit works in a similar manner to the Color Wheel, where a color change is viewed. However, the Pentair Pool Test Kit that was being used is an indicator of total chlorine and not FCR. The test kit contains two columns, one for measuring total chlorine and the other for measuring pH. Othotolidine drops are added to the water in the test tube, and a yellow change is matched to a spectrum for total chlorine. The scale on this test kit contains fewer points than the Color Wheel. The CDC warns of a lack of standardization and calibration associated with this test, as well as the degradation of the othotolidine solution over time. [**72**]

In La Margarita, a Hach Digital Colorimeter was used to measure FCR and total chlorine using methods 8021 and 8167 respectively. A sample for the digital colorimeter is prepared in much the same manner as the Color Wheel with the addition of a DPD powder that changes pink. The colorimeter is first calibrated with a sample of the test water. The colorimeter reads the intensity of the color change by emitting a wavelength of light into the sample tube and displaying its readout digitally.

***Physical Testing***

*Turbidity*

Turbidity is a measurement related to the clarity and amount of suspended solids in the water. The materials suspended in water may include among other things soil particles, algae, plankton, and microbes that range in size from 0.004 mm to 1.0 mm. High turbidity water increases the temperature of the water and decreases the amount of light penetrating the water, thereby decreasing the concentration of dissolved oxygen. [**73**] Suspended solids in water provide shelter to microbes, thereby reducing their exposure to a disinfectant. Turbidity measurements were collected in the field studies and used as an indicator of treatment process efficacy. Details on turbidity tests are included in Appendix D**.**

In El Cristal, a Lamotte Turbidity Test Kit was used in field tests of the source and residential waters. Turbidity tests were conducted prior to collecting a sample for either chlorine or microbial analysis. The Lamotte kit consists of two test tubes that contain a black dot on a white background at the bottom. Either 25 or 50 mL of water was poured into one tube, and a corresponding amount of stock solution water into the other. While viewing the black dot from above, drops of a reagent were added to the stock solution until the relative cloudiness of the black dot matched the relative cloudiness of the sample. The number of drops was recorded, and a subsequent JTU and NTU measurement was calculated. It is noted that this method of measuring and calculating turbidity is a poor test. Inaccuracies easily arise from the "cloudiness" judgment that the researcher makes. This test was used because the Tufts EWB Ecuador Program did not have access to other equipment.

In La Margarita, the Hach Digital Colorimeter was used to measure the turbidity of the sampled water. Similar to the chlorine test, the sample was first calibrated, then a reading was taken by passing a wavelength of light through the sample and a digital readout displayed.

*Temperature, pH, Electrical Conductivity, Nitrates*

Additional parameters that were measured in La Margarita were the temperature, pH and electrical conductivity of the water. These measurements were collected using a probe and were to help establish a more complete picture of the water supply and treated waters.

Additionally, in La Margarita, nitrate levels were measured with the Hach Digital Colorimeter using method 8039. The nitrate was used to inform of possible agricultural contamination of the water supply.

## Surveys

### *Household Surveys*

In addition to garnering demographic information, household surveys were designed to capture important knowledge, attitude, and practices in relation to the household's water and treatment methods and may be found in Appendix E. All surveys received an exemption status from the Tufts Institutional Review Board. Additionally, the enumerators did not collect names of the interviewees and household IDs were only held in the research database until all WQ information had been matched to its household. At that time, all linkage IDs were destroyed.

An intentional component missing from the surveys was information relating to health. It was deemed impractical and irrelevant to collect information about health, as it is difficult to pinpoint the exact cause of a certain health issue on drinking water. Furthermore, sample sizes were not large enough to meaningfully conduct this type of survey, due to small community sizes. Additionally, the researcher and EWB teams did not have a member with a specialty in community public health or epidemiology.

Overall survey structures were adapted from an evaluation of Oxfam biosand filters for a cholera emergency response program. [**74**] The surveys took approximately 10 minutes to complete in El Cristal and 15 minutes to complete in La Margarita. The surveys were constructed to assess the household across a variety of interest areas

- Demographics (El Cristal & La Margarita Programs)
- Source water (El Cristal & La Margarita Programs)
- Perceptions of water safety (El Cristal & La Margarita Programs)
- Household water treatment methods in practice (El Cristal & La Margarita Programs)
- Water treatment training (El Cristal & La Margarita Programs)
- Water use information (El Cristal & La Margarita Programs)
- Water storage information (El Cristal & La Margarita Programs)
- Use/disuse of filter (La Margarita Program)
- Operation & maintenance of filter (La Margarita Program)

Instead of determining a specific number of households to be surveyed in each community, a goal of randomly surveying at least 50% of the variable community and 33% of the control community was established. This parameter was determined because of the limited number of enumerators, time in country, and water quality testing equipment. This was the key limitation to conducting the household surveys.

***Key Informant Interviews – El Cristal***

In El Cristal, interviews were conducted with all Water Board operators, Appendix F. Additionally, an interview was held with some members of the Water Board of each neighborhood. Questions asked during these interviews consisted of demographic information, questions related to job duties, information on training, and an assessment of knowledge of the systems. Again, these surveys received an exemption status from the Tufts Internal Review Board. Furthermore, the enumerators did not collect names of the interviewees and survey IDs were never held in the research database.

## Statistical Methods

Because of the small travel teams and multiple projects being conducted by each team while in country for a week, the surveying methodology was convenience sampling. The goal was to survey at least 50% of households from the variable community at random, but the end number of surveys was dictated by time and resource constraints.

In El Cristal, the control selected were the neighborhoods of Santa Rosa and Las Tolas. These communities were selected because their water is sourced from similar snow melt, they have systems of piped water into their homes, they have Water Boards and operators maintaining their systems, and they are under the governmental structure of El Cristal. A key factor in choosing these as the control communities was that they do not have a treatment process on their water distribution, nor have the Tufts EWB team ever worked in their neighborhoods before.

The selection of a control in La Margarita was more difficult. Previous survey work conducted in La Margarita that would make the community a good control in time is minimal. Therefore, the community was divided between those that used a ceramic filter (variable) and those households that did not (control).

Data was entered into Excel from the surveys by the researcher and cleaned in both Excel and Stata. Stata was used for all descriptive statistics in which chi-square tests were run to determine the statistical similarity of the variable and control communities. Additionally, ttests and logistic regressions were conducted at a significance level of $p > 0.05$ to determine the efficacy of the systems on water quality and the relationship between survey answers and water quality. Data that is presented visually was constructed in Excel.

# Case Study 1: Tufts EWB in El Cristal, Ecuador

## Introduction to El Cristal

El Cristal is a small, rural community in the Imbabura province of Ecuador in the Sierra Region consisting of about 120 families (Figure 7). El Cristal is six hours (90 miles by bus) north of Quito, and is located in the foothills of the Andes. The region is mountainous and the center of El Cristal is at approximately 7,500 feet above sea level. [**75**]

**Figure 7: Views from El Cristal** [76]

In the late 1950's the Ecuadorian national government conducted a mosquito elimination program to eradicate malaria in the Imbabura region. They then offered tax breaks and incentives for people to buy a plot of land and begin farming in this region. The community of El Cristal was founded at this time as people moved from the cities for a promise of land. [**77**]

### *Cultural Description*

El Cristal is an agricultural community that relies mostly on subsistence farming, with household weekly income averaging $20 USD. [**75**] Some families generate an income by selling crops such as coffee, fruta del árbol and bananas, which are sold in larger towns and cities outside of the village. Many families have animals on their farms such as cattle, pigs, horses, chickens, ducks, and guinea pigs. These animals are raised for eating, providing milk and eggs, and sometimes for breeding and selling.

Residents of El Cristal usually get married and begin families around 15-18 years old. Children attend school in the town center through seventh grade. Afterwards, 90% of families send their children to the neighboring town of Peñaherrera for high school. Fewer than 5 students per year pursue higher education; most children stay home to work with their parents and start families of their own. [**75**] If able to attend university, the closest tertiary school is located in Otavalo, which is a city 3 hours away by bus. Tufts EWB found family ties to be important to the people of El Cristal. It was estimated that at least 75% of residents stay in El Cristal their entire lives, with people moving primarily for marital purposes. Occasionally, people may move to nearby towns or to Quito or El Oriente in search of job opportunities. [**78**]

### ***Government and Water Board Structure***

The community of El Cristal has three water systems, which are used to identify the neighborhood in which residents live. These neighborhoods are El Cristal, Santa Rosa, and Las Tolas. Until August of 2012, Tufts worked almost solely with the neighborhood of El Cristal and their accompanying water system. A Water Board consisting of a president, secretary, and treasurer supervises each water system. Each Water Board also hired a number of Operators to handle the day-to-day maintenance of the systems. [**77**]

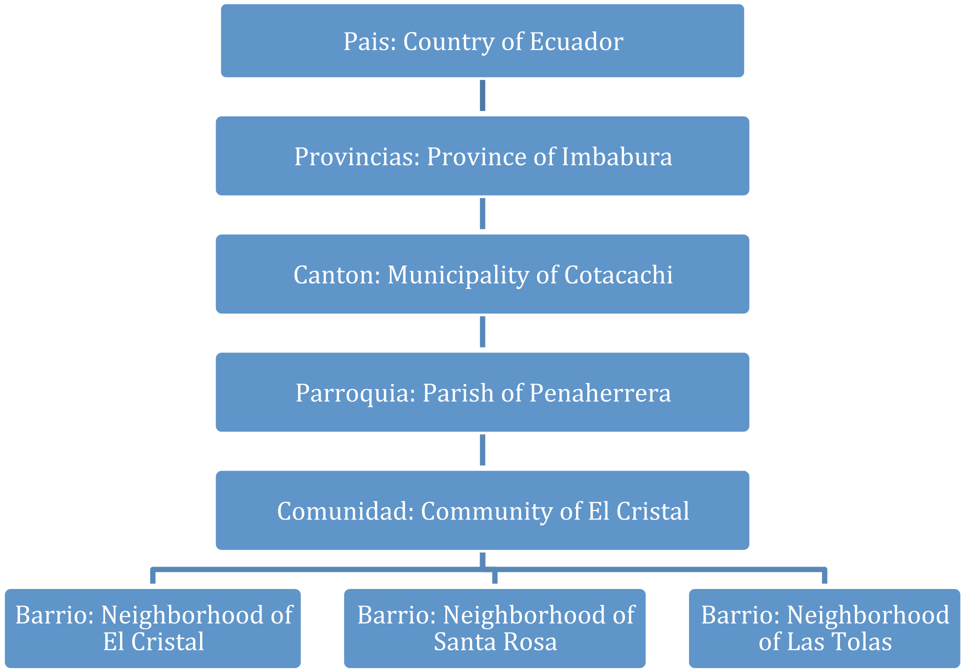


**Figure 8: Hierarchy of Government Structure in El Cristal**

The organization of the local government is depicted in the diagram in Figure 8. The slow-sand filters that serve the neighborhood of El Cristal were constructed around 1993 by the Water Resources Department of the Cotacachi Canton. The SSFs actually serve both the neighborhood of El Cristal and the community of Peñaherrera, located 10 km farther down the mountain. Approximately 2/3 of filtered water is distributed to Peñaherrera . The filters were inoperable for the first 15 years after construction because there was little training on how to use and maintain them and they were not a community priority. As a result, the filters became clogged and plants began to grow in them, and people from El Cristal stole sand to use in the construction of their homes. In 2005 Carlos Ruiz became president of El Cristal. During this time, there was a younger group of residents involved in the organization of the community who became interested in water and sanitation. Ruiz, with the support of the new generation, approached the local government in 2006-2007 with a request to rehabilitate the filters. After two years of lobbying for funding, the water system of El Cristal became a priority for the local government. The new sand and rock was delivered during Winter 2008, and the filter beds were reconstructed in Spring 2009. When the joint Water Board dissolved between Peñaherrera and El Cristal in 2008, El Cristal established their own Board and began to charge users a fee of $1.00 USD per month. [**79**]

Filter Operators were chosen by the Water Boards (2 from El Cristal and 1 from Peñaherrera) to maintain and operate the system. The original Operators received training from the local government when they were first nominated to the position. Operators receive compensation from their respective Water Board for their work at a current salary of $70 USD per month. To pay for this, in 2011 the Water Board increased user fees to $2.00 USD per month for the first 10 cubic meters and $0.10 USD for every cubic meter used after that. [**77**] This indicates a significant change from when the water was unmetered and people allowed their taps to run all day. [**75**]

## El Cristal Program History

Table 7 is a brief overview of the program history, which is followed by more detailed descriptions of the trips and activities of the Tufts EWB Project teams. When planning for the trips and projects, Tufts maintained contact with the community by emailing with Carlos Ruiz.

**Table 7: Tufts EWB Ecuador Travel History**

| Dates of Travel | Purpose of the Trip | Description |
|---|---|---|
| Summer 2006 | Assessment | Established relationship with FBU. The students performed health surveys and assessed how the community could be helped. |
| Summer 2007 | Implementation | Implemented a back-up water storage system at the hacienda. Water quality testing and health surveys in El Cristal. Community decided that water quality was an issue and wanted to collaborate with EWB. |
| January 2008 | Implementation | Additional water testing. Students learned that the community was in the process of building a slow sand filter in the main water system. |
| August 2010 | Post-Implementation Assessment | Assessed EWB-Tufts impact on community. Evaluated government funded slow sand filters. |
| August 2011 | Assessment | Evaluated operation of slow-sand filters, worked to develop new filter cleaning methods. Met with the community and engineers from local government to gage interest in future projects. |
| August 2012 | Monitoring and Evaluation for this research thesis | Assessed the functionality of the filters through water quality testing. Completed a significant round of household surveys. Also did an evaluation of Las Tolas and Santa Rosa systems, both of which are in El Cristal. Assessed slow-sand filter of neighboring community, La Magdelena |

***Summer 2006 Assessment Trip***

The Tufts EWB group began working in Ecuador in 2006. The purpose of the first trip was to establish a solid relationship with the NGO contact in the area, Fundación Brethren y Unida (FBU), as well as to assess the possibilities of implementing a green building design at FBU headquarters in future trips. Water quality testing was conducted on the hacienda's drinking sources, and community health surveys were given to residents of both FBU's hacienda and the community of El Cristal. [**80**]

***Summer 2007 Implementation Trip***

By 2007, the EWB Ecuador group had identified water as one of the primary issues of concern at both FBU and in the community of El Cristal that was within the realm of feasible projects. During the summer of 2007, six students, one professor, and his wife returned to Ecuador with the primary goal of developing a relationship with the community, identifying its needs, and jointly defining a project for the next year. The team conducted interviews and health surveys with community members and key informants, although the questions and answers were not to be found in the final report. Additionally, the team had designs for a rainwater collection, storage, and biosand filtration system to prototype and use for educational dissemination at FBU's hacienda. The group received a warm welcome in El Cristal, and built two prototypes of the household biosand filter during their stay (Figure 9).

**Figure 9: Completed biosand filter 2009** [55]

*Source Water Surveying*

The Tufts travel team completed a surveying of the water systems, one in each of the three neighborhoods of El Cristal.

El Cristal System:

The main components of the El Cristal system include two source streams, La Florida and San Francisco, which both fee to a capture tank **(**Figure 10**),** a series of five aeration tanks (Figure 11), and a distribution tank (Figure 12) located in the center of town. The operator of the system estimated that the difference in elevation between the capture tank and the distribution tank is approximately 30 m. The Tufts EWB team was not confident of this approximation, although a reason for this was not provided in the report. An overview of the system can be found in Figure 13. [**55**]

**Figure 10: Capture tank for the El Cristal system. The Tufts EWB travel team noted that the tank was uncovered, but the entrance to the tank was a wire mesh in need of repair.** [55]

When facing uphill, the stream to the right, San Francisco, is used year round for water supply. Alternately, the stream on the left, La Florida, is only used during the dry season when flows are lower. [**55**]

**Figure 11: Aeration tanks for El Cristal system. The Tufts EWB travel team noted the presence of animal feces in the left picture. They also noted the generic tank set-up in the right picture, including the T junction to relieve pressure in the piping system.** [55]

The depth to which the water fills the distribution tank is approximately 2 meters. The tank typically fills during the night and then the majority, if not all of the water, drains throughout the day. Maximum usage rates are in the morning when families collect water for the rest of the day. Attached to the tank is a system for chlorination that was not in use when the 2007 team conducted this evaluation. [**55**]

There exist two main lines of distribution, one which leads from the distribution tank to houses on the right (if facing uphill) and then descends to the district of El Cristal. The other major distribution line runs from the tank through the center of town and continues down the main road. [**55**]

**Figure 12: The distribution tank for El Cristal located after the slow sand filters.** [55]

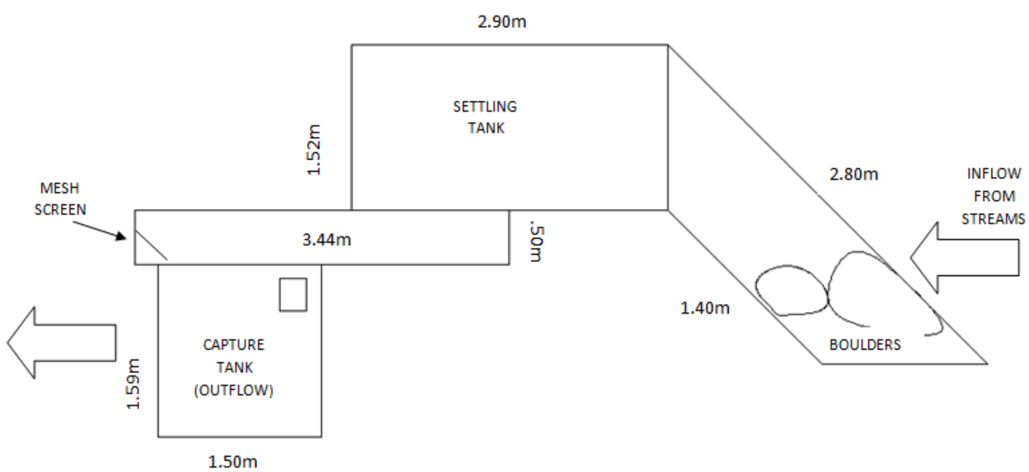


**Figure 13: Overview of El Cristal source and capture system** [78]

The operator of the Water Board provided maintenance for this system about once every two weeks. Maintenance mainly included removing major debris from the capture tank and ensuring that the feed from the two different source streams was maintained in accordance with the season. The capture tank is also set up such that it may be drained and cleaned although it was unclear to the travel team how often this occurred. [**55**]

Santa Rosa System:

The system that serves Santa Rosa has fewer major components than the El Cristal system and consists of two source streams (Figure 14), a capture tank (Figure 15), and tubing for distribution. From inspection by the Tufts EWB travel team, it appeared that this system did not receive much, if any, maintenance, but it was not identified in the report if this suspicion was confirmed. At the time of their visit, one of the source streams had been entirely blocked by debris. There was no system for preventing sediment and debris to enter the distribution tubing (Figure 16). [**55**]


**Figure 14: Junction of source streams in the capture box. The travel team noted that before the clogs were removed, the water was only trickling into the box.** [55]

**Figure 15: Left and right holding tanks.** [55]

**Figure 16: Accumulated sediment inside the capture tank.** [55]

Las Tolas System:

This system is the highest of the three water systems and includes two source streams, an uncovered capture tank (Figure 7), and tubing for distribution. The capture tank contained much fallen debris at the time of the Tufts EWB visit, but the sediment load appeared to be relatively low. [**55**]

**Figure 17: Capture tank for Las Tolas** [55]

*Water Quality Surveying*

The group conducted water quality tests of source waters (streams, tanks, and household taps) throughout all three of the systems. The methodology cited in the report is summarized as follows. Results are displayed in **Figure 18** as they appeared in the report.

Microbial testing: A presence/absence test was first used to determine whether a quantization test was needed. The report does not list the type of test or materials, but shows an image of vials being used to watch for yellow/black color change. If their vial showed black, they collected three water samples (collection details including volume are unknown) of the contaminated water and prepared three 3M Petri cards. Presumably these were incubated in some manner (not indicated in the report) and enumerated. The control was boiled tap water.

Physical testing: Test strips (source unknown) were used to test pH, total alkalinity, nitrate/nitrite, phosphate, total/free chlorine, and turbidity. Procedures for the tests were conducted according to the bottle the strips were contained in. The control was deionized water.

It is important to note several errors in the manner of data presentation in **Figure 18** First, there is no record of the indication of the volume of water the bacteria growth was seen in, nor is there and indication of the units of bacteria growth. Bacterial contamination is traditionally presented as CFU/100mL. If they followed the standard procedure for 3M Petri films, then the volume of water was 1mL and they underestimated the overall level of contamination. The table is also missing incubation time/temperature, and incorrectly labels coliform counts as 0 instead of ≤1 CFU.

**Figure 18: Water quality test results of Summer 2007 sampling. Note: "Cristal Center" refers to El Cristal system, "Above Stadium" refers to las Tolas system, and Ruiz refers to a single-family home system in use that year.** [75]

| | | | | | *Physical/Chemical Analysis* | | | | | | | *Microbiological Analysis* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | | Date | Time Taken | pH | Total Alkalinity [ppm] | Nitrate [ppm] | Nitrite [ppm] | Total Chlorine [ppm] | Free Chlorine [ppm] | Phosphate [ppm] | Turbidity | Coliform 1 | Coliform 2 | Coliform 3 | Total Coliform | E. Coli 1 | E. Coli 2 | E. Coli 3 | Total E. Coli |
| Cristal Center | Left | 24-Aug-07 | 8:57 AM | X | 0-40 | 0 | 0 | 0 | 0 | 15 | 4 | 46 | 28 | 44 | 118 | 0 | 0 | 0 | 0 |
| | Right | 24-Aug-07 | 8:58 AM | X | 40 | 0 | 0 | 0 | 0 | 15 | 7 | 29 | 40 | 39 | 108 | 0 | 0 | 0 | 0 |
| | Capture Tank | 24-Aug-07 | 8:59 AM | X | 40 | 0 | 0 | 0 | 0 | 15 | 8 | 2 | 1 | 0 | 3 | 0 | 0 | 0 | 0 |
| | Distribution Tank [1] | 25-Aug-07 | 12:20 PM | 6 | 0-40 | 0 | 0 | 0 | 0 | 15 | 3 | > 500 | > 500 | > 500 | > 1,500 | 0 | 0 | 0 | 0 |
| | *Tap (Yani and Luis)* [2] | *24-Aug-07* | *10:24 AM* | *X* | *40-80* | *0* | *0* | *0* | *0* | *15* | *5* | *0* | *2* | *1* | *3* | *0* | *0* | *0* | *0* |
| | Tap (Yani TRIAL 2) | 25-Aug-07 | 12:14 PM | 6 | | | | | | | | 1 | | | 1 | 0 | | | 0 |
| Santa Rosa | Left | 24-Aug-07 | 9:36 AM | X | 0-40 | 0 | 0 | 0 | 0 | 15 | 7 | 58 | 46 | 42 | 146 | 2 | 1 | 0 | 3 |
| | Right | 24-Aug-07 | 9:34 AM | X | 40-80 | 0 | 0 | 0 | 0 | 15 | 85 | 74 | 64 | 69 | 207 | 0 | 0 | 1 | 1 |
| | Capture Tank | 24-Aug-07 | 9:49 AM | X | 40-80 | 0 | 0 | 0 | 0 | 15 | 10 | 58 | 77 | 108 | 243 | 1 | 0 | 1 | 2 |
| | *Tap* [3] | *24-Aug-07* | *9:26 AM* | *X* | *40-80* | *0* | *0* | *4* | *2* | *15* | *7* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| Above Stadium | Left | 24-Aug-07 | 9:25 AM | X | 0-40 | 0 | 0 | 0 | 0 | 15 | 12 | 5 | 2 | 0 | 7 | 0 | 0 | 0 | 0 |
| | Right | 24-Aug-07 | 9:25 AM | X | 0 | 0 | 0 | 0 | 0 | 5 to 15 | 7 | 3 | 10 | 4 | 17 | 1 | 0 | 1 | 2 |
| | Capture Tank | 24-Aug-07 | 9:25 AM | X | 0-40 | 0 | 0 | 0 | 0 | 5 to 15 | 5 | 0 | 1 | 2 | 3 | 0 | 0 | 0 | 0 |
| | *Tap (Enrique)* [4] | *24-Aug-07* | *10:00 AM* | *X* | *0-40* | *0* | *0* | *10* | *10* | *15* | *4 to 5* | *0* | *0* | *0* | *0* | *0* | *0* | *0* | *0* |
| | Tap (Trial 2 Enrique) | 25-Aug-07 | 11:00 AM | 6 | | | | | | | | 2 | 1 | 1 | 4 | 1 | 0 | 0 | 1 |
| Ruiz | Capture Tank | 24-Aug-07 | 10:50 AM | X | 0-40 | 0 | 0 | 0 | 0 | 15 | 1 | 118 | 143 | 144 | 405 | 1 | 1 | 3 | 5 |
| | Distribution Tank | 24-Aug-07 | 8:30 AM | X | 40-80 | 0-1 | 0 | 0 | 0 | 5 to 15 | 2 | 0 | 2 | 3 | 5 | 0 | 0 | 3 | 3 |
| | Tap (Carlos) | 24-Aug-07 | 8:15 AM | X | 40 | 0.5 | 0 | 0 | 0 | 15 | 2 | 1 | 0 | 2 | 3 | 0 | 2 | 1 | 3 |
| Control | Boiled/ DI Water | 24-Aug-07 | NA | X | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

[1] Sample was taken from the inlet to the distribution tank because the water level in the tank was very low. Future tests should take sample from standing water in the tank.

[2] This test was repeated due to the uncertainty that all bacteria could be removed from the system in the distribution tubing.

[3] Tap test here was taken from a bucket of water taken from the tap earlier that morning. Additionally, all disinfection chlorine was not fully rinsed, causing the bacteria results to be invalid.

[4] First test for Enrique's tap did not fully remove the chlorine solution used for disinfection and therefore the bacteria readings were null.

All of the water sources tested showed serious bacteria contamination, but the team concluded that the physical and chemical characteristics were all with in the acceptable range for potable water, with the exception of turbidity. The travel team held a meeting with the community to discuss the results of their testing and surveying. They presented the Petri films so that people were able to visibly see the poor quality of their water by the sheer number of bacterial colonies that had grown. The films were given to the community to share with others outside the meeting. [**75**]

### ***Winter 2008 Implementation Trip***

An additional assessment trip was conducted in January of 2008 to assess water quality of the source waters indicative of the rainy season to supplement the work that had been completed the prior summer. Three students and an alumni advisor stayed in the community for 10 days completing the surveying. They discovered that during the Fall of 2007, empowered with knowledge and evidence about their water quality by the Summer 2007 travel team, the community brought their water test results and films to their local government in order to lobby for improvement of their situation. The local government devoted $25,000 USD to the rehabilitation of the slow sand filters that serve the neighborhood of El Cristal. By the Winter 2008 trip, the Jose Otuna engineering firm had begun construction on the slow sand filter bed, fixing pipes, and replacing valves. The Water Board for Las Tolas was also in the process of applying for a grant. [**63**]

#### *Water Quality Surveying*

Surveying was again conducted on all three water systems, but only the El Cristal and Santa Rosa system where monitored the whole trip due to time and material constraints. The methodology cited in the report was quite convoluted and is summarized below to the best of the researcher's ability. Results from the reports are displayed in Table 8, Table 9, and Table 10 as they appeared in the report. [**56**]

> Microbial testing: Water samples were collected in small plastic bottles that were washed between uses with a few millimeters of isopropyl alcohol and 10 mL of deionized water. Before a final sample was collected, the bottle was first rinsed three times with water from that location. If one bottle of sample water had been collected at a particular site, then 3 3M Petrifilms were prepared from that bottle. If two bottles of sample water had been collected from the site, then only one Petrifilm was prepared for each bottle. The number of samples collected was based upon convenience and bottle availability. Petrifilms were prepared by pipetting 1mL of water (with a disposable pipet) onto each card. Samples were incubated at 35°C for 24 hours in a Hach portable incubator. Two people enumerated each Petrifilm and the final count averaged. The counts were then averaged by sample location and collection time. [**56**]
>
> Physical Testing: Test strips (source unknown) were used to test pH, total alkalinity, nitrate/nitrite, phosphate, total/free chlorine, and turbidity. Procedures for the tests were conducted according to the bottle the strips were contained in. [**56**]

As can be seen in Table 8, Table 9, and Table 10, there are numerous errors in the manner of data reporting. First and foremost, there is no clear indication of what the coliform growth is, although the reader assumes that falls in the column labeled "count." Written in the report is an indication that no *E.Coli* colonies were detected; therefore we are left to assume that "count" refers to total coliforms. Furthermore, it is not indicated whether the "count" is per 1mL or 100mL. Another issue with the presentation is that there is no indication as to what exactly the other data columns represent.

**Table 8: Winter 2008 microbial test results for El Cristal system** [56]

| Date | **7-Jan** | | | | **9-Jan** | | | |
|---|---|---|---|---|---|---|---|---|
| Weather | Rain at night | | | | Rain all day | | | |
| Time of collection | 9:40 - 11:55am | | | | | | | |
| | count | std dev | bot | n | count | std dev | bot | n |
| Source rocks | **0** | 0 | 3 | 2 | | | | |
| Source pipe | **5** | 3.90 | 3 | 2 | | | | |
| Stream | **22** | 0.82 | 1 | 3 | | | | |
| Tank 3 | **3** | 0.71 | 2 | 2 | | | | |
| Tank 2 | **14** | 1.70 | 1 | 3 | | | | |
| Tank 1 | | | | | | | | |
| Luis Tap | | | | | **0** | 0 | 1 | 3 |
| Store in Plaza | | | | | | | | |
| | | | | | | | | |
| Date | **10-Jan** | | | | **11-Jan** | | | |
| Weather | Sunny am<br>Rain starting at 5pm | | | | Sunny | | | |
| Time of collection | 9:34 - 9:41am | | | | 8:15 - 9:50am | | | |
| | count | count | std dev | bot | count | std dev | bot | n |
| Source rocks | **0** | **0** | 0 | 1 | **0** | 0 | 1 | 3 |
| Source pipe | **7** | **0.3** | 0.47 | 1 | **0.3** | 0.47 | 1 | 3 |
| Stream | **65** | **28** | 3.77 | 1 | **28** | 3.77 | 1 | 3 |
| Tank 3 | **5** | **12** | 2.94 | 1 | **12** | 2.94 | 1 | 3 |
| Tank 2 | | | | | | | | |
| Tank 1 | **22** | **25** | 1.41 | 1 | **25** | 1.41 | 1 | 3 |
| Luis Tap | | **0.7** | 0.94 | 1 | **0.7** | 0.94 | 1 | 3 |
| Store in Plaza | | **0.3** | 0.47 | 1 | **0.3** | 0.47 | 1 | 3 |

**Table 9: Winter 2008 microbial test results for Santa Rosa system [56]**

| | 8-Jan | | | | 9-Jan | | | |
|---|---|---|---|---|---|---|---|---|
| Weather | Overcast<br>Rain starting in the pm | | | | Rain all Day | | | |
| Time collected | 9:13 - 9:28am | | | | 9:22 - 11:50am | | | |
| | count | std dev | bot | n | count | std dev | bot | n |
| Source | | | | | **24** | 3.74 | 1 | 3 |
| Stream 1 | **13** | 4.30 | 2 | 2 | **200+** | | 2 | 2 |
| Pipe 1 | **4** | 1.64 | 2 | 2 | **56** | 18.36 | 2 | 2 |
| Stream 2 | **47** | 9.84 | 2 | 2 | **200+** | | 2 | 2 |
| Pipe 2 | **6** | 2.38 | 2 | 2 | **18** | 4.97 | 2 | 2 |
| Tank 1 | **0** | 0 | 2 | 2 | **104** | 14.25 | 2 | 2 |
| Tap 1 | | | | | **0** | 0 | 1 | 3 |
| Tap 2 | | | | | **7** | 2.80 | 1 | 3 |
| Tap 3 | | | | | **10** | 2.71 | 1 | 3 |
| | | | | | | | | |
| | 10-Jan | | | | 11-Jan | | | |
| Weather | Sunny am<br>Rain starting at 5pm | | | | Sunny | | | |
| Time collected | 10:26 - 10:52am | | | | 10:40 - 11:18am | | | |
| | count | count | std dev | bot | count | std dev | bot | n |
| Source | | | | | | | | |
| Stream 1 | | | | | | | | |
| Pipe 1 | **53** | **110** | 1.72 | 1 | **110** | 1.72 | 1 | 3 |
| Stream 2 | | | | | | | | |
| Pipe 2 | **34** | **64** | 6.93 | 1 | **64** | 6.93 | 1 | 3 |
| Tank 1 | **87** | **49** | 5.32 | 1 | **49** | 5.32 | 1 | 3 |
| Tap 1 | | | | | | | | |
| Tap 2 | | | | | | | | |
| Tap 3 | **90** | **48** | 3.98 | 1 | **48** | 3.98 | 1 | 3 |

**Table 10: Winter 2008 microbial test results for Santa Rosa system [56]**

| | 10-Jan | | | | 11-Jan | | | |
|---|---|---|---|---|---|---|---|---|
| Weather | Sunny am<br>Rain starting at 5pm | | | | Sunny | | | |
| Time collected | 8:38 - 10:37am | | | | 10:01-10:44am | | | |
| | count | std dev | bot | n | count | std dev | bot | n |
| Tank | **1.3** | 0.47 | 1 | 3 | **2.7** | 0.47 | 1 | 3 |
| House Enrique | **2.3** | 1.25 | 1 | 3 | **3.3** | 1.25 | 1 | 3 |
| House Luis Farm | **2** | 0.82 | 1 | 3 | **3** | 0.82 | 1 | 3 |
| House A | **1.3** | 0.94 | 1 | 3 | | | | |
| House B | | | | | **3.3** | 3.40 | 1 | 3 |

The team documented during their survey of the El Cristal system that the Water Board had connected the SSF influent pipes to a bypass of the system and linked directly to the distribution tank (Figure 19).

**Figure 19: Piped bypass of sand filters 2008** [54]

The travel team held a meeting with 30-40 community members before their departure. They presented the results of their most recent water quality testing, reiterated the significance of fecal coliform presence in the water and held a question and answer session. The travel team noted in the report their impression that after seeing the Petrifilms people were taking extra precautions in boiling their water and that the meeting had significantly impacted community members.

***Summer 2010 Post-Implementation Assessment***

The purpose of the Summer 2010 trip was to conduct follow-up community health surveys, water quality testing, and work with the community to ensure the project's sustainability. This trip served as a post-implementation evaluation of the impact EWB-Tufts had on El Cristal. Community surveys were administered to measure any improvements in the health of the community members as well as to determine any changes in perceptions of the importance of potable water. The effectiveness of the slow sand filters in the El Cristal system was assessed through water quality testing. [**78**]

It was found by the team that a primary barrier to successful operation of the filters was a non-standardized cleaning process that led to sand being inadvertently removed. The filters would be allowed to dry out when they became clogged with particulate. The Operators then shoveled the caked silt out of the filters (Figure 20). It became a goal of the team to develop a cleaning method during the following year. The team also conducted trainings on filter maintenance with the Operators. Finally, the team trained the community on different methods for household water disinfection, including boiling, SODIS, and chlorination. [**78**]

**Figure 20: The east filter drying and the west filter in use 2010 [**78**]**

*Water Quality Surveying*

Water quality surveys were conducted at influent and effluent points in the sand filter as well as in the tanks and at household taps. Multiple surveys were conducted at each location across a range of days. The travel team prepared a methodology and sampling plan in their report, which is paraphrased below. Results are presented in and Table 11, Table 13, and Table 12 directly from their trip report.

Microbial testing:  Water samples were collected in 250 mL HDPE narrow mouth sample bottles and held for no more than two hours before prepped for MF. Bottles were reused and rinsed with isopropyl alcohol and boiled water. Coliscan MF apparatuses and mColiBlue24 broth was used in the preparation of the plates. Each plate represented 100mL of water. Samples were incubated at 35°C for 24 hours in a Hach portable incubator. Two enumerators counted the growth on each plate. An average of the two counts was recorded. [**78**]

Physical testing:  Turbidity, hardness, nitrate, and iron were monitored as well. Chemical characteristics were completed using test strips as described in previous years. Turbidity was conducted with a Portable Turbidimeter using a secondary turbidity standard of calibration.

As an additional parameter effecting water quality, the superficial velocity of water flowing through the SSF was calculated and compared to the designed flow rate to determine if the unit was properly sized (Table 11). It was determined that the superficial velocity was 2.7 times higher than the maximum desired rate. The travel team calculated that this averaged out to a usage of 56 $m^3$/household/month meaning that there was increased strain on both the system and the Operators to clean the system. [**78**]

**Table 11: Summer 2010 current and contractual superficial velocities** [78]

| At Current usage rate* (m/hr) | | At Contractual usage rate** (m/hr) | | Desired Range*** (m/hr) |
|---|---|---|---|---|
| One filter operating | Both filters operating | One filter operating | Both filters operating | |
| 0.643 | 0.322 | 0.287 | 0.143 | 0.112-0.238 |

*Current usage rate used to calculate superficial velocity was 1601cm$^3$/s with a standard deviation of 23.9.
**Contractual usage rate is 25m$^3$/family/month or 0.713L/s assuming 5 people per household and 75 households as dictated by system operators.
***Desired range was obtained through conversation with technical expert, Mark Youngstrom.

Comparing the turbidity of the inflow and outflow waters, the slow sand filter was functioning properly, exhibiting particulate removal factors of 7-43 (Table 12).

**Table 12: Summer 2010 turbidity test results** [78]

| Sample Location | Date collected | Turbidity (NTU) | Particulate Removal Factor |
|---|---|---|---|
| Inflow with bypass on<br>Outflow with bypass on | 20-Aug | 6.71<br>0.93 | 7 |
| Inflow with bypass off<br>Outflow with bypass shut off immediately before | 21-Aug | 3.27<br>0.23 | 14 |
| Inflow<br>Outflow | 21-Aug | 6.41<br>0.15 | 43 |
| Inflow<br>Outflow | 22-Aug | 2.40<br>0.12 | 20 |
| Inflow<br>Outflow | 22-Aug | 2.48<br>0.16 | 15 |
| Inflow<br>Outflow | 23-Aug | 2.70<br>0.14 | 19 |
| Inflow<br>Outflow | 24-Aug | 2.31<br>0.08 | 28 |
| Inflow<br>Outflow | 25-Aug | 1.00<br>0.09 | 12 |

**Table 13: Summer 2010 microbial test results for El Cristal system** [78]

| Sample Location | Date collected | Turbidity (NTU) | General coliform (cfu/100mL) | E. coli (cfu/100mL) | Total coliform (cfu/100mL) |
|---|---|---|---|---|---|
| bottled water control | 22-Aug | n/a | 0 | 0 | 0 |
| bottled water control | 23-Aug | n/a | 0 | 0 | 0 |
| bottled water control | 24-Aug | n/a | 0 | 0 | 0 |
| bottled water control | 25-Aug | n/a | 0 | 0 | 0 |
| Inflow | 22-Aug | 2.40 | 110 | 29 | 138.75 |
| Outflow | 22-Aug | 0.12 | 28 | 6 | 33.25 |
| Inflow | 22-Aug | 2.48 | 109 | 20 | 128.5 |
| Outflow | 22-Aug | 0.16 | 5 | 2 | 6.75 |
| Inflow | 23-Aug | 2.70 | 45 | 30 | 74.5 |
| Outflow | 23-Aug | 0.14 | 28 | 3 | 30.5 |
| Inflow | 24-Aug | 2.31 | 11 | 11 | 21.5 |
| Outflow | 24-Aug | 0.08 | 10 | 4 | 13.75 |
| Inflow | 25-Aug | 1.00 | 68 | 11 | 79 |
| Outflow | 25-Aug | 0.09 | 37 | 2 | 38 |
| Surge Tank | 25-Aug | 0.27 | 171 | 4 | 174.5 |
| House #1 | 23-Aug | 0.35 | 13 | 4 | 16.5 |
| House #2 | 23-Aug | 0.12 | 18 | 3 | 21 |
| House #3 | 23-Aug | 0.10 | 1 | 2 | 3 |
| House #4 | 23-Aug | 0.11 | 44 | 1 | 44.5 |
| House #5 | 23-Aug | 0.24 | 18 | 2 | 19.5 |
| House #1 | 25-Aug | 0.26 | 26 | 0 | 26 |
| House #2 | 25-Aug | 0.15 | 20 | 0 | 19.5 |
| House #3 | 25-Aug | 0.10 | 12 | 0 | 12 |
| House #4 | 25-Aug | 0.13 | 7 | 0 | 6.5 |
| House #5 | 25-Aug | 0.63 | 7 | 2 | 8.5 |
| House #6 boiled | 22-Aug | n/a | 0 | 0 | 0 |
| House #6 tap | 23-Aug | 0.15 | 34 | 380 | 414 |
| House #6 tap | 25-Aug | 0.12 | 110 | 657 | 767 |
| House #6 biosand | 25-Aug | 0.12 | 44 | 260 | 303 |
| House #6 SODIS | 25-Aug | n/a | 0 | 0 | 0 |
| House #6 chlorine | 25-Aug | n/a | 0 | 0 | 0 |

At the time of this testing, the team found that the filter was not operating as a bacteria remover and no schmutzedecke was present in the system. It is important to note that there are several inaccuracies in the data presentation in Table 13. First, “general coliforms” is an incorrect term to describe the non-fecal coliforms found on the plate. Another is that there are fractions of coliforms presented, when they should only be presented as whole colonies. There is also selection bias present in the representation of household data, as the chosen households were members of the Water Board and community President.

*Health Surveying*

The 2010 Tufts EWB travel team completed a health survey of 19 adults with 18 kids among them and an interview of a nurse at the community clinic in El Cristal. They constructed a rudimentary comparison of information from the health surveys given in 2007 (number of surveys is unknown) to the surveys completed in 2010. \The results are presented in Table 14 below as they appeared in the report.. It is noted that the methods for data collection, choice of interviewees, number of respondents, etc. are not listed in the report. Also unclear are the numbers of people experiencing specific ailments, as they have been grouped in the table. Also shown is information from the interview of the nurse in Table 15 as it appeared in the report.

**Table 14 : Comparison of common health complaints from 2007 to 2010 [78]**

| | Condition | Before filters (2007) | After filters (2010) |
|---|---|---|---|
| **Gastrointestinal complaints** | Diarrhea and dehydration | 85% | 41% |
| | Stomach problems | 69% | 57% |
| **Other common complaints** | Flu | 54% | 79% |

**Table 15: Interview of nurse on patient numbers from last three months [78]**

| Condition | Number of Patients |
|---|---|
| Flu | ±30 |
| Parasites | ±13 |
| Cough | ±13 |
| Fever | ±8 |
| Headache | ±3 |
| Diarrhea | ±2 |

The nurse was asked to recall the number of times she estimated that the clinic had treated each condition in the three months prior. Unfortunately, the team did not have any other historical data to compare this information to. Furthermore, it is noted by the researcher that sample sizes were too small for the team to draw any conclusions from the health data collected. Another note from the health surveys was that the team found 47% of people self-reported boiling water in 2010 as compared to 15% in 2007. [**81**]

### *Summer 2011 Assessment*

The August 2011 trip was conducted as both a follow-up to the 2010 trip and as an assessment for possible future projects. Four students and the Program's Professional Mentor spent five days in the community. The primary goal of the trip was to implement a cleaning system as requested by the Operators the previous summer (Figure 21). However, upon arrival in the community the team was informed that the Water Boards of El Cristal and Peñaherrera had jointly purchased a gasoline powered pump for $250 to aid the Operators in cleaning the SSFs. The travel team readjusted their trip goals to work with the Operators in optimizing the cleaning process.

**Figure 21: The siphon system developed by Tufts EWB [**82**]**

Although the 2010 team had conducted trainings with the Operators, it was clear to the 2011 team they still did not understand: the importance of having a wet filter bed, not removing the fine sand layer, the shmutzdecke, adjusting inflow rates to match demand, and how to chlorinate the water supply. Informal workshops were conducted to improve the effectiveness of the Operator's efforts to clean the filters as well as to educate them on the importance of maintaining a healthy filter system.

The community also surprised Tufts EWB by informing them that they were going to be chlorinating their distribution tank, pictured in Figure 22. It was indicated that this measure stemmed from the Tufts team showing them household methods of disinfection and passing around the petri dishes from the microbial tests in 2010. The pool chlorine that the community ordered arrived the morning the team left, so Tufts was unable to help dose the system properly, so they documented it to determine proper dosage of the water supply upon return to Tufts. [**79**] The team also met with local government engineers who had plans to construct a roughing filter upstream of the slow-sand filters during the 2011-2012 academic year. [**79**]


**Figure 22: The pool chlorine and accompanying test kit purchased by El Cristal 2011** [83]

During the fall of 2011 it became evident that the Tufts EWB project no longer fit under the guidelines of a Program with EWB-USA's definition. A primary reason for closing the Program with National was that the new roughing filter project was a joint venture between Tufts and the local government engineers. Under EWB-USA guidelines, Tufts was not able to act in a consultant role and provide designs to the local engineers for them to adjust and implement. Tufts felt that it was for the best of the community if they still maintained an advisory role and continued on without the restrictions of EWB-USA. [**84**]

## Results from Monitoring and Evaluating in Summer 2012

The mission of Tufts University in El Cristal and other communities in the region continues under the university group Developing Rurally Optimized Projects for Sustainability (DROPS). DROPS completed their first trip in August 2012 to determine the functionality of the filtration system and gauge the impact of this system throughout the community via water quality testing and household surveys created by the researcher. The team surveyed the El Cristal water system as well as the systems of Santa Rosa and Las Tolas, marking Tufts first return to those outlying neighborhoods since 2008. They also conducted surveys in 32 household in El Cristal and 21 households combined between Santa Rosa and Las Tolas. All surveying, both social and technical, was conducted in accordance with the methodology presented in the Methods Chapter. At the request of the El Cristal Water Board, the team developed and implemented a new cleaning tool to attach to their pump to prevent sand from being sucked out of the filters. Also on behalf of the Water Board, the team conducted a survey of sand levels in the SSFs to document losses (Figure 23). [**77**]

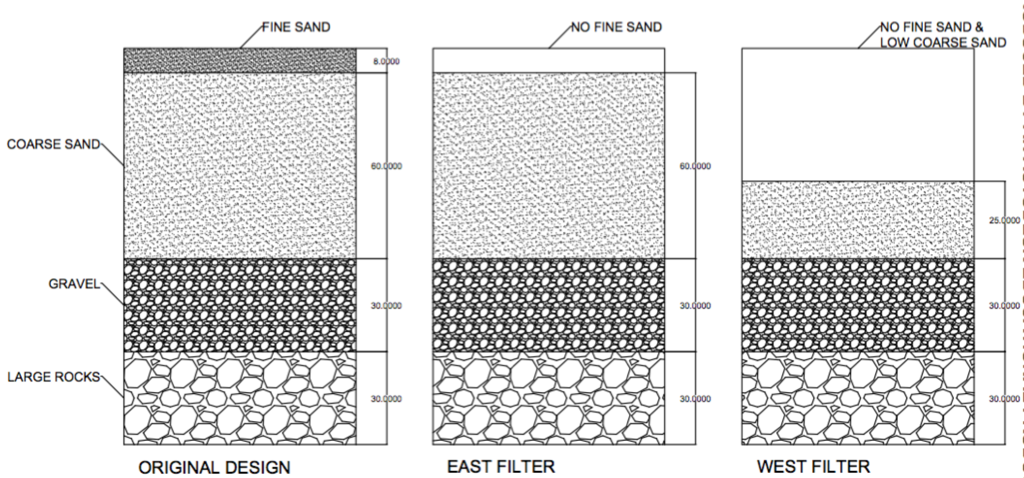


**Figure 23: 2012 sand levels as compared to intended design** [77]

During the time of the team's visit, it was made clear that El Cristal had not yet been able to secure funding for the roughing filter project. The community was debating whether money would be better spent on a new project or on once again rebuilding their SSF to its designed operational status. Lastly, a morning was spent on a preliminary assessment of the SSF of the neighboring community of La Magdelena to gauge the potential of a future Program. [**77**]

### *Demographics*

The first presentation of data from the household surveys is a demographic comparison of the variable and control communities using a chi-square test (Table 16).

**Table 16: Demographic Information for El Cristal**

| | **El Cristal (n = 32)** | **Las Tolas & Santa Rosa (n = 21)** | **Total (n = 53)** | **p-Value ($x^2$ test)** |
|---|---|---|---|---|
| ***Demographic Information*** | | | | |
| Total Population (households) | 65 | 50 | 115 | |
| Surveyed households | 32 | 21 | 53 | |
| % Households surveyed | 49.2 | 42.0 | 46.1 | |
| Age of respondents; average (min-max) | 51 (14-82) | 52 (24-86) | 52 (14-86) | |
| Female respondents; number (%) | 21 (66) | 17 (81) | 38 (72) | **0.226** |
| Attended school; number (%) | 31 (97) | 18 (86) | 49 (93) | **0.132** |
| Years of schooling; average (min-max) | 5.9 (1-15) | 5.1 (2-11) | 5.6 (1-15) | |
| Household size; average (min-max) | 3.2 (1-7) | 4.6 (1-10) | 3.7 (1-10) | |
| ***Water Collection Site*** | | | | **0.016** |
| Tap; number (%) | 32 (100) | 15 (71) | 47 (89) | |
| Hose; number (%) | 0 (0.0) | 4 (19) | 4 (7.6) | |
| Metal drum; number (%) | 0 (0.0) | 1 (4.8) | 1 (1.9) | |
| Don't know; number (%) | 0 (0.0) | 1 (4.8) | 1 (1.9) | |
| ***Water Source*** | | | | **<0.001** |
| Water filter; number (%) | 29 (91) | 0 (0.0) | 29 (55) | |
| Capture boxes; number (%) | 0 (0.0) | 21 (100.0) | 21 (40) | |
| Earth; number (%) | 1 (3.1) | 0 (0.0) | 1 (1.9) | |
| Don't know; number (%) | 1 (3.1) | 0 (0.0) | 1 (1.9) | |
| ***General Water Information*** | | | | |
| Monthly water bill USD; average (min-max) | 2.1(1.5-2.8) | 0.8 (0.0-10) | 1.6 (0.0-10) | |
| Collected a water sample; number (%) | 32 (100) | 19 (91) | 51 (96) | **0.202** |

El Cristal is statistically similar to the control neighborhoods of Santa Rosa and Las Tolas across almost all of the demographic categories, except the source of the water and the monthly cost of water. Although all source waters for these communities generate in small mountain streams of ice melt and run-off, the water for El Cristal passes through a sand filter before being distributed to homes whereas the water in the other neighborhoods does not. Because of the operation of the filter, the monthly water bill is on average $1.34 USD more in El Cristal than the surrounding communities. El Cristal also had a more standardized monthly fee, whereas respondents indicated a wider range of fees in Santa Rosa & Las Tolas.

Most everyone in these communities receives some form of education, with an average attendance of 5.9 years in El Cristal and 5.1 years in Santa Rosa & Las Tolas. The percentage of female respondents was higher in the control neighborhoods (71% $p=0.226$) where there was also a slightly larger average household size (4.6 ppl) as compared to El Cristal.

***Water knowledge, attitudes, and practices***

The next presentations of information from the household surveys is a comparison of the variable and control communities using a chi-square test on several topics related to their water usage, perceptions, education, and treatment.

*Water Usage*

Water usage in these communities is statistically similar, as can be seen in Table 17, with no notable differences in usage. Fewer people used water for their gardens in both communities, which could be attributed to the small streams that exist on many properties that households use for other, farming needs.

**Table 17: Water Usage in El Cristal**

| | **El Cristal Number (%) (n=32)** | **Las Tolas & Santa Rosa Number (%) (n=21)** | **Total Number (%) (n=53)** | **p-Value ($x^2$ test)** |
|---|---|---|---|---|
| Drinking | 32 (100) | 21 (100) | 53 (100) | |
| Cooking | 31 (97) | 19 (91) | 50 (94) | **0.324** |
| Bathing | 29 (91) | 18 (86) | 47 (89) | **0.581** |
| Washing hands | 29 (91) | 18 (86) | 47 (89) | **0.581** |
| Washing dishes | 29 (91) | 18 (86) | 47 (89) | **0.581** |
| Washing clothes | 29 (91) | 18 (86) | 47 (89) | **0.581** |
| Washing fruit/veg | 28 (88) | 17 (81) | 45 (85) | **0.515** |
| Watering the garden | 9 (28) | 9 (43) | 18 (34) | **0.268** |

*Perceptions of Water Safety*

To understand the communities' attitudes towards their water systems, they were asked if they believed their water was safe, and then asked to provide reasons for why they believed this (Table 18). Multiple responses were possible within the categories "Unsafe because" and "Safe because" with a total of 29 respondents providing reasons for unsafe water and 20 respondents providing reasons for safe water. Because multiple responses were possible, percentages indicated with each response correspond to the percentages responding positively to that particular question. Therefore, percentages relate to the row, and not the column response of the group. Overall, 53% of respondents in El Cristal and 29% of respondents in Santa Rosa & Las Tolas (p=0.068) believe their water is safe.

**Table 18: Perception of Water Safety**

| | El Cristal Number (%) | Las Tolas & Santa Rosa Number (%) | Total Number (%) | p-Value ($x^2$ test) |
|---|---|---|---|---|
| Perceive water is safe | 17 (53) | 6 (29) | 23 (43) | **0.068** |
| Don't know | 4 (13) | 1 (4.8) | 5 (9.4) | |
| ***Reasons for unsafe water (n=29)*** | **(n = 25)** | **(n = 4)** | | |
| Suspended materials in water | 1 (7.7) | 1 (6.3) | 2 (6.9) | |
| Cloudy water | 2 (15) | 4 (25) | 6 (21) | |
| Water has color | 0 (0.0) | 1 (6.3) | 1 (3.5) | |
| Unprotected source | 0 (0.0) | 5 (31) | 5 (17) | |
| Water not chlorinated | 1 (7.7) | 5 (31) | 6 (21) | |
| "Dirty" water | 0 (0.0) | 3 (19) | 3 (10) | |
| Bugs in water | 2 (15) | 2 (13) | 4 (14) | |
| Mistrust Operators | 9 (69) | 0 (0.0) | 9 (31) | |
| ***Reasons for safe water (n=20)*** | **(n = 16)** | **(n = 4)** | | |
| Clear water | 6 (38) | 0 (0.0) | 6 (30) | |
| Water is filtered | 8 (50) | 0 (0.0) | 8 (40) | |
| Water is chlorinated | 8 (50) | 1 (25) | 9 (45) | |
| Operators clean water system | 2 (13) | 3 (75) | 5 (25) | |

The reasons provided for believing their water was safe or unsafe are not statistically significant when stratifying the results across multiple answers between the two groups. However, general trends can be noticed within each group. In reasons for unsafe water, 31% of people in Santa Rosa & Las Tolas indicate an unprotected source and 31% indicate lack of chlorination as the primary causes for concern. In El Cristal 69% of respondents, the highest among all answers indicate a mistrust of the Operators. Some provided elaboration upon this including, “the chlorine taste changes”, “[one of the Operators] is not reliable”, “too much chlorine flavor”, “they don’t know what they’re doing”, “sometimes you can taste and smell the chlorine”, “they don’t clean the system.”

In Santa Rosa & Las Tolas 75% of respondents indicated that the Operators cleaning the system as a reason for perceiving the water as safe; this indication being the most prevalent. Water filtration and water chlorination were the primary responses for the belief in safe water in El Cristal at 50% each. It is important to note that far fewer respondents indicated reasons for safe water in Santa Rosa & Las Tolas, n=4, than did in El Cristal, n=16. Also, there was less variation in reasons for perception of safe water in both communities than there were for perceptions of unsafe water.

*Water Education*

Respondents were asked about whether or not they had received any information on their water systems and to identify the source of that information. Table 19 is a presentation of this suite of questions. Most people received their information from some form of group training, El Cristal 38% and Santa Rosa & Las Tolas 30%, displaying statistically similar answers (p=0.566). In El Cristal 47% received information from their Water Board, higher than any other information source. It was also indicated to the enumerator by many people that the Water Board had instituted three mandatory meetings per year that residents were required to attend. In Santa Rosa & Las Tolas the source of information was divided at 33% each between the Water Board and the Operators.

**Table 19: Education about water systems in El Cristal**

| | El Cristal Number (%) | Las Tolas & Santa Rosa Number (%) | Total Number (%) | p-Value ($x^2$ test) |
|---|---|---|---|---|
| ***Type of information*** | **(n = 32)** | **(n = 21)** | **(n = 53)** | |
| Received a pamphlet/poster | 0 (0) | 0 (0) | 0 (0) | |
| Received a household visit | 4 (14) | 0 (0) | 4 (8.2) | |
| Received a group training | 11 (38) | 6 (30) | 17 (35) | **0.566** |
| Received a heath promotion | 0 (0) | 0 (0) | 0 (0) | |
| Don't know | 3 (9.1) | 1 (4.7) | 4 (7.5) | |
| ***Source of Information (n=21)*** | | | | |
| Tufts University | 5 (33) | 0 (0) | 5 (24) | |
| Water Board | 7 (47) | 2 (33) | 9 (43) | |
| Operator | 0 (0.0) | 2 (33) | 2 (9.5) | **0.039** |
| Ecuadorian Technical University | 1 (6.7) | 0 (0) | 1 (4.8) | |
| Don't know | 2 (13) | 2 (33) | 4 (19) | |

*Household Water Treatment and Storage*

Reported HWTS (Table 20) is statistically similar between El Cristal and Santa Rosa & Las Tolas. Of the respondents, 44% reported household treatment in El Cristal while 33% reported positively in Santa Rosa & Las Tolas (p=0.488). At the time of the survey, however, the availability of treated water was much lower, with only 36% of respondents who treat in El Cristal able to provide a sample and 29% who treated in Santa Rosa & Las Tolas able to provide a sample.

Of the respondents who were treating their water, 79% reported boiling in El Cristal and 72% reported boiling in Santa Rosa & Las Tolas (p=0.063). This was the most common household treatment. Three households (21.4%) reported using a ceramic filter in El Cristal. These candle-style filters were gifts of Tufts EWB Ecuador's professional mentor and were set-up in August of 2011. Microbiological testing and further visual inspection of the filters showed serious malfunctions, and filter use was discontinued immediately. The amount of time since household treatment varied greatly between El Cristal (avg. 59.2 hours) and Santa Rosa & Las Tolas (avg. 25 hours)

**Table 20: HWTS in El Cristal**

| | **El Cristal (n = 32)** | **Las Tolas & Santa Rosa (n = 21)** | **Total (n = 52)** | **p-Value ($x^2$ test)** |
|---|---|---|---|---|
| Household treatment; number(%) | 14 (44) | 7 (33) | 21 (40) | **0.448** |
| Treated water available; number (%) (n=21) | 5 (36) | 2 (29) | 7 (33) | -- |
| Report covering water; number (%) (n=21) | 6 (43) | 2 (29) | 8 (38) | -- |
| ***Type of treatment reported (n=21)*** | | | | |
| Chlorine; number (%) | 0 (0.0) | 2 (29) | 2 (9.5) | **0.063** |
| Boiling; number (%) | 11 (79) | 5 (72) | 16 (76) | |
| Ceramic filter; number (%) | 3 (21) | 0 (0.0) | 3 (14) | |
| ***Treatment details if sample available*** | | | | |
| Treated water is covered; number (%) (n=7) | 4 (80) | 2 (100) | 6 (86) | -- |
| Liters stored; average (min-max) (n=7) | 8.8 (4-20) | 34 (8-60) | 20 (4-60) | -- |
| Hours since treatment; average (min-max) (n=7) | 59 (24-120) | 25 (2-48) | 49 (2-120) | -- |
| Received instructions for chlorine; number (%) (n=2) | -- | 1 (50) | 1 (50) | -- |
| Cost of chlorine in USD; average (min-max) (n=2) | -- | 1.0 (0-2.0) | 1.0 (0-2.0) | -- |

### *Water Quality*

A presentation of microbiological water quality followed by physical quality is presented first for the source water of the three systems and secondly in the households of the three neighborhoods.

*Source Waters*

The data in Figure 24 represents the microbiological contamination of the source waters. Due to time availability and the difficulty of accessing the sources of Santa Rosa and Las Tolas, the data represents multiple samples taken on one day. The data for El Cristal is representative of the inflow to the SSF, the outflow of the SSF, and the distribution tank post-chlorination across a series of 4 days with multiple samples per day. In general, *E. Coli* counts were low in all systems, which follows a trend that has been seen in the community since pasturelands were being fenced out to protect the source streams. Coliform counts were high in the source streams for the Santa Rosa system. They were also higher in the distribution tank of El Cristal than the outflow (avg. 55 CFU/100 mL vs. avg. 9 CFU/100 mL). The El Cristal tests indicate that the filter is operating well, with a reduction of both *E. Coli* and total coliforms.

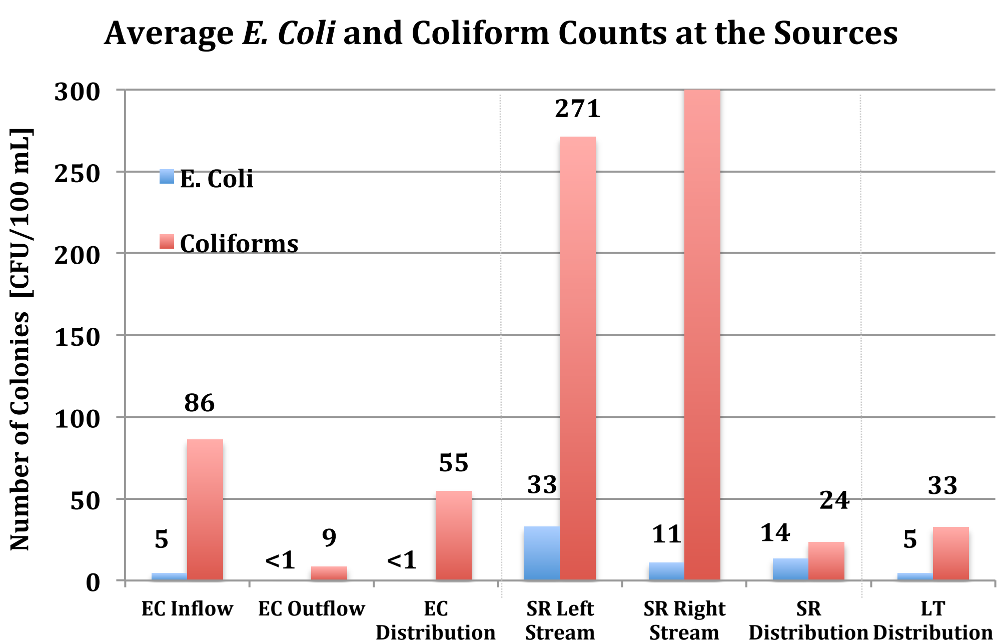


**Figure 24: Microbiological contamination at the source waters El Cristal 2012**

Source water displayed similar turbidity readings trends (Figure 25). In El Cristal, the efficacy of the SSF in removing turbidity from the water was shown. The water in the distribution tank for Santa Rosa was higher than either of its streams was alone, and Las Tolas showed the lowest turbidity in its distribution tank among control neighborhoods.

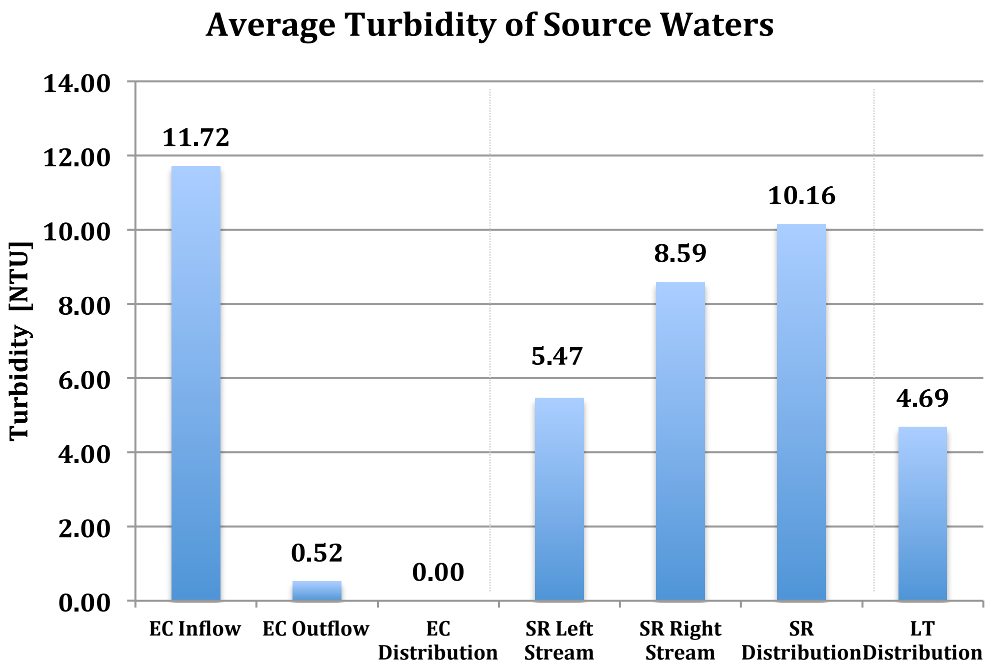


**Figure 25: Average turbidity of source waters El Cristal 2012**

The free chlorine residual in the distribution tank of El Cristal was tracked over the course of 4 days. Table 21 is an overview of the average FCR value present each day. All values were higher than the recommended 0.2 mg/L, but do not meet the WHO guidelines for piped water, which is 0.2-0.5 mg/L.

**Table 21: Average Free Chlorine Residual in El Cristal distribution tank 2012**

| | Average FCR [mg/L] |
|---|---|
| Day 1 | 0.9 |
| Day 2 | 0.5 |
| Day 3 | 0.7 |
| Day 4 | 0.2 |

*Household Water*

All water quality testing at the household level was conducted over the course of 4 random days and times in each neighborhood, and therefore reflects the systems over the course of a week. Microbiological testing of the household water indicates an overall trend that bacteria contamination was higher in Santa Rosa & Las Tolas than it was in El Cristal (Figure 26 and Figure 27). It is believed that the coliform counts were so high in the household level because of recontamination of treated water at the tap. In general, enumerators commented on the presence of dirty taps that they collected water from.

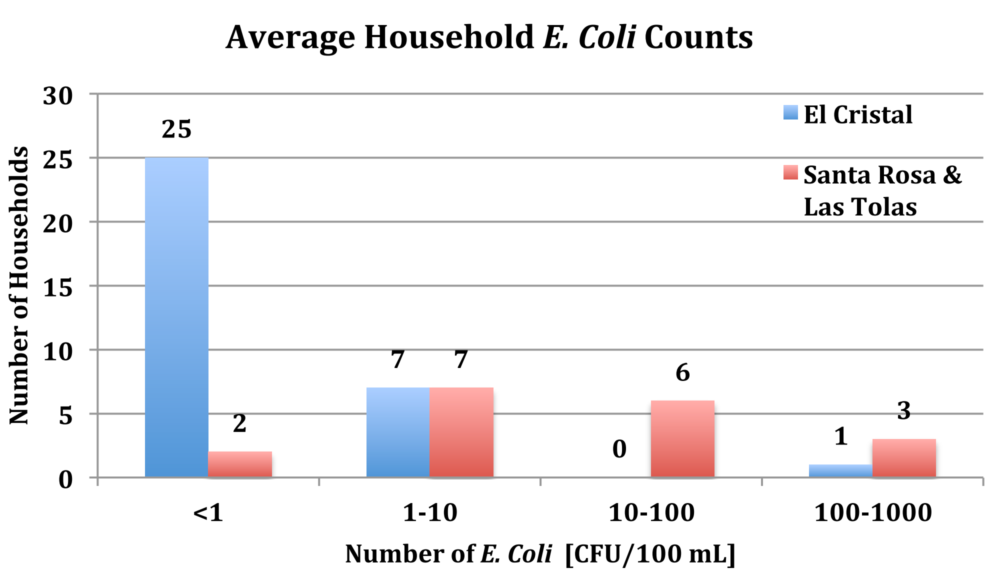


**Figure 26: Average household *E. Coli* counts El Cristal 2012**

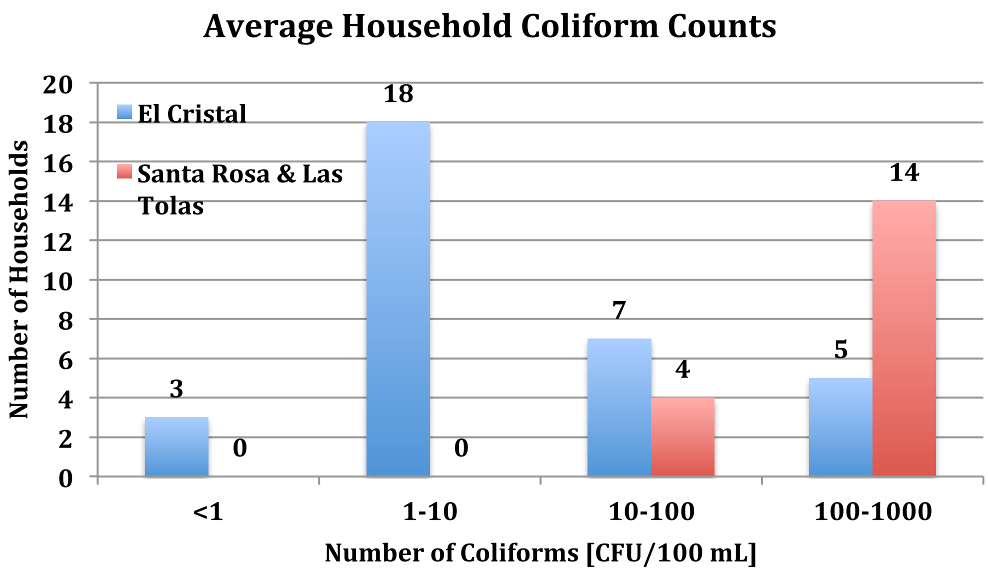


**Figure 27: Average household coliform counts El Cristal 2012**

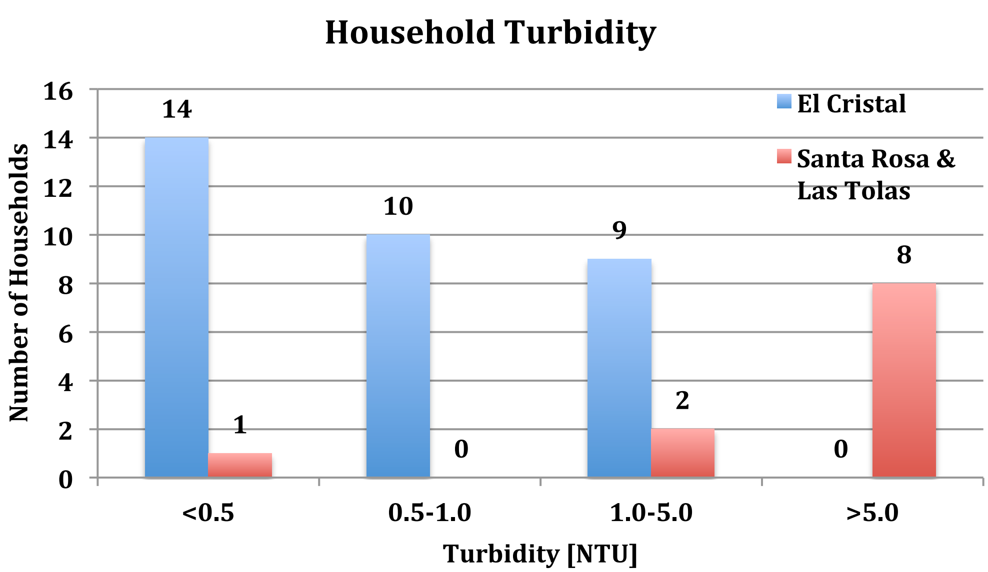


**Figure 28: Household turbidity El Cristal 2012**

Turbidity followed a similar trend, ranging from <0.5-5 NTU in El Cristal, while predominantly ranging from 1-20 NTU in Santa Rosa & Las Tolas (Figure 28). There was only one data point for FCR in Santa Rosa & Las Tolas, as the water is not chlorinated at the source (Figure 29). In El Cristal, the majority of FCR readings fell at or below the detection limit of 0.1 mg/L, which is below the recommended guideline of a minimum of 0.2 mg/L.

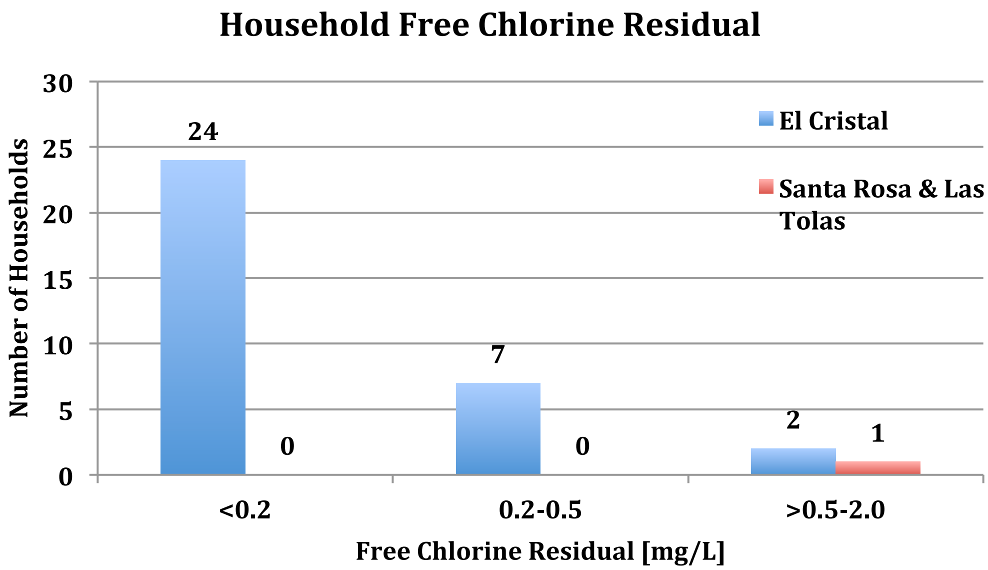


**Figure 29: Household FCR El Cristal 2012**

### *Operator Focus Groups*

The Operator focus groups were comprised of two components. The first part was an interview with each of the Operators to gain information about their background and training. For the El Cristal system, they were also asked to identify components of a slow sand filtration system as illustrated in Figure 30. The second component to the El Cristal system interviews was to sit down with the Operators together to listen to dialog about their jobs and to observe their interactions.

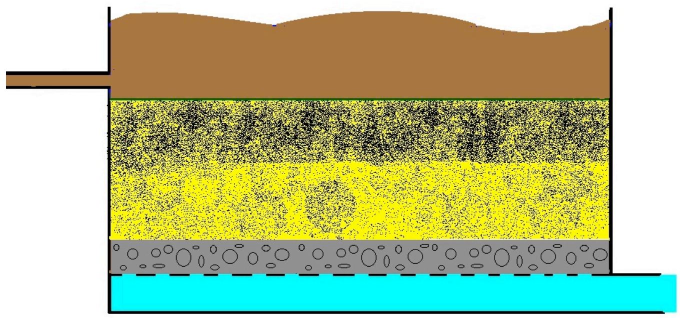

**Figure 30: Slow Sand Filter representation given to operators**

*El Cristal Slow Sand Filter Operators*

Three Operators maintain the El Cristal system. Two work for the Water Board of El Cristal and one works for the Water Board of Peñaherrera.

Operator 1 (El Cristal Water Board)

Operator 1 is a male, aged 70 with 7 years of schooling. He has been working on the El Cristal system for 10 hours and on another system an hour away for 10 years. He received training on this system in 2008 from a combination of sources: Cuenca University, Camaren, Ayuda en Accion (ActionAid UK's sister program in Ecuador), and the Ministry of Urban Development and Housing (MIDUVI). In between trainings he has read books on the process to help him improve. Four days a month are spent cleaning the system, which requires two operators to complete. However, only one operator from El Cristal will check the system daily and chlorinate, which takes about an hour. They rotate the daily job monthly.

He identified the components of the system from top to bottom: water, special sand, fat sand, gravel, rocks & boulders. He explained the filtration process

*"The water comes from above – a little bit enters the tank – and divides between the two filters. There is a divider, and part of the water goes to Peñaherrera and part to El Cristal. Filter water comes back into one tube and then the water is split. El Cristal's*

*water also passes through the chlorination system (small tank/box); and then it enters the larger cement box to be distributed at the various houses in the community."*

He also drew a map of the tanks and pipes associated with the filtration, chlorination, and distribution systems. His map corroborated the understanding that Tufts has of the system.

<u>Operator 2 (El Cristal Water Board)</u>

Operator 2 is a 36-year-old male with 6 years of schooling. He has been helping at the filter for 1.3 years when he was suggested to the position by members of the Water Board. He replaced one of the prior El Cristal Operators who had been fired by the Water Board for not performing the tasks as trained. Operator 2 was trained on filter operation by Tufts University in August of 2011 and received training on the chlorination system from MIDUVI in September of 2011. He indicated that he spends about 7 hours per week working on the system when he is in charge of its daily maintenance and chlorination.

He identified the components of the system from top to bottom: water, sediment, sand, gravel, and rocks. He explained the filtration process

*"From above, the small tank that gets all the water separates and is shared by both filter tanks. The process of cleaning occurs in the filters every 15 days. I close the valve so the water doesn't exit/leave. We need to keep the water in the filters so the good bacteria doesn't die. If it is dry the good bacteria dies. Water then goes on to be chlorinated. Right now the issue is that the sand is being removed by the filter. Last year the box helped prevent the sand from leaving – only the water entered to be filtered/cleaned. I worry that in a year, if sand continues to be sucked in the pipe, that it won't work anymore and there won't be a functioning filtration system."*

<u>Operator 3 (Peñaherrera Water Board)</u>

Operator 3 is a male, aged 47 with 6 years of schooling. The Operator from Peñaherrera has been working with the filtration system for 4 years, 3 of which have been with the "new" sand filters. He received a 3 day training program in 2009 that was offered by MIDUVI, the police, Ayuda en Accion, and a specialist from Canada, who gave a presentation on how to maintain the filter and chlorination system. Another municipal engineer showed them how to operate and maintain the filters in the year prior. He works on the system for 4-5 hours per week.

He identified the components of the system from top to bottom: water, sand, rocks and gravel, and screen, that empties to the tanks. He explained the filtration process

*The water enters the filter and leaves clean. The sediment on top of the sand needs to be cleaned or the filter does not work properly. I need to clean the filter every 15 days or it would stop working."*

El Cristal Focus Group Summary

Much of the discussion during the focus group revolved around the chlorination process. Operator 1 puts six ounces of chlorine for every one and a half liters of water, which is the same as four ounces per liter. The Peñaherrera operator puts a bottle of chlorine plus a little bit into a 1100 liter tank, and that amount lasts for two days. The chlorine amount does not change with the seasons. Operators 1 & 2 are in charge of the chlorination for El Cristal and the third operator is in charge of the chlorine for Peñaherrera. Sometime during the spring of 2011 both communities were able to join together to lobby for a health inspector to check the filters. Every Saturday, an inspector from Peñaherrera samples from the El Cristal and Peñaherrera distribution tanks to check that the FCR is at least 0.2 mg/L. The Operators would like a Hach Color Wheel like the inspector uses because they say it is more accurate and they are out of the chemicals for their Pentair Pool Test Kit

Operators 1 and 2 clean the filters every 15 days in the summer and every eight days in the winter. The filters are the most difficult part to clean and maintain. There are pre-filters higher up in the system and they take a long time to get to. It takes a little over an hour to clean the filters. They clean the capture tanks every eight days and those too take about an hour to clean.

Operator 3 works year round, but Operators 1 and 2 switch roles every 30 days. They are paid $70 every 30 days and they do get overtime. If something is wrong with the water it is their responsibility to take care of it. They work with each other and share materials between themselves. The Water Boards will get them the materials they use to fix things and will work out joint costs between El Cristal and Peñaherrera. The price of water is $2 per month for 20 cubic meters and an extra $0.10 for every additional cubic meter in both communities.

They do feel as though they have been prepared for their positions and that they have enough resources to perform those positions. When they do not have the materials or resources to fix something, they simply don't fix it. When Operator 3 is away, he sends his family to check on the system; they all know how it works and can deal with any problems. Operator 1 never leaves for more than one day at a time. If Operator 2 leaves, his wife will dose the chlorine. Operator 1 was elected to his position at a town meeting and then trained for four months. Operator 3 was selected to his position by is Water Board. He likes his job, but the commute to and from Peñaherrera is taxing; the town is an hour away by foot.

*Santa Rosa System*

The Santa Rosa Operator is a 36 year old male with 6 years of education. He has been working on this system for two years, when his friends told him to take the job because they thought he would be good at it. The Santa Rosa capitation and distribution system was constructed in 1997 and more cement was added to the distribution tank two years ago. The system serves 25 homes and 7 farms. It takes him approximately 4 hours to clean all of the tanks in the system, which he does once a week. The hardest part of his job is the cleaning of the tanks, especially in the winter when the water is very cold. He gets paid $15 USD per month by the community's Water Board. Because there is no filter or chlorination system, he has received no formal training on the system.

His biggest concern is maintaining the system and making sure the pipes don't break so that the water stays clean. He frequently has to fix pipes that burst under pressure and break when the land slides out during the rainy season. The water in Santa Rosa is not used just for the household, but also for animals and farm watering, and he is concerned that this will cost a lot of money to chlorinate.

*Las Tolas System*

The Las Tolas Operator has been working on this system for two years, since he was picked by the community to become the Operator. He also happens to be one of the Operators on the El Cristal system. The distribution tank and system for Las Tolas was constructed in 1991, with 42 houses on the system. Ice melt is captured in different locations and passes over three ravines to get to the distribution tank. He has calculated that water enters the distribution tank at 1.5 L/s. Because there is no filter or chlorination system, he has received no formal training on the system.

The amount of time he spends working on the system varies. It usually takes him a half hour to clean the distribution tank once per month and one hour to clean the other tanks twice per month. In the winter months there is more water because it is the rainy season and he may be cleaning the whole system four times per month. The distribution tank no longer has a cover, so wind blows a lot of trash into the system. Although he finds cleaning to be a difficult task, particularly when it gets muddy during the rainy season, the biggest problem he identified was the broken pipes. The pipes, which at times may be strung across valleys, break frequently because of poor system design or are cut by people who don't respect the system. He is very concerned about the quality of water and wants a sand filter to be built in Las Tolas. He had been told that the municipality of Cotaccahi had plans to someday make some type of filter on this site.

## Summary and Discussion

After six years of Tufts EWB working in the community of El Cristal, Ecuador, there have been many changes in regards to the community's water system. The following summary looks at what improvements have been made to the water system and what challenges the community still faces. It also summarizes some of the challenges and improvements that the chapter faced in conducting this project.

### ***Successes and Challenges in El Cristal***

#### *Technical Functionality of the El Cristal Water System*

Filter Functionality

When Tufts EWB first arrived in the community, the SSFs had been inoperable for about 15 years and the community had hooked up pipes to bypass them in their piped network. Results of water quality testing by the travel team indicated fecal coliform contamination and turbidity levels above potable water standards. After securing a government grant for $25,000 USD the filter beds and pipes were rehabilitated and Operators trained on how to maintain the system.

In 2010, the Tufts EWB team exclusively spent their trip surveying the El Cristal SSF. Water quality tests indicated levels of fecal contamination stemming from an improperly maintained filter with no shmutzdecke present. Additionally, the team found that the filter was functioning properly as a particulate remover, reducing turbidity by a factor of 7 to 28 times from the inflow to the outflow. A concern of the team was that the superficial velocity of the filter was 2.7 times higher than it was designed, meaning that water usage was at much higher rates in the community than intended for the system.

Water quality tests were not conducted to examine the functionality of the filter in 2011. The travel team noted signs of improved filter health because the filter bed was mostly wet, providing an opportunity for a shmutzdecke to grow.

During evaluation of the system in 2012, it was found that *E. Coli* levels dropped from an average of 4.5 CFU/100mL at the inflow to <1 CFU/100mL at the outflow and in the distribution tank. Fecal coliforms were reduced from an average of 86 CFU/100mL in the inflow to 9 CFU/100mL in the outflow, but again increased to an average of 55 CFU/100mL in the distribution tank. The filters were also functioning properly as a particulate remover, reducing turbidity by a factor of 22 from an average of 11.7 NTU at the inflow to 0.52 NTU at the outflow.

In the households, *E.Coli* remained low with 25 houses averaging <1 CFU/100mL and 7 averaging between 1-10 CFU/100mL. Coliform counts were much higher at the household level with the majority of houses, 18, exhibiting 1-10 CFU/100mL 12 indicating 10-1000 CFU/100mL. Turbidity readings for >1 NTU were present in 24 of the homes.

Filter Operation and Maintenance

After the filter beds were reconstructed and Operators hired to maintain the system, Tufts EWB began tracking the cleaning procedures and maintenance of the SSF. It was found that in 2010 the Operators would have one SSF dry out at a time, thereby allowing the silt to form a crust on the surface of the bed. On a monthly basis the Operator shoveled this crust out of the filter. This cleaning procedure rendered it impossible for the shmutzdecke to form in the bed, thereby decreasing the microbiological functionality of the system. Shoveling the silt out also meant the inadvertent removal of the fine sand layer from the system. The Tufts EWB team worked with the Operators to stress the importance of never letting the filter dry out and not removing the sand with a shovel.

When the team travelled in 2011 to implement a cleaning system with the Operators they discovered that they now had access to a gasoline powered pump. Their new procedure involved raking the silt out of the bed and allowing it to mix with water sitting on top of the filter bed. They then utilized the pump to suck the dirty out of the filters. However, they were still allowing the filter to partially dry out and the hose was sucking up about 0.5 $m^3$ of sand per cleaning. Tufts EWB conducted another training session with the Operators to review proper maintenance, again stressing the importance of keeping the filter wet.

In 2012 the team aided the Operators in devising a new cleaning tool to attach to the end of the hose to prevent the fine sand from being removed by the pump. The team also conducted interviews with the three Operators of the system to learn about operation and maintenance practices. Two of the Operators had received formal training on the filter from the government and an NGO among others. One Operator had only received SSF training from Tufts and his co-workers. From the interviews Tufts learned that the cleaning process has been standardized amongst the Operators, with cleanings varying based upon the season and daily work being apportioned according to agreements with the Water Boards. Operators were able to generally explain slow sand filtration correctly and reported being confident in their abilities to perform their jobs.

Chlorination of the Water System

Chlorination of the system began in Fall 2011. Tufts EWB sent the community their recommendations for properly dosing the system. As reported by the Operators, the mother solution is prepared every morning in the chlorination shed. Chlorine drips into the distribution tank at a rate adjusted by the Operators, where water is held until it is needed. From the Operator interviews, it is clear that there are differences in the dosing used by each Operator. This is compounded by the fact that the Operators were out of the solutions for the Pentair Pool Test Kit to test FCR levels in the distribution tank. Dosage, therefore, was a best guess amount by the Operator on duty. At the source, the FCR reading in the distribution tank varied on average from 0.2 mg/L to 0.9 mg/L over the four days it was tested. In 24 households, the FCR was below 0.2 mg/L, the recommended minimum, while only 7 homes tested a FCR in the proper range of 0.2-0.5 mg/L.

*Cultural Acceptance of the El Cristal Water System*

Water Board

The Water Board of El Cristal changed drastically over the course of Tufts EWB's involvement with the community. Originally the Water Board advocated for the funding and eventual reconstruction of the SSFs from the local government. The Water Board has demonstrated to Tufts that they have taken full ownership of the system through a series of decisions and practices they have adopted.

The Water Board of El Cristal took it upon them to be responsible for the hiring and firing of Operators. They instituted the firing right when they had a former Operator refuse to adjust to the new maintenance and cleaning procedures. Additionally, the Water Board began charging fees in an effort to reign in unnecessary use of the SSFs. Fees went from \$0 USD in 2007 to \$2.00 for the first 10 $m^3$ per month and an additional \$0.10 USD for every gallon after that allocation.

The Water Board showed initiative in bringing Tufts EWB to their community, dissolving bonds with the Water Board of Peñaherrera and establishing their own governance system, joint purchasing the pump with Peñaherrera, and requiring user attendance at the Water Board's semi-annual town meetings.

Community Response

The citizens of El Cristal have been particularly integral to the success of the SSFs. During their first trip, the team noted that household spigots ran continuously and the community did not pay for their water. By 2012, households were being charged \$2.50 USD for the first 10$m^3$ of water. Of this amount, a large portion will go to pay the Operator fees. This shows a clear willingness to pay on behalf of the consumers.

The community was also instrumental in supporting the Water Board to advocate on their behalf for the rehabilitation of the system. Additionally, after being shown the microbiological tests and results and being taught household disinfection techniques by Tufts EWB, the community lobbied for the addition of in-line chlorination at the source. The community has also always been one step ahead in time in what they were advocating. The typical theme appeared to be that Tufts EWB would conduct tests and arrive in country with a plan for an implementation. This would be to only learn that the community had already devised a separate solution that it was putting into place.

Trust issues appear to play a large role in acceptance of the water system. Some of the mistrust of the Operators stems from a complaint about the fluctuation taste of the water. As was evidenced previously, the FCR readings were wildly variable as were the dosage practices implemented by the Operators. Building the community-Operator trust will be a key component of the Water Board as community buy-in to the system will be crucial to moving forward.

*Systems of Santa Rosa and Las Tolas*

Technical functionality of the systems is a key barrier in the provision of potable water to these communities. Water quality testing from 2007, 2008, and 2012 indicates high levels of coliform and *E. Coli* in the systems. In order to create an operable filter for the communities, a function Water Board must be created for each system. A barrier to achieving this is the lack of education and the prevalence of miscommunication about water that exists amongst the residents of these two communities. Education about the water systems may lead to better care being taken of the fragile and perilous piping networks that are srtung along the hillsides in La Margarita.

A functioning Water Board in these systems would allow for lobbying of the local government to procure funds for the construction of SSFs in these communities. With the implementation of the SSF would come training for the Operators and the creation of a user fee by the Water Board.

***Successes and Challenges in the Tufts EWB Group***

*Partnership with El Cristal*

Tufts EWB shifted the focus of their Ecuador Program from working with FBU to working with El Cristal because they felt that they could have more of an impact working directly with a community. Due to Carlos Ruiz's strong presence in the community and influence amongst the local government, El Cristal was able to successfully organize and lobby for improvements to their system. Tufts was then able to provide technical expertise and water quality testing of the system to work with the Water Board on honing and improving its operation and maintenance.

During the history of the Program in El Cristal, the citizens in the community had always been one step ahead of the Tufts EWB team. They continually pushed forward on Projects proposed by Tufts, such as the filter cleaning system and the chlorination system, under their own initiative. Because of communication issues while Tufts was not in El Cristal, they were frequently surprised by the discovery of changes the community had made to the system. While this was frustrating for the Tufts EWB team because it meant a lot of planning and design conducted during the academic year was not fruitful, it indicates strong community buy-in and ownership of the system. Reviewing the history of the Ecuador Program, Tufts EWB's greatest contribution was in continuously providing the spark for the community to move forward with their own decisions and improvements to their water system.

*Documentation*

A key component in evaluating the Tufts EWB Ecuador Program is to understand the history of the Projects including the original and adjusted goals and all accompanying data to frame the context of the work completed. To evaluate the Programs, prior reports submitted to EWB-USA as well as internal documents were collected and read. Many reports, however, were either lost or were only partially completed, making it difficult to piece to together the work and thought of previous Tufts EWB teams. In addition to missing reports, many of the raw data files are also unavailable, leaving the summary tables, which were not always presented properly, the only information upon which to evaluate the prior states of the systems and their functionality.

An additional issue with the documentation for evaluating the Program is its focus on trip narrative rather than technical information. This is not a reflection of the quality of work completed by the student teams, but rather a result of the information requested by EWB-USA in its reports. While trip narrative helps gauge the impact of this work on the growth of the students, it does not lend itself well to evaluating the type and quality of work completed.

*Metrics and Methods*

In the original design of this Program, there was not an outline of the manner in which Tufts EWB would monitor the water systems in El Cristal or a definition of how Tufts would measure their impact and the sustainability of their Projects. This lack of defined metrics makes it difficult to track the development of specific Project criteria in time. The lack of defined benchmarks in the Program also makes it difficult to evaluate whether Tufts EWB met their goals and if they adjusted their efforts to meet those goals accordingly.

This lack of overall metrics manifested in each travel team collecting data relevant only to that trip's work. For instance, in 2007 and 2008 water quality data was collected at the source waters in all three neighborhoods. In 2010 it was collected only for the El Cristal system and in 2011 it was not collected at all. When evaluating in 2012, there was little consistent historical data to compare the source water and household water quality information against. Furthermore, methods for data collection and water quality analysis were not outlined in the reports making it difficult to determine what data was exactly representative of. Having a more clearly defined metric and data collection method may have made water quality analysis more cohesive over the years of the program.

Tufts EWB also conducted health surveys in the community in accordance with EWB-USA's 509 Compendium requirement. Because the neither the original survey questions nor were the raw data was available, the only results from the surveys were those presented by the 2010 team in their summary report. Although 19 households were surveyed in-depth, the results to not inform as a public health survey intends. The lack of a baseline health survey and subsequent follow-up surveys, along with the lack of control group surveys makes the information unusable to tracking public health. Furthermore, the small sample size renders the health information as anecdotal rather than technical knowledge. This metric was used by the Tufts EWB team to maintain compliance with

EWB-USA's operating procedures and required a significant amount of time and manpower to conduct.

# Case Study 2: Clarkson EWB in La Margarita, Ecuador

## Introduction to La Margarita

A community of approximately 320 people, La Margarita lies on the banks of the Los Tintos River five miles upstream of its confluence with the Guayas River in the Guayas Province of southern Ecuador, Figure 31. La Margarita is situated about a half hour by car from the town of Samborondón. This translates to a distance of approximately an hour and a half from Guayaquil, the largest city in Ecuador. Its remote location and the difficulties of traveling to it make it expensive for the government to provide the community with water and sanitation services. [**85**]

**Figure 31: The rice fields surrounding La Margarita (left) and fisherman on the Los Tintos River (right)** [86]

Like other similar communities in the coastal plains, La Margarita lacks access to clean drinking water and other basic services such as sewage treatment and refuse removal. With limited alternatives, villagers use Los Tintos River to remove untreated refuse and septic wastes from their community, as do other communities upstream. These activities, as well as runoff from livestock agriculture, have polluted the river with refuse and high levels of fecal pathogens. Prior to Clarkson EWB's involvement, the people of this community used water from the river with little or no treatment resulting in high incidence reports of gastrointestinal illnesses. [**87**] The Clarkson EWB chapter worked with the community and a local NGO, Hogar de Cristo (HdC), to develop a ceramic pot filtration household treatment option for the community.

***Cultural Description***

Many of the residents in this agrarian community are rice farmers, and work as part of a cooperative in the fields surrounding their community. Household farming is not particularly common within the community, although there have been promotions and initiatives by HdC to train families on crop growing. It is more common for households to purchase needed vegetables and fruits from a truck that sells these items and drives through town several times a week. Most families own chickens, with many families also owning pigs and ducks. Few families own other farm animals, such as cows and horses. Instead, many community members will purchase meat as needed from the store in the center of the community. [**87**]

Nearly a third of the population of La Margarita is below the age of 16. Children attend school through $8^{th}$ grade within the community. Families who are able to pay for secondary education will send their children by boat to Samborondón for continued schooling. Many families are started at a young age, and Clarkson EWB finds it is not uncommon for a man to have multiple families within the community. [**87**] Many children, after finishing primary school, help their parents at home or in the fields before moving out and starting their own families.

Due to the fluctuations associated with farming, the community does not have a steady stream of income. Reliant on two rice crop rotations a year and subject to the weather patterns and a snail infestation, it is not easy for the villagers to guarantee continual funds to development projects within their community. [**88**]

The Los Tintos River is essentially the "life-force" of this community. People use the river as a source of water for household needs, to flood their rice fields, for transportation, for fishing, and for waste removal. The river is under tidal influence, meaning that twice a day the water level drops such that most of the muddy riverbed is exposed. The Los Tintos also causes problems for the community during the rainy season, overflowing its banks and flooding many areas for months at a time. Because of this, the community has adapted their homes and lives around the environmental change. [**89**]

La Margarita does have electricity, which is wired to most every home in the community. Additionally, there are light poles installed down the main road of town for safety at night. Most households have at least a radio over which news and community events in the area are broadcast. Some homes also have televisions, refrigerators, portable washing machines, and electric fans. Most households have telephone access with many people choosing cellular phones over landlines. As was previously mentioned, the community does not have running water, sanitation, and refuse services. [**88**]

### *Government and Water Board Structure*

The community of La Margarita has a simple governmental structure in which members of the community are elected to be leaders and serve for a couple of years at a time. Figure 32 below is a diagram of the community within the larger governmental structure. The leaders of the community lobby the local government for support and development projects within their community. Examples of these projects include a health clinic, subsidized housing, and a new school.


**Figure 32: Hierarchy of Government Structure in La Margarita**

Upon partnering with the community, Clarkson EWB signed a Memorandum of Understanding with leaders in which the community agreed to organize a Water Board. Additionally, the agreement outlined responsibilities of all parties in terms of the project. The Water Board for La Margarita was eventually organized via the community's Parent Teacher Organization. [**90**]

## La Margarita Program History

Table 22 is a brief overview of the program history, which is followed by more detailed descriptions of the trips and activities of the Project teams.

**Table 22: Clarkson EWB Ecuador Travel History**

| Dates of Travel | Purpose of the Trip | Description |
|---|---|---|
| Summer 2008 | Assessment | Establish a relationship with La Margarita, map the community, and conduct baseline health surveys. Gather preliminary data on the socio-economic status of the community, water quality, and possible solutions. |
| Summer 2009 | Implementation | Establish a relationship with Hogar de Cristo and begin talks of designing a ceramic filter manufacturing facility. Reassess the community after new house construction and more detailed water quality sampling and health surveying. |
| Spring 2011 | Implementation / Assessment | Meet with the ceramic filtration factory in Pifo and deliver filters to La Margarita. Assessment of Hogar de Cristo and project needs for facility start-up. |
| Fall 2012 | Monitoring and Evaluation for this research thesis | Assess the functionality of the filters in La Margarita. Visit Hogar de Cristo's new facility and assess future needs. |

***Summer 2008 Assessment***

Clarkson EWB began their partnership with La Margarita in 2007 via a personal contact the founding graduate student had made. Five students and a faculty advisor made the first assessment trip the following summer. During the first whirlwind visit the group completed a community mapping that included measuring the sizes of every home, for possible rainwater catchment in the future (Figure 33). With the help of Prof. Alby

Aguilar and her civil and environmental engineering students at Escuela Superior Politecnica de Litoral in Guayaquil the team completed an extensive round of health surveying. The travel team also met with a representative of the Mayor of the nearby town and conducted activities for the school children to teach them about bacteria and hand washing. Other activities included formalizing the partnership with the community through the Memorandum of Understanding and water quality testing of water sources identified by the community as drinking water supplies. [**91**]

**Figure 33: Typical house in La Margarita 2008** [86]

It was identified that most of the community uses the Los Tintos River as their source of drinking water and that many community members improperly treat their water with alum and store it unsafely (Figure 34). Alum is used as a coagulant in the water to cause sediment to flocculate. Community members then skim the “clean” water off the top for consumption. Many families try to buy bottled water for children under the age of two, but supply is subject to the availability of sufficient funds. [**88**]


**Figure 34: Typical water storage in La Margarita 2008 [**86**]**

As with all community-oriented projects, gaining the trust of the community was a top priority during their Summer 2008 trip. La Margarita felt that Clarkson EWB might have been there to take advantage of them or would make promises that could not be followed through.. This was not unfounded concern on behalf of the community. In the two years prior to Clarkson EWB's involvement, the community saw a half finished health clinic built in their town by an international charity and a well installed by the government without community input that the community subsequently did not use, Figure 35. [**88**]

**Figure 35: Semi-completed health clinic 2008 (left) and unused well and storage tank 2011 (right) [**92**]**

*Metrics*

Clarkson EWB outlined their metrics for data collection during their trip in their pre-assessment report to account for project longevity (Table 23). Goals were divided into three general categories in accordance with EWB-USA's 507 Project Design Compendium: technical, economic, and health. It was noted that they would follow-up on their criteria for two years post-implementation in order to track sustainability of the Project. [**85**]

**Table 23: Clarkson EWB Project Metrics** [85]

| Goal | Metric | Data Needed |
|---|---|---|
| ***Technical*** | | |
| Sustainable water source | Physical characteristics of Los Tintos River | - River flowrate/depth/width<br>- Withdrawal rate |
| | Water demand | - Per capita daily usage |
| | Population growth | - Change in birthrate |
| Sustainable system operates at 20 yr design level | Successful operation and maintenance | - Willing persons to be trained on O&M<br>- System still operating at designed level post-implementation |
| | Ease of repairs | - Local availability of materials<br>- Presence of necessary tools in community |
| | Water quality meets or exceeds WHO standards | - Microbiological testing for total coliforms and *E. Coli*<br>- Physical/chemical testing for color, smell, pH, turbidity, conductivity, temperature, alkalinity/hardness, nitrate+nitrite, ammonium-N, phosphates, dissolved oxygen |
| | Location of system | - Mapping of source water<br>- Mapping of topography<br>- Mapping of property lines<br>- Soil types for construction and stabilization of possible distribution lines |
| ***Economic*** | | |
| Decreased reliance on external water sources | % change in population using external water sources | - Type and usage of each external source before & after system<br>- Cost of each external source |
| | % change in population using internal sources | - Number of users of internal source before & after system<br>- Cost of internal source |
| Water Board responsible for finances of system | Water Board fundraises portion of capital costs | - Amount fundraised (USD) |
| | Water Board institutes user fees for O&M | - Amount taxed to users (USD) |
| ***Health*** | | |
| Increase in productivity | Increase in household income | - Average earnings pre and post system |
| | Increase in free time | - Average hours spent on work and education pre and post system |
| Statistically significant reduction in reported prevalence of waterborne illness | Decrease in incidents of gastrointestinal illness | - Baseline health survey in each household<br>- Daily health diaries from each household for pre-implementation and 2 yrs post-implementation<br>- Post-implementation health survey |

*Water Quality Surveying*

Water samples were collected at five locations throughout the community of drinking water sources for microbiological, physical, and chemical sampling. Three additional samples were collected from source waters in the community for herbicide and pesticide sampling. Samples were collected in glass bottles and stored on ice for 8 hours before being transported to Grupo Quimico Marcos S.A. in Guayaquil for analysis. The lab results of the drinking water testing were translated and are presented in Table 24. [**93**]

**Table 24: Water quality results from Clarkson EWB's Summer 2008 sampling** [93]

| PARAMETER | River Upstream | River Center | Well Water | Treated Household | Rice Field | UNITS | METHOD |
|---|---|---|---|---|---|---|---|
| pH | 7.46 | 7.48 | 6.74 | 6.67 | 7.01 | -- | 4500pH B |
| COLOR* | 13 | 11 | 28 | 5 | 24 | UClPt | 2120 B |
| ODOR | EARTHY | EARTHY | EARTHY | EARTHY | EARTHY | -- | -- |
| TURBIDITY | 30.9 | 35.7 | 74.7 | 7.45 | 51.8 | NTU | 2130 B |
| ALKALINITY | 44.28 | 65.88 | 48.4 | 21.6 | 47.52 | mg/l | 2320 B |
| CONDUCTIVITY | 106.63 | 95.25 | 4.868 | 126.05 | 123.64 | us/cm | 2510 B |
| DISSOLVED OXYGEN | 1.10 | 1.07 | 1.35 | 1.85 | 1.50 | mg/l | 4500 O B |
| NITRATES | 0.3 | 0.5 | <0.3 | 0.3 | 0.4 | mg/l | 4500 $NO_3$ B |
| NITRITES | 0.016 | 0.026 | <0.003 | 0.004 | 0.079 | mg/l | 4500 $NO_2$ B |
| PHOSPHATES | 0.61 | 0.40 | 2.56 | 0.21 | 0.30 | mg/l | 4500 P D |
| AMMONIUM | 0.08 | 0.06 | 3.7 | 0.07 | 0.38 | mg/l | 4500 AMONIA B |
| FECAL COLIFORMS | 8 | 6 | 1 | 1 | 1 | MPN/100 ml | 9221 E |
| *E.COLI** | 8 | 12 | 0 | 1 | 4 | CFU/ml | -- |

*Community Health Surveying*

Originally, five full-length health interviews, EWB-USA's 509 Compendium, were conducted in the community. The team found that the surveys were too long and too in-depth for their needs and modified their own survey while in country. This second survey was given to 55 households with the assistance of Prof. Aguilar's students. The questions administered in the second survey, along with the results of the survey were not present in detail in the Post-Assessment Report. It was indicated that the primary health issues were: flue, typhoid, chicken pocks, tetanus, asthma, abdominal pain, diarrhea, nosebleeds, fever, arthritis, heart issues, liver disease, irritated/itching skin, allergies, jaundice, and high cholesterol. The community estimated approximately 5-10 births per year. It was indicated that most children in the community receive vaccinations at birth according to the Ecuadorian Health Ministry. There were no dietary differences noted between males, females, and pregnant females, and the report concluded that malnutrition was an issue as many children were under height and weight for their age. The last finding of the survey was that there were no public health programs available to the people of La Margarita. [**88**]

***Summer 2009 Implementation***

A quick, unofficial EWB-USA trip was made to visit La Margarita by the founding graduate student while he was home in Guayaquil during the winter of 2009. Recognizing that community participation and input was an important aspect of the project, he presented the community with pamphlets explaining their options for water treatment that Clarkson EWB had developed the previous fall. Upon reading through the pamphlets, which included information on each technology and its associated costs and maintenance, the community chose ceramic filtration as their solution of choice, citing its familiarity to a pumice stone filtration method used by an elder. [**94**]

The goal of the Summer 2009 trip was to source materials and begin construction on a ceramic filter manufacturing facility in the community. Nine students and a faculty advisor travelled to the community for two weeks to complete the outline implementation. When Clarkson EWB returned to La Margarita in the summer of 2009 the team was surprised to find prefabricated homes constructed in the community in place of traditional housing, Figure 36.

Over the course of two months in late Spring 2009, 44 of the 75 households in La Margarita opted for a government subsidized housing program and had new homes constructed. Participants purchased pre-fabricated concrete homes complete with indoor plumbing for $250 USD. Each home included two sinks, one in the bathroom and one in the kitchen, a flushing toilet, and a shower. The water and sewer lines, however, were not connected to anything, leaving many toilets emptying onto the ground outside. During August 2009, many of the remaining households were applying for homes after the original government subsidization program at a price of $500 USD per house. Families shared with the travel team their plans to construct elevated water storage outside their homes and share pumps to bring water into their new houses. [**87**]

**Figure 36: New MIDUVI housing in La Margarita** [92]

Because households spent their money on the new homes, they did not have extra income to dedicate to the Water Board. The Water Board, therefore, was unable to provide the agreed upon portion of the capital cost for construction of a ceramic filtration factory in their community. Additionally, the travel team learned that it would be dangerous to build a ceramic manufacturing facility in the community because of the risk of flooding to the chosen site. Clarkson EWB readjusted the goals of their trip. [**88**]

While in La Margarita the team completed another extensive mapping of the community with the locations of the new homes, a round of improved health surveying, water quality sampling, and door-to-door training of an example ceramic filtration system. The team also instructed a local potter on the construction of handmade ceramic filters and tested them for flowrate and microbial removal. [**94**] The team was introduced to Hogar de Cristo (HdC) via the Guayaquil Rotary Chapter and plans were set into motion to collaborate with HdC on a ceramic manufacturing facility. Details about Hogar de Cristo and Clarkson EWB's efforts with the organization are detailed in the section following the monitoring and evaluation in La Margarita.

*Water Quality Surveying*

From the Summer 2008 survey, fecal contamination was identified as the primary concern for water quality issues in the community. The travel team, therefore, only conducted microbial testing. Two river samples were taken directly from the river at points where residents were known to collect water for household use, one each at upstream (River Up) and downstream (River Down) ends of the village. Three samples were also taken directly from drinking water supplies at three typical houses using river water for human consumption, two using alum and chlorine for treatment (House 1 and 2) and one using alum only (House 3). A final set of samples was prepared by filtering untreated river water (screened through a t - shirt) through two ceramic filters produced by the potter in Samborondón. The methodology is presented below, followed by the results of their findings in Table 25. [**88**]

Microbial Testing Procedure: At each sampling site, 20mL subsamples were placed into clear glass vials and the turbidity measured on a Hach 2100P Portable Turbidimeter. Additionally, two 50mL samples were collected using sterile techniques for +/‐ screening with the IDEXX Colisure test kit and one 100mL sample was collected using sterile techniques for MPN quantification on Chromagar ECC. For river samples, 100‐10‐2 dilutions were prepared using bottled drinking water; other samples were undiluted. The bottled drinking water was also used as a negative control. Colisure reagents were directly added to appropriate samples and incubated at 35ºC for 24 hours prior to reading test results. 100mL samples were aseptically filtered onto 0.2µm Supor membranes using sterile disposable 100mL cups (Pall Corporation) and a hand vacuum, then carefully removed with sterile forceps and laid upon Chromagar ECC Agar plates. The plates were incubated at 35ºC for 24 hours, and putative coliforms and E. coli counted as per manufacturer's instructions. Plates containing greater than 100 colonies were labeled as too numerous to count (TNTC). Portable incubators calibrated to a NIST‐traceable thermometer were used for incubation, and were capable of achieving $35^{\circ}C \pm 0.5^{\circ}C$. [**88**]

**Table 25: Water quality surveying in La Margarita Summer 2009** [88]

| Sample | **Turbidity** (NTU) | **Coliforms** (MPN/100mL) | ***E. Coli*** (MPN/100mL) | **IDEXX** (Coliforms/*E.Coli*) |
|---|---|---|---|---|
| River Up | 132 | TNTC | 1300 | +/+ |
| River Down | 78.6 | TNTC | 5700 | +/+ |
| House 1 | 12.5 | TNTC | 25 | +/+ |
| House 2 | 4.93 | TNTC | 37 | +/+ |
| House 3 | 30.1 | TNTC | TNTC | +/+ |
| Filter B1 | 2.4 | TNTC | 21 | +/+ |
| Filter A6 | 1.65 | TNTC | TNTC | +/+ |

*Community Health Surveying*

The team surveyed 70 households and gathered information on 271 residents using an improved health survey designed the previous year. The survey collected information on health and sanitation practices of the community. Specifically, residents were asked to provide the monthly frequency with which they had experienced particular health symptoms associated with poorly treated or untreated water.

**Table 26: Percent of Population Experiencing Health Symptoms in La Margarita (2009)**

| Rank | Symptom | # affected/ 271 | % of population |
|---|---|---|---|
| 1 | Fever | 126 | 47% |
| 2 | Headache | 124 | 46% |
| 3 | Stomach Cramps | 110 | 41% |
| 4 | Diarrhea | 89 | 33% |
| 5 | Nausea | 54 | 20% |
| 6 | Vomit | 48 | 18% |
| 7 | Constipation | 45 | 17% |
| 8 | Skin Rash | 33 | 12% |

Symptoms such as diarrhea, fever and others associated with fecal-oral routes of transmission were included in the survey and are presented in Table 26. Chronic symptoms, those identified as ten or more occurrences per month, were headache, constipation, and skin rash. Additionally, information was gathered on household practices of water and wastewater treatment, which are presented in Table 27 and Table 28. [**95**]

**Table 27: General Drinking Water Information for La Margarita (2009)**

| | # households |
|---|---|
| *Household Water Source* | |
| Los Tintos River | 30 |
| Los Tintos River & Bottled | 39 |
| Bottled | 1 |
| *Household Water Treatment* | |
| Chemical | 56 |
| Chemical & Boiling | 11 |
| Boiling | 1 |
| None | 2 |
| *Household Water Storage* | |
| Metal Drum | 1 |
| Metal & Plastic Drums | 3 |
| Plastic Drum | 60 |
| Cistern | 2 |

**Table 28: Human Waste Removal in La Margarita (2009)**

| | # households |
|---|---|
| Have latrine | 13 |
| Burn wastes | 4 |
| Bury wastes | 2 |
| Latrine & Burn | 4 |
| Dump in river | 10 |
| Hole under house | 3 |
| Share latrine | 1 |
| No latrine | 3 |
| Will build latrine | 30 |

***Spring 2011 Implementation/Assessment***

In May of 2011 3 students and a faculty advisor returned to Ecuador on an EWB-USA unofficial trip to accomplish an array of tasks. They visited a ceramic filter factory in Pifo, north of Quito, Ecuador (Figure 37) to learn about their manufacturing process and challenges.

**Figure 37: Pifo filter manufacturing facility 2011 [82]**

Clarkson purchased 100 filters from Pifo, which were delivered to La Margarita during the trip as the solution to the drinking water issues within the community, Figure 38. Employees from Pifo conducted training with the community on how to operate and maintain the filters. The Water Board was responsible for distributing filters to households in the community.

**Figure 38: Filter distribution and training (right) and a household set-up (left) 2011 [92]**

While in La Margarita, the travel team discovered that the community had been successful in securing funding and construction for a new schoolhouse (Figure 39). The team helped fix a pump at the school that allowed trucked water to be used in the sinks and bathrooms on the campus.

**Figure 39: Schoolhouses in La Margarita circa 2009 (left) and 2011 (right) [82]**

The team also toured Hogar de Cristo's numerous facilities and pitched in on a couple of projects in the Monte Sinai region that HdC was working on in order to more fully understand the NGO and the communities they serve. Work with HdC is discussed in more detail following the evaluation section.

## Results from Monitoring and Evaluating in Summer 2012

During the Fall of 2012 a Clarkson EWB team again traveled to Ecuador to evaluate Pifo filter operation in La Margarita. The goal for the team while in La Margarita was to complete household surveys on knowledge, attitudes, and practices surrounding water use and treatment and water quality test in each home surveyed as developed by the researcher and outlined in the prior chapter on methods. Additionally, the team assessed the progress of the HdC filter factory and surveyed water in the Monte Sinai region to garner an understanding of water quality issues in the communities where HdC would next implement ceramic filters. For details about the relationship with HdC, see section following these results.

There is scarce data in through time on the questions asked in the community for this survey, as previous surveys have mostly focused on health and sanitation. Therefore, a control was selected from within the surveyed population of La Margarita. The study of La Margarita, which looks at efficacy of the system, compares the portion of the population using the filters (n=19) to those using other forms of treatment (n=25). It is important to note that there was a household where the enumerator was informed that the household was using the filter, but it was difficult to corroborate this further in the survey. Some of the later information is presented on only those households the enumerator could confirm ceramic use (n=18). The sampling was conducted at random in the community with a total of 44 of the approximately 75 homes surveyed. The sampling size was dictated by how many surveys and water samples could be collected during the time in the community given two enumerators and two days of collection as the time limit.

### *Demographics*

The first presentation of data from the household surveys is a demographic comparison of the variable and control communities using a chi-square test (Table 29). The two populations are statistically similar across most categories. A noticeable difference between the two is the average age of respondents, which is almost over 10 years younger amongst the population using other forms of treatment.

**Table 29: Demographics Information of La Margarita**

| | Filter Users (n = 19) | Non- Users (n = 25) | Total (n = 44) | p-Value ($x^2$ test) |
|---|---|---|---|---|
| Surveyed households | 19 | 25 | 44 | - |
| % households surveyed | 25 | 33.3 | 59 | - |
| Age of respondents; average (min-max) | 51 (25-88) | 38 (14-74) | 44 (14-88) | - |
| Female respondents; number (%) | 14 (74) | 20 (80) | 34 (77) | 0.620 |
| Attended school; number (%) | 16 (84) | 22 (88) | 38 (86) | 0.717 |
| Years of schooling; average (min-max) (n=38) | 4.8 (0-10) | 4.8 (0-10) | 4.8 (0-10) | - |
| Household size; average (min-max) | 3.5(1-7) | 4.0 (2-8) | 3.8 (1-8) | - |

### *Water knowledge, attitudes, and practices*

The next presentations of information from the household surveys is a comparison of the variable and control groups using a chi-square test on several topics related to their water usage, perceptions, education, and treatment.

#### *Water Sources*

The two populations are statistically similar (p=0.652) between sources of water. The top choice for water in the community was the Los Tintos River with 53% of filter users and 48% of everyone else collecting water primarily from the river. Amongst people who were not using the filters, the second most popular water source was bottled water, with 28%. The remaining collection sites were spread over a number of sources in the community.

**Table 30: Water sources in La Margarita**

| | Filter Users Number (%) (n = 19) | Non-Users Numbers (%) (n = 25) | Total Numbers (%) (n = 44) | p-Value ($x^2$ test) |
|---|---|---|---|---|
| ***Water Source*** | | | | |
| Los Tintos River | 10 (52.6) | 12 (48.0) | 22 (50.0) | 0.652 |
| Bottled Water | 3 (15.8) | 7 (28.0) | 10 (22. ) | |
| Los Tintos + Bottled Water | 3 (15.8) | 4 (16.0) | 7 (15.9) | |
| Truck + Bottled Water | 1 (5.3) | 1 (4.0) | 2 (4.6) | |
| Los Tintos + Well | 1 (5.3) | 0 (0.0) | 1 (2.3) | |
| Los Tintos + Truck | 1 (5.3) | 0 (0.0) | 1 (2.3) | |
| Rice Fields + Well | 0 (0.0) | 1 (4.0) | 1 (2.3) | |
| ***General Water Information*** | | | | |
| Collected a water sample; (n=44) | 19 (100.0) | 25 (100.0) | 44 (100.0) | |
| Share your water with others; (n=31) | 7 (50.0) | 2 (11.8) | 9 (29.0) | |

*Water Usage*

As is evidenced by data in Table 31, everyone in the community uses water for drinking. The answers for usages were not enough to conduct a statistically significant chi-square test. No filter users wash dishes with their filtered water whereas 20% of non-users indicated using their water for dishes. No filter users wash clothes with their filtered water whereas 24% of non-users indicated using their water for clothes. A possible reason for this difference is that filtered water takes longer to prepare than other types of treated water and is stored in smaller volumes. Those using a filter indicate saving their filtered water for uses more directly related to consumption and hygiene.

**Table 31: Water usage in La Margarita**

| | **Filter Users Number (%) (n = 19)** | **Non-Users Number (%) (n = 25)** | **Total Number (%) (n = 44)** | **p-Value ($x^2$ test)** |
|---|---|---|---|---|
| Drinking | 19 (100) | 25 (100) | 44 (100) | -- |
| Cooking | 4(21) | 9 (36) | 13 (30) | -- |
| Bathing | 0 (0.0) | 2(8.0) | 2 (4.6) | -- |
| Washing hands | 1 (5.3) | 6 (24) | 7 (16) | -- |
| Washing dishes | 0 (0.0) | 5 (20) | 5(11) | -- |
| Washing clothes | 0 (0.0) | 6 (24) | 6 (14) | -- |
| Washing fruits/vegetables | 2 (11) | 7 (28) | 9 (21) | -- |
| Watering the garden | 0 (0.0) | 3 (12) | 3 (6.8) | -- |

*Perceptions of Water Safety*

To understand the communities' attitudes towards their water systems, they were asked if they believed their water was safe, and then asked to provide reasons for why they believed this (Table 32). Multiple responses were possible within the categories "Unsafe because" and "Safe because" with a total of 26 respondents providing reasons for unsafe water and 30 respondents providing reasons for safe water. Because multiple responses were possible, percentages indicated with each response correspond to the percentages responding positively to that particular question. Therefore, percentages relate to the row, and not the column response of the group. Percentages by group are represented in the pie charts in the figures following. In La Margarita, 79% of filter users and 56% of non-users perceive the water they drink as safe (p=0.273).

**Table 32: Perceptions of Water Safety in La Margarita**

| | Filter Users Number (%) (n = 19) | Non-Users Number (%) (n = 25) | Total Number (%) (n = 44) | p-Value ($x^2$ test) |
|---|---|---|---|---|
| Perceive water is safe (%) | 15 (79) | 14 (56) | 29 (66) | 0.273 |
| Don't know if water is safe (%) | 1 (5.3) | 2 (8.0) | 3 (6.8) | |
| ***Reasons for unsafe water*** | ***(n = 17)*** | ***(n = 15)*** | ***(n = 26)*** | |
| Suspended materials in water | 5 (39) | 4 (31) | 9 (35) | -- |
| Cloudy water | 7 (54) | 4 (31) | 11 (42) | -- |
| Water has color | 5 (39) | 4 (31) | 9 (35) | -- |
| Water has an odor | 0 (0.0) | 3 (23) | 3 (12) | -- |
| ***Reasons for safe water*** | ***(n = 15)*** | ***(n = 15)*** | ***(n=30)*** | |
| Clear water | 5 (29) | 7 (50) | 12 (39) | 0.242 |
| Water is from protected source | 1 (5.9) | 1 (7.1) | 2 (6.5) | -- |
| Water is treated | 9 (53) | 7 (50) | 16 (52) | 0.870 |

Among respondents who indicated reasons for unsafe water, cloudy water was the most popular answer amongst filter users with 54% positive response within the category. The reasons provided by non-users were spread fairly evenly amongst possible answers. The reasons indicated by respondents for unsafe water is spread amongst a relatively small number of possibilities. Amongst filter users response to unsafe water, cloudy water had 43% of the overall response. There was an even overall response of 27% each between suspended materials, cloudy water, and colored water amongst non-users.

Among residents who indicated reasons for safe water, the water being treated was the highest overall answer, with 53% positive response within the category. As with reasons for unsafe water, reasons for safe water was distributed between it appearing clear and it being treated. Some categories for safe water were statistically significant between filter users and non-users. Water being treated was the predominant response for why it was safe by the filter users, with a 60% overall response to the question. Non-users with a positive response of 47% each equally responded to water being clear and water being treated. Amongst both populations a small percentage of respondents indicated that the water was from a protected source.

*Water Education*

There were no statistically significant differences between the populations in relation to education about water and water treatment or its sources (Table 33). At least one person indicated being educated by all of the methods in each group. Across the board, group training received the highest response with 61% of filter using respondents and 50.0% of non-using respondents indicating receiving this type of training (p=0.482). The predominant response for source of information was Clarkson EWB by filter users with 78% responding positively and was also Clarkson EWB by non-users with 60% responding positively (p=0.405).

**Table 33: Water education in La Margarita**

| | **Filter Users** | **Non-Users** | **Total** | **p-Value ($x^2$ test)** |
|---|---|---|---|---|
| ***Type of information*** | ***(n = 18)*** | ***(n = 22)*** | ***(n=40)*** | |
| Received a pamphlet/poster (%) | 7 (39) | 8 (36) | 15 (38) | 0.870 |
| Received a household visit (%) | 5 (28) | 10 (46) | 15 (38) | 0.251 |
| Received a group training (%) | 11 (61) | 11 (50) | 22 (55) | 0.482 |
| Received a heath promotion (%) | 3 (17) | 1 (4.6) | 4 (10) | -- |
| ***Source of Information*** | ***(n = 9)*** | ***(n = 10)*** | ***(n=19)*** | |
| Clarkson University | 7 (78) | 6 (60) | 13 (68) | 0.405 |
| Never received | 2 (22) | 4 (40) | 6 (31) | |

*Household Water Treatment and Storage*

There are many different types of treatment processes and combinations of treatments being used in La Margarita (Table 34). Among the non-users population, 40% of households do not treat their water. A portion of this number, 7 households, is because they are using only bottled water purchased from the truck. Because of the way the groups have been divided in the study, there is not a p-value indication of statistically significant similarity for treatment or storage.

It can be seen that there are a multitude of different household practices. Amongst filter users, there is a slightly higher (37%) use of the ceramic filter in combination with coagulation and chlorination than the other methods. Households use the ceramic filter as the final treatment, therefore both coagulation and chlorination will occur as a pretreatment option. Amongst non-users, "coagulation only" occurred in 28% of households while coagulation in combination with chlorination occurred in 24% of households.

**Table 34: Household water treatment and storage in La Margarita**

| | Filter Users | Non-Users | Total | p-Value ($x^2$ test) |
|---|---|---|---|---|
| Report household treatment; number (%) | 19 (100) | 15 (60) | 34 (77) | 0.002 |
| Report covering water; number (%) (n=39) | 18 (95) | 14 (70) | 32 (82) | 0.126 |
| ***Treatment of Sampled Water*** | ***(n = 19)*** | ***(n = 25)*** | ***(n=44)*** | |
| Ceramic filter; number (%) | 6 (32) | 0 (0.0) | 6 (14) | -- |
| Chlorine; number (%) | 0 (0.0) | 2 (8.0) | 2 (4.6) | |
| Coagulation; number (%) | 0 (0.0) | 7 (28) | 7 (16) | |
| Coagulation + Chlorine; number (%) | 0 (0.0) | 6 (24) | 6 (14) | |
| Ceramic filter + Coagulation; number (%) | 6 (32) | 0 (0.0) | 6 (14) | |
| Coagulation + Chlorine + Ceramic filter; number (%) | 7 (37) | 0 (0.0) | 7 (16) | |
| No Treatment; number (%) | 0 (0.0) | 10 (40) | 10 (23) | |
| ***Treatment details if sample available*** | ***(n = 18)*** | ***(n = 23)*** | ***(n = 21)*** | |
| Liters stored; average (min-max) | 17 (1-208) | 56 (0-208) | 39 (0-208) | -- |
| Hours since treatment; average (min-max) | 42 (4-192) | 23 (0-72) | 32 (0-192) | -- |
| ***Water Storage Information*** | ***(n = 19)*** | ***(n = 23)*** | ***(n = 42)*** | |
| Water Cooler Drum; number (%) | 1 (5.3) | 10 (44) | 11(26) | -- |
| Metal Drum; number (%) | 0 (0.0) | 2 (8.7) | 2 (4.8) | |
| Filter Bucket; number (%) | 18 (95) | 2 (8.7) | 20 (48) | |
| Other Plastic Bucket; number (%) | 0 (0.0) | 9 (39) | 9 (21) | |

### *Ceramic Filter Use*

In general, some of the non-users responded to this portion of the survey in reference to their practices from when they used the filter. For this reason, many of the categories will still have responses under the non-users group. Table 35 is a summary of details on ceramic filter use in La Margarita. Important to notice is that only 84% of all households surveyed ever received a filter, even though 100 were given to the community for them to distribute amongst the 75 homes.

**Table 35: Information about filter use in La Margarita**

| | Filter Users | Non-Users | Total | p-Value ($x^2$ test) |
|---|---|---|---|---|
| Received a filter; number (%) (n=44) | 19 (100) | 18 (72) | 37 (84) | 0.012 |
| Received filter for free; number (%) (n=12) | 7 (100) | 5 (100) | 12 (100) | - |
| Months of filter use; average (min-max) (n=39) | 11 (1-12) | 4.9 (0-12) | 7.7 (0-12) | - |
| Self-reported filter still in use; number (%) (n=41) | 19 (100) | 1 (4.6) | 20 (49) | -- |
| Plan to continue filter use; number (%) (n=41) | 18 (95) | 20 (90) | 38 (93) | 0.234 |
| Filter was wet at time of sample collection; number (%) (n=44) | 18 (95) | 1 (4.0) | 19 (43) | -- |
| ***Reasons for filter use*** | ***(n = 19)*** | ***(n = 2)*** | ***(n = 21)*** | |
| Cleans water; number (%) | 14 (74) | 2(100) | 16 (76) | -- |
| Prevents disease; number (%) | 7 (37) | 1 (50) | 8 (38) | -- |
| Cools water; number (%) | 9 (47) | 2 (100) | 11 (52) | -- |
| Easy to use; number (%) | 14 (74) | 1 (50) | 15 (71) | -- |
| Like the taste; number (%) | 6 (32) | 1 (50) | 7 (33) | -- |
| ***Reasons for filter disuse*** | ***(n = 0)*** | ***(n = 16)*** | ***(n = 16)*** | |
| Broken filter; number (%) | 0 (0.0) | 13 (81) | 13 (81) | -- |
| Slow filter rate; number (%) | 0 (0.0) | 0 (0.0) | 0 (0.0) | |
| Bad taste; number (%) | 0 (0.0) | 1 (6.3) | 1 (6.3) | |
| Difficult to use; number (%) | 0 (0.0) | 0 (0.0) | 0 (0.0) | |
| Don't know how to use; number (%) | 0 (0.0) | 0 (0.0) | 0 (0.0) | |
| Other; number (%) | 0 (0.0) | 2 (13) | 2 (13) | |
| ***Education*** | ***(n = 18)*** | ***(n = 20)*** | ***(n = 38)*** | |
| Received enough installation education; number (%) | 14 (78) | 14 (70) | 28 (74) | 0.587 |
| Received enough maintenance education; number (%) | 14 (78) | 14 (70) | 28 (74) | 0.587 |

On average, the length of filter use among users was 11 months and 4.9 months for non-users. There was a discrepancy of note in reference to the question "Do you still use your filter?" in that one non-user household answered yes, although upon sample collection no filter was to be found. Furthermore, 2 households in the non-user group responded that they were unsure of whether or not they used the ceramic filter. Some of the 20 positive respondents in the non-user group to the question “Do you plan to continue filter use?” indicated that they would continue use if their filter wasn’t broken. However, some of the respondents did not later report that their filter broke. This would seem to indicate that some people were responding positively to the surveyor when there were reasons other than a broken filter for disuse.

Amongst filter users, 28% indicated using the filter because it cleans water and another 28% indicated they use it because it is easy. Furthermore, 18% of respondents indicate using it because it keeps the water cool. The predominant reason cited for disuse was a broken filter, with 87% of non-users indicating this. Some of the respondents cited that it broke because “there was a hole in the bottom”, “the lip broke off”, “my son accidentally pushed it off the counter”, “the side broke off”, and “the edge that holds it in the bucket broke off.”

As indicated from the data in Table 36, a high rate of respondents indicated that they cleaned their system and from that group, households across both groups predominately cleaned the inside of their pots and the bucket. There was no statistically significant difference in cleaning habits amongst respondents who indicated cleaning between the two groups. Amongst current filter users, it was most common to clean 2/week (47%) and among non-users to clean either 1/week or 2/week (33% each). A statistically significant difference was between filter users reporting no problems (78%) and non-filter users reporting no problems (40%) with a p=0.027. It is not clear from the survey what those other problems are that the non-users experienced from their answers.

**Table 36: Details on ceramic filter use in La Margarita**

| | Filter Users | Non-Users | Total | p-Value ($x^2$ test) |
|---|---|---|---|---|
| ***Information about Cleaning*** | | | | |
| Clean the filtration system; number (%) (n=35) | 18 (100) | 15 (88) | 33 (94) | 0.325 |
| Scrub inside of pot; number (%) (n=34) | 17 (94) | 16(100) | 33 (97) | 0.339 |
| Scrub outside of pot; number (%) (n=34) | 6 (33) | 7 (44) | 13 (38) | 0.559 |
| Clean the bucket; number (%) (n=34) | 18 (100) | 15 (94) | 33 (97) | 0.282 |
| Clean the taps; number (%) (n=34) | 11 (61) | 8 (50) | 19 (56) | 0.439 |
| ***Frequency of Cleaning*** | ***(n = 18)*** | ***(n = 15)*** | ***(n = 33)*** | |
| Daily | 1 (5.6) | 1 (6.7) | 2 (6.1) | 0.362 |
| 1/week | 5 (28) | 5 (33) | 10 (30) | |
| 2/week | 8 (44) | 5(33) | 13 (39) | |
| 3/week | 3(17) | 1 (6.7) | 4 (12) | |
| 2/month | 0 (0.0) | 3(20) | 3 (9.1) | |
| ***Problems with Filter*** | ***(n = 18)*** | ***(n = 15)*** | ***(n = 33)*** | |
| Slow flow/clogging | 2(11) | 0 (0.0) | 2 (6.1) | -- |
| Cracks | 0 (0.0) | 0 (0.0) | 0 (0.0) | - |
| Brocken bucket | 0 (0.0) | 1 (6.7) | 1 (3.0) | -- |
| Odor | 0 (0.0) | 1 (6.7) | 1 (3.0) | -- |
| Broken taps | 0 (0.0) | 0 (0.0) | 0 (0.0) | - |
| No Problems | 14 (78) | 6 (40) | 20 (61) | 0.027 |

*Observations from Enumerators*

Enumerators were asked to record their observations of systems in use, which are presented in Table 37. Of note, is that 78% of filter units appeared “clean” to the surveyor. Also, only 83% of the households were using a lid on their filter set-up.

**Table 37: Observations on ceramic filters in households in La Margarita**

| | Filter Users (n = 18) |
|---|---|
| Liters in pot; average (min-max) | 1.9 (0-5) |
| Liters in bucket; average (min-max) | 5.6 (0-12) |
| Filtration system is "clean"; number (%) | 14 (78) |
| Filtration system has an odor; number (%) | 0 (0.0) |
| Lid is in use; number (%) | 15 (83) |

***Water Quality***

A presentation of microbiological water quality followed by physical quality is presented first for the source water second for the household water.

*Source Water*

The Los Tintos River is under heavy contamination loads by the time it reaches La Margarita. The locations on the river represent multiple points along the way from its upstream measurement location to its downstream location from the community. As can be seen in Figure 40, the *E. Coli* and total coliform concentration was high.

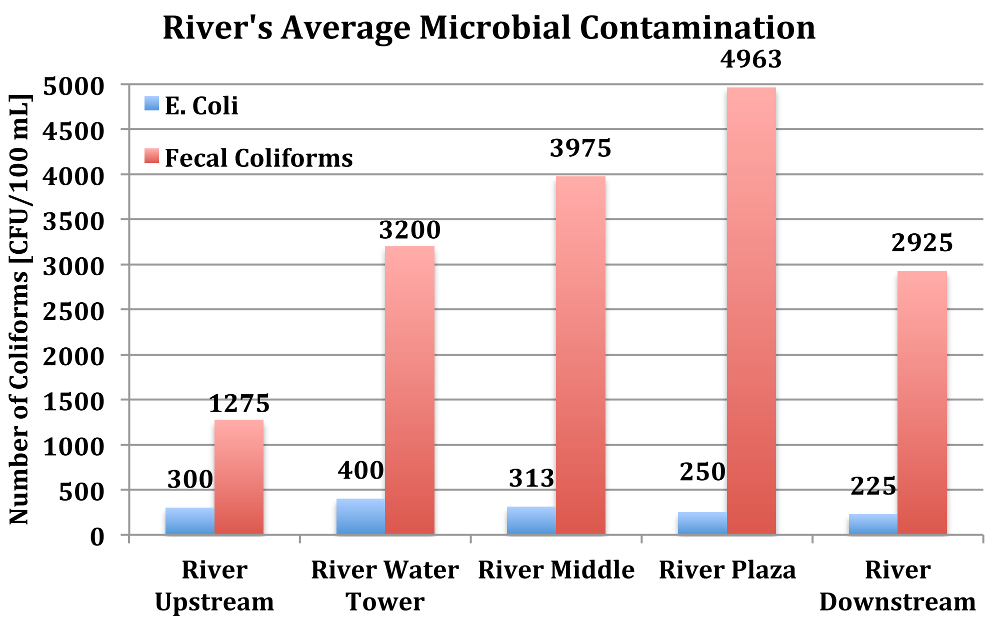


**Figure 40: Average bacteria contamination by location on the river**

Figure 41 is a representation of the turbidity measurements through time and by location. Measurements taken at the middle of the community corresponds to periods of high tide and high flow. Measurements were taken approximately 0.3 m below the surface of the water.

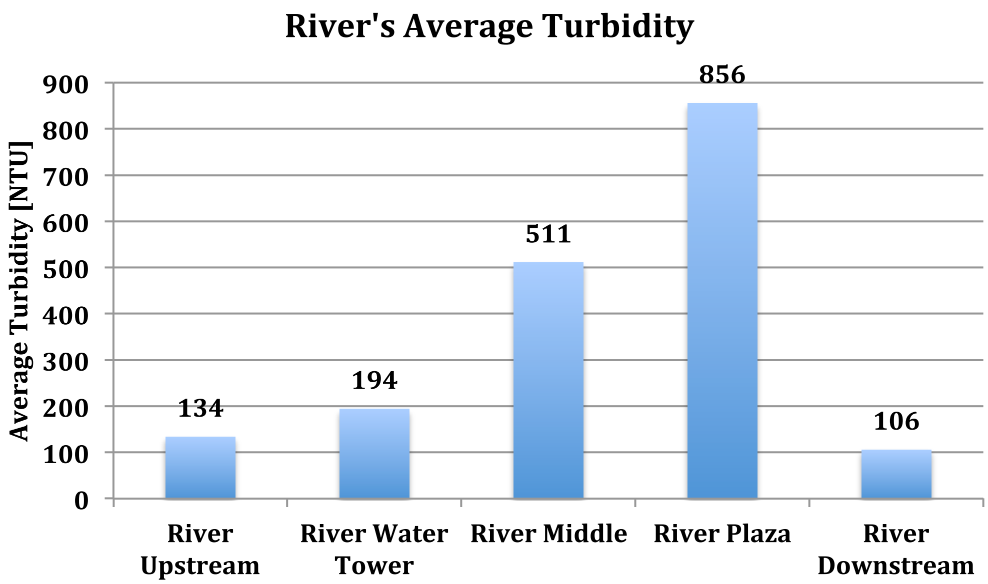


**Figure 41: Average turbidity by survey at varying locations on the river**

Table 38 provides physical and chemical data averaged across the length of the river for a variety of water properties.

**Table 38: Average physical and chemical properties of the river water**

| | **Los Tintos River 2012** |
|---|---|
| Temperature [°C] | 25.32 |
| pH | 7.18 |
| Elecritcal Conductivity [µS] | 113.98 |
| Nitrate Concentration [mg/L] | 6.52 |

*Household Water*

Figure 42 - Figure 45 represent a comparison of the non-user group to the efficacy of the ceramic filters across four water quality measurements: total coliforms, *E. Coli*, turbidity, and free chlorine residual.

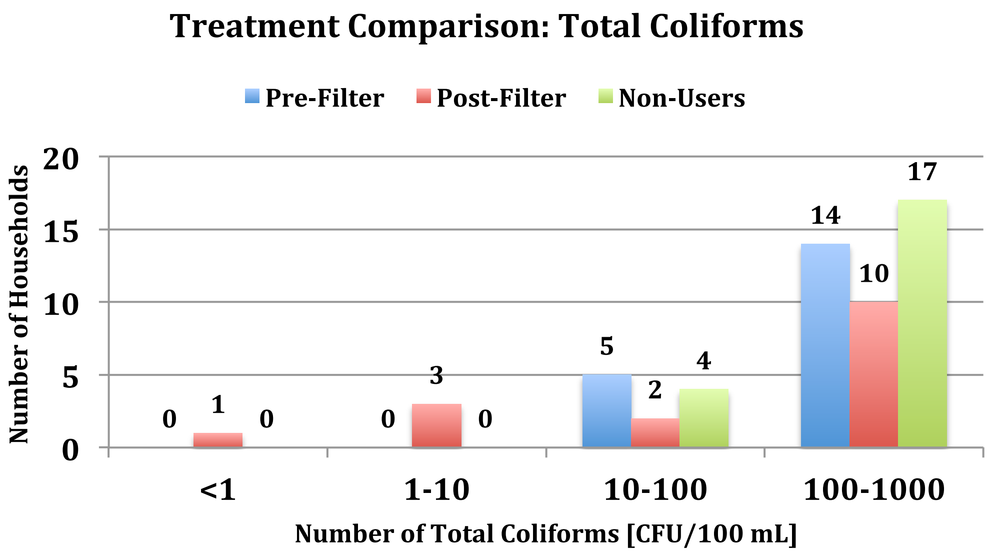


**Figure 42: Comparison of total coliforms across all types of treatment in La Margarita**

During enumeration of the plates, it was discovered that there was an error in preparation of the pads with growth media because the plates were quite a bit wetter than anticipated. This humid environment could have caused more bacteria to grow and skew the results across all groups higher than they actually were. By looking at the trend in total coliforms, it appears that there is no difference in the user and non-user communities.

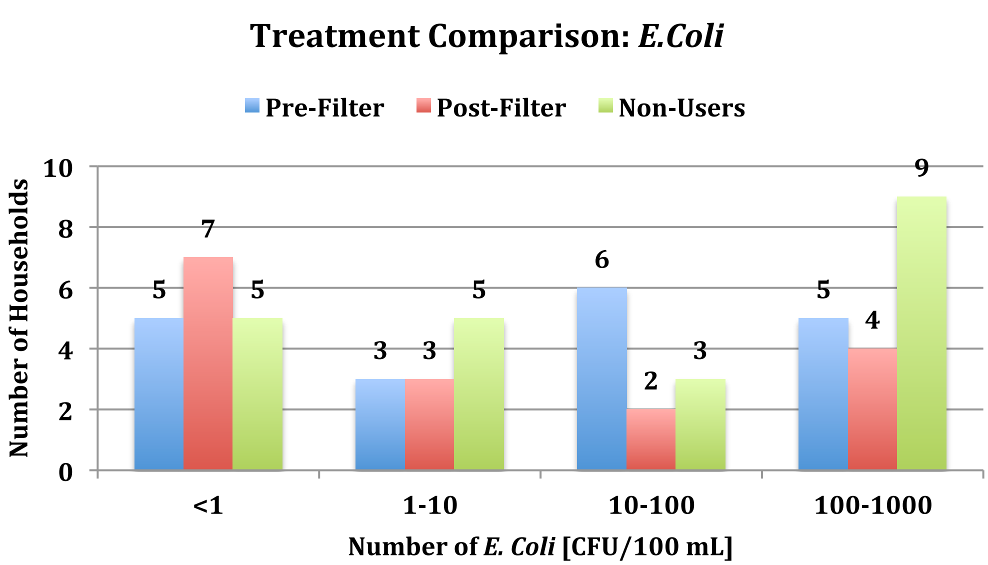


**Figure 43: Comparison of *E.Coli* across all types of treatment in La Margarita**

From the above graph it looks like there is a general trend towards effective performance by the ceramic filter in reducing *E.Coli* counts, but this cannot be proved since the test was not performed properly.

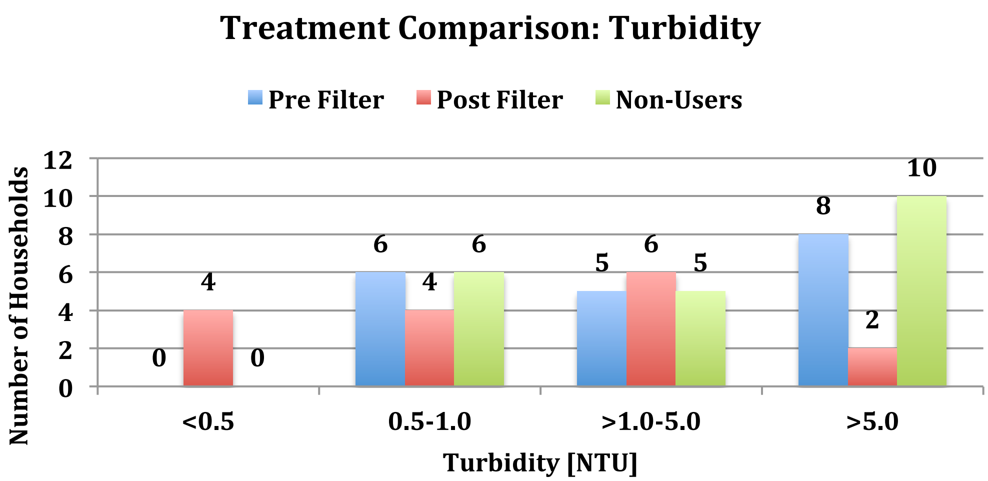


**Figure 44: Comparison of turbidity across all types of treatment in La Margarita**

Turbidity in general was lower in the samples both pre and post-filter. This is most likely a result of many households using a flocculation technique before using the filter. In general there appears to be a slight positive effect of the filters on the reduction of turbidity.

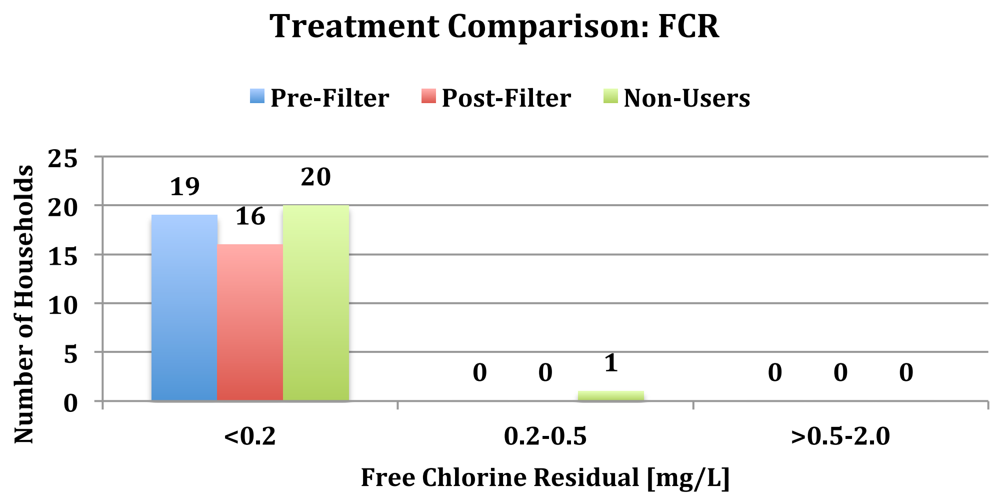


**Figure 45: Comparison of free chlorine residual across all types of treatment in La Margarita**

From Figure 45 it can be seen that there is not the recommended amount of free chlorine (0.2-2.0 mg/L) in most of the households. This indicates that although people responded positively to chlorinating, there may not be enough chlorine in the stored water to work effectively against contamination. It is likely that there is a dosage and storage problem within the community, regardless of which type of treatment method is used.

Additional physical and chemical water quality measurements were taken and are presented in Table 39 for all households in La Margarita.

**Table 39: Physical and chemical water quality measurements**

| | La Margarita Households average (min-max) |
|---|---|
| ***Sample A (n=60)*** | |
| Temperature of Sample A [°C] | 24 (22-30) |
| pH of Sample A | 6.9 (4.7-8.2) |
| Elecritcal Conductivity of Sample A [µS | 176 (108-870) |
| Turbidity of Sample A | 37 (0.5-745) |
| Nitrate Concentration of Sample A [mg/L] | 0.8 (0-2.4) |
| | |
| ***Sample B (n=17)*** | |
| Temperature of Sample B [°C] | 24 (22-25) |
| pH of Sample B | 6.9 (5.1-8.0) |
| Elecritcal Conductivity of Sample B [µS] | 589 (113-6320) |
| Turbidity of Sample B | 2.1 (0-6.1) |
| Nitrate Concentration of Sample B [mg/L] | 3.0 (0-35) |

## Hogar de Cristo

### *History*

Hogar de Cristo Ecuador is a non-profit organization founded by Jesuits and modeled after an organization of the same name that was founded in Chili in 1944. Hogar de Cristo was founded in Ecuador in 1971 with the mission of providing housing to the poorest in the country and in the process "more than a house, a home." Originally focused in Guayaquil, the organization grew its facilities such that it was producing more than 100 wooden pre-fabricated homes per month by the mid '80's. The organization then experienced a growth through to the mid '90's in which operations were expanded into other major cities throughout the Ecuadorian coastal region affected by El Niño.

HdC was recognized for their work by being awarded the United Nation's World Habitat Award in 1996. [**96**]

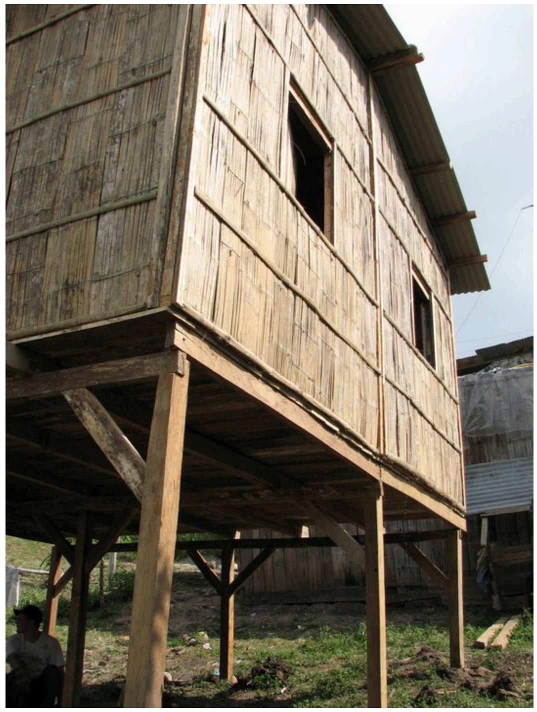

**Figure 46: Example of an Hogar de Cristo House** [92]

In 2001, under a new director, HdC restructured their organization to begin offering a network of services including microcredit, educational initiatives, health initiatives, and social protection. The framework was again updated in 2007 to allow HdC to start making even more of an impact in the communities they are serving. New programs were undertaken such as producing soymilk as part of a school meals program, creating the first women's shelter in Guayaquil, and building a ceramic filter manufacturing facility. The organization relies on both volunteers and employees to advance its mission. [**96**]

HdC's headquarters are in the Monte Sinai neighborhood located on the Perimetral in northwest Guayaquil. Habitation of the Monte Sinai region began approximately 10 years ago when cheap plots of land went up for sale in swampland.

Housing was constructed with no formal infrastructure in place, therefore people had to walk over a mile to wait for water trucks or to catch a bus to buy food and attend school. Over the years, neighborhood shops, schools, and churches have moved into the area. The government recently funded projects to lay water and sewer lines, pave roads, and bring electricity to the region. [**97**] The Monte Sinai region is HdC's initial target for ceramic filter distribution.

***Ceramic Filter Production at Hogar de Cristo***

**Figure 47: Hogar de Cristo Ceramic Filter Facility 2012 [**98**]**

Ceramic filter production is not an easy task and provides a unique set of challenges to each facility with much research still needed in this area. The Ceramics Manufacturing Working Group has already written one Best Practices manual for production in an attempt to summarize existing knowledge, establish production and quality control guidelines, and quantify how production variables affect the efficacy of the filter. [**38**] Many of the challenges described in the Best Practices document reflect items that the facility at Hogar de Cristo has faced Figure 47.

Over the course of several years, HdC was able to secure funding via Rotary International to bring the filter facility to reality. They worked closely with PFP in the design of their facility and in the overall operations and materials sourcing for the project. Part of Clarkson EWB's agreement with HdC was to design and provide the facility with a press, which was developed and modified with input from PFP. [**87**]

In December 2010, Clarkson EWB machined molds and constructed a second-generation press for use at the facility by HdC. Members of HdC visited the filter factory in Pifo to learn about the manufacturing process in preparation for the construction and start-up of their own facility. [**99**] In late 2011, PFP made their first trip to the facility at HdC to begin to set up equipment. They returned in 2012 to fix issues with the kiln and to construct a new press. The original molds provided by Clarkson were insufficient, so they designed new ones that were taken by PFP to HdC. [**100**]

***Interview with Hogar de Cristo during 2012 monitoring trip***

An interview was conducted with the volunteer at HdC who is in charge of the build-up of the ceramic filtration factory. A visual descriptor of the facility is provided in **Figure 48.**

**Figure 48: From left to right: the kiln, the press, and tested, fired, and drying filters 2012** [**98**]

The following information was provided during the interview in review of different components of the factory.

*Clay:* HdC purchases one bag of clay for approximately $7 USD. One run of pots (approximately 300) will cost around $200 USD in clay. They source their clay from the same buyer, but he purchases the clay from different sites depending upon what construction is occurring in his neighborhood. This results in a number of issues including: proper clay/sawdust ratio, effects of shrinkage in pots, and the added time and resources to constantly be optimizing for different mixes.

*Sawdust:* The sawdust used by HdC is free and comes to them from their house construction facility. It is not always the same type of wood, and depends upon they types of housing being constructed. The sawdust is ground up in the hammermill and then sieved to achieve a uniform size.

*Kiln:* HdC has had many issues with the insulation of the kiln, resulting in its reconstruction several times to overcome the issue. The final solution was to put ceramic matte panel insulation around the brick and build adobe on top. This solution has allowed them to fire the kiln with a capacity of 60 pots per firing. One firing cycle, 12 hours of firing and 36 hours of cooling, requires three industrial sized tanks of propane. One industrial sized tank of propane costs $50-$60 USD, therefore a firing cycle can be quite expensive.

*Press*: The original press that Clarkson EWB constructed is not in use. Instead, HdC sourced and modified an in-country 20-ton partial scissor press that Clarkson EWB paid for. A member of Potters Without Borders helped build the press while setting up the first phase of the facility. The press is using aluminum molds that were milled and shipped down by Clarkson in November 2011. The pressing process is quite slow and it takes upwards of 10 min to press one pot. When a pot is removed from the press it is finished with a comb to open up the pores and brushed with a wet rag to smooth and even the bottom and lip. The last step is for it to be stamped.

*Drying:* The pots dry in about 5 days during the summer months. Originally they were drying faster than that, so HdC decided to wrap them in plastic to prevent cracking. In the rainy season it can take anywhere from 10 days to 2 weeks for a pot to dry.

## Summary and Discussion

After five years of Clarkson EWB working in the community of La Margarita, Ecuador, there have been many changes in regards to the community's water treatment practices. The following summary looks at what improvements have been made to their drinking water and what challenges the community still faces as well as looking at successes and challenges with Hogar de Cristo's filter factory. It also summarizes some of the challenges and improvements that the chapter faced in conducting this project.

### *Successes and Challenges in La Margarita*

*Technical Functionality of Household Water Treatment Practices*

When Clarkson EWB first began working with the community of La Margarita in 2008, most households were using an alum coagulant to treat river water for consumption. *E. Coli* contamination of the river was found to range from 8-12 CFU/mL and at the household level of 1 CFU/mL. Turbidity of the river water was found to be 30.9 to 35.7 NTU and turbidity of the household water at 7.45 NTU. Water quality testing conducted again in 2009 indicated *E. Coli* contamination of the river in the range of 1300-5700 MPN/100mL and households to be from 25 MPN/100mL to too numerous to count. Turbidity measurements taken during the trip indicated 78.6-132 NTU for the river and 4.93-30.1 NTU for the households. The vast range of *E. Coli* counts and turbidity readings at the household level show that household treatment practices were conducted to a varying degree of success.

In spring of 2011, Clarkson EWB delivered ceramic filters to La Margarita from the Pifo filter factory. During this trip the team did not conduct any water quality testing. Water quality testing conducted during the evaluation in 2012 is inconclusive with regards to filter functionality. This is due, in part, to the error of putting too much growth media in the petri dishes, causing the environment to be more humid and potentially causing more colonies to inadvertently grow. Readings of pre-filtered river water and non-filtered water showed slightly more incidence of turbidity over 5.0 NTU than filtered water. Furthermore, free chlorine residual testing indicated that most households, regardless of treatment method, were not chlorinating to even the minimum level.

*Cultural Acceptance of Water Treatment in La Margarita*

<u>Water Board</u>

The Water Board was never as definitive as La Margarita and Clarkson EWB had agreed to in the Memorandum of Understanding. Because of this loose governance, it was difficult for the community to unite on water treatment. This manifested itself in the community lacking the funds for both the original filter manufacturing facility and the ceramic filters from Pifo. Distribution of the ceramic filters in 2011 was left to the Water Board. It was indicated from the 2012 evaluation that 7 of the 44 households surveyed has never received a filter, although Clarkson EWB originally supplied more filters than households. This points to overall communication issues between the Water Board and the community and between the community and Clarkson EWB.

<u>Community Response</u>

The community responded positively to improved household treatment practices in 2008 and 2009 by participating in the selection of ceramic filters as the implemented design. The community expressed to Clarkson EWB during the Summer of 2009 that they would like to purchase the filters but that they did not want to be producing them within their community. Among other issues, this led Clarkson EWB to search for filters in other places.

Of the 44 households surveyed in 2012, 19 were using their filters while 25 other households were practicing other forms of treatment. Of the filter users, 100% of households responded positively to conducting some sort of cleaning and maintenance of their system. Enumerators reported that 78% of the ceramic filtration systems that they saw would rate as "clean." Amongst non-users, 81% indicated not using the filter because it had broken, and 90% indicated that they would plan to continue filter use if they had an operable filter.

*Factory Facility at Hogar de Cristo*

Funded via grants from Rotary International, and constructed with assistance from Potters for Peace, the ceramic factory facility at Hogar de Cristo was conceived in 2009. By Fall 2012, the facility was mostly online, but challenges to production were identified by a full time HdC volunteer and a full time HdC employee as follows:

1. Securing a consistent source of clay
2. Redesign of the molds
3. Securing a bucket and lid supplier
4. Conducting microbiological testing of filters
5. Decreasing the difficulty and time-consuming nature of the existing press
6. Operate within allotted budget

Although producing filters, as of Fall 2012 HdC was not selling these filters due to many fluctuating variables in the process. They were focused on creating a uniform operation and set of procedures as well as testing each new batch to develop the correct clay to burn out ratios.

A key component of the ceramic filter implementation in the community of La Margarita is the reliance on the Hogar de Cristo factory to be producing filters. It was an intention of the Clarkson EWB implementation that members of La Margarita could purchase additional filters or replacement filters from HdC when their Pifo filters were no longer operable. In addition to HdC not currently being able to produce functioning filters reliably, no supply chain has yet been established to make the filters available to the businesses frequented by the citizens of La Margarita.

### ***Successes and Challenges in the Clarkson EWB Group***

#### *Partnership with La Margarita*

Clarkson EWB started their Program in Ecuador via a contact in the nearby town that was aware of La Margarita's desire to work with an aid organization. Although the community has been receptive of the Clarkson EWB team, maintaining communication with the community and outlining clearly defined roles and goals has been difficult.

It was difficult for the Clarkson EWB group to gain the trust of the community. La Margarita had seen an international aid organization begin a project to construct a health clinic in the community, only to halt construction when the community was unable to make payments due to a bad harvest. The community had also seen the local government come into town and construct a well without consultation of the citizens. The well was unwanted because the community did not like the taste of the water, which tested high for phosphates and ammonium in 2008. La Margarita is a community that lies linearly along the river for about a mile and a half. The well was located a quarter of a mile from the end of town, rendering it a much farther walk than the 30-50 feet most people went to reach the river. As a result, the community did not use the well and allowed the original pump to be flood during the rainy season. La Margarita was slow to buy into the Clarkson EWB group because of their past mishaps with aid.

*Documentation*

A key component in evaluating the Clarkson EWB Ecuador Program is to understand the history of the Projects including the original and adjusted goals and all accompanying data to frame the context of the work completed. To evaluate the Programs, prior reports submitted to EWB-USA as well as internal documents were collected and read. Many reports, however, were lost; making it difficult to piece to together the work and thought of previous Clarkson EWB teams. In addition to missing reports, many of the raw data files are also unavailable, leaving the summary tables in the reports the only information upon which to evaluate the prior objectives of the Program.

An additional issue with the documentation for evaluating the Program is its focus on trip narrative rather than technical information. This is not a reflection of the quality of work completed by the student teams, but rather a result of the information requested by EWB-USA in its reports. While trip narrative helps gauge the impact of this work on the growth of the students, it does not lend itself well to evaluating the type and quality of work completed.

*Metrics and Methods*

In the original design of this Program, there was a clear outline of the manner in which Clarkson EWB would monitor the water system in La Margarita and a definition of how Clarkson would measure their impact and the sustainability of their Projects. Defining these metrics showed great forethought on behalf of the team in tracking the long-term impacts of their system, and having historical data to rely on when developing different iterations of the system. An issue with the developed metrics, however, is that they were not necessarily the most appropriate for the Program and they were not readjusted as clear Project goals were defined.

One of the categories of the technical metrics pertains almost solely to the assumption that Clarkson EWB was going to construct some form of community scale treatment system. As a household treatment option was chosen, the metrics should have been readjusted accordingly. Further inappropriate health metrics that were developed pertained to the health goals of "increase in productivity" of the community members and "a statistically significant reduction in reported prevalence of waterborne illness." Both of these goals would be difficult to track and not necessarily the most clear in identifying the success of the implemented water treatment option. All of Clarkson EWB's metrics were approved by EWB-USA in their initial 507 Design Compendium.

The water quality test methods were clearly defined in the reports submitted after the teams submitted post travel. The reporting of the water quality testing was rigorous, making the data useful and reliable points for historical contamination comparison. Other testing methods, excluding health surveying, were also clearly presented and the data reported clearly and concisely.

Clarkson EWB also conducted health surveys in the community in accordance with EWB-USA's 509 Compendium requirement. Because the neither the original survey questions nor were the raw data was available, the only results from the surveys were those presented by the 2009 team in their summary report. Impressively, surveys conducted 2009 represented the health of 271 community members at that snapshot in time. While there is a wealth of data that makes the information more than just anecdotal, there is no control or baseline health survey to compare information against. However, two important data points from the survey indicate that 39 households were using a combination of river water and bottled water to meet needs while an additional 30 households indicated only using the river water. Furthermore, 56 households reported using some for of chemical household water treatment. Unfortunately, the results of the health survey do not inform as a public health survey intends. The lack of a baseline health survey and subsequent follow-up surveys, along with the lack of control group surveys makes the information unusable to tracking public health. This metric was used by the Clarkson EWB team to maintain compliance with EWB-USA's operating procedures and required a significant amount of time and manpower to conduct.

## Conclusions and Recommendations

From the two case study EWB student Programs, there are many similarities in the way the university Chapters conducted their Projects and a common narrative occurring within each Program. These similarities are summarized along with recommendations for improvements to EWB-USA's operating procedures.

### Creation of Measureable Metrics

The Tufts EWB Ecuador Program did not have defined metrics to use throughout the history of the project to track progress and to use in evaluating the SSFs in El Cristal. The Clarkson EWB Ecuador Program did have well defined goals and accompanying metrics and methods by which to collect data in support of these goals. However, the Chapter did not redefine their metrics after selecting a final Project within the community, nor were the chosen metrics the most appropriate for evaluating the progress of the system.

The creation of smarter indicators by Chapters would aid in structuring a Project and in thinking to the long term monitoring of it. For instance, defining what would be measured could be used to help clarify Project goals by both the EWB team and the community. Setting benchmark goals and using the defined metrics to evaluate progress towards these goals would help Chapters identify successful and not so successful components of Project in an early stage. This, in turn, could aid in more informed and faster decision making.

Another component of the indicators process that EWB-USA should examine more critically is the push to conduct health surveys of the community. In many instances, communities are too small for a health survey to give meaningful data, there are too many variables for why certain health trends may be appearing in the community, and they are not necessarily and indicator of project success or failure. Furthermore, health surveys tend to take more time to complete in the community, thereby cutting back on information gathering that could be conducted elsewhere, and many Chapters do not have trained community health professionals or epidemiologists on their teams. Instead, tracking water quality indicators, for example, may give a better representation of system functionality than tracking personal health trends.

Additionally, one of the Objectives outlined by EWB-USA in its Strategic Plan was to “ensure that the technologies and project delivery systems are appropriate and sustainable to the communities.” Their tactic identified to accomplish this Objective is to implement a monitoring and evaluation program. Although not indicated in the Strategic Plan by EWB-USA, one of the feasible ways to implement this at the Chapter level would be to require that Programs have clearly specified metrics and that they continuously report on those metrics.

## Enhancement of the EWB-USA Technical Advisory Committee

Going hand in hand with the creation of measurable metrics is the creation of metrics for non-technical components of the Projects. For instance, the Tufts and Clarkson Chapters only vaguely indicated ideas such as “community acceptance” as important to the definition of Project sustainability. Although EWB-USA requires that Projects undergo a TAC approval process, there is no mandate for a review of the Programs from a social standpoint.

Based upon transcripts of TAC reviews from the Tufts and Clarkson EWB teams, it would appear that little of the feedback is on the cultural context of the programs. This manifested in the Chapters not indicating social aspects of the Programs as measurable outcomes of Project success or failure. Many of the challenges faced by the EWB groups in the case studies were social in nature, relating to communication, trust, and educational issues that the teams seemed least prepared to handle

The first Objective of the Strategic Plan is to "build and strengthen the project delivery system through a focus on project quality." A tactic to achieving this is to maintain and "enhance the Technical Advisory Committee and its operation." Based upon the need for a social or cultural review of Programs demonstrated by the case studies, it is recommended that the TAC is expanded to evaluate potential Programs on these grounds as well. The Chapters in these case studies may have benefited greatly from a review by someone with a non-technical background or a special skill set in international development, instead of only from a technical background.

## Creation of Open Source Network for Chapters

The students in the Tufts EWB Ecuador Program benefitted from being involved in a large EWB Chapter that had a history of Programs within the EWB-USA system and also being at a university with a long and rich history of international development work. Additionally, the Tufts EWB Ecuador Program was based in Boston, a city with many student Chapters and one of the premiere professional Chapters in the country available for mentoring. Contrastingly, the Clarkson EWB Ecuador Program was the only EWB-USA Program being conducted at Clarkson. Clarkson University does not have the critical mass of knowledge, people, or resources in international development. Furthermore, the Clarkson EWB Chapter was the only EWB Chapter in over a 100-mile radius.

To supplement the lack of support that the Clarkson EWB Chapter had in its physical location, the students turned to online resources. However, they were unable to find a community of support through either EWB-USA or the student conferences they attended. To support the Objective of the Strategic Plan that states "build an education program to facilitate the development, dissemination, and application of knowledge and resources throughout EWB-USA" National identified a tactic of "implementing web-based forums for country and technology sharing."

Although the webinars and instruction booklets on technologies that EWB-USA has put together have represented an improvement over prior operations, there still is little support for Chapters to share information and knowledge. The creation of an open source network for groups to share manuals and standard operating procedures would be beneficial to all Chapters in general, particularly those like Clarkson who are isolated from their counterparts. The networking would help Chapters find support when they encounter particular problems or when they are looking for advice and have no one within their own network that could help. Instead of individual Chapters all reinventing the wheel, an open source platform could help the organization develop and grow organically, adapting to the best set of operating procedures.

## Creation of Database and File-Sharing

As was seen in both of the case studies presented, one of the biggest issues in conducting this research was tracking down important internal documents, reports, and data. EWB-USA has recognized this as well and made it an Objective to "create fully integrated software systems which allow for accumulation, storage and sharing of information.” The specific tactic related to this is the “implementation of a fully integrated system to accurately track and maintain information on projects.”

The creation of a searchable database for each Chapter’s documents would be exceedingly useful. For student groups, where the turnover rate is high, it is particularly easy to lose old documents and work when students graduate and move on. In some cases, such as the two Chapters evaluated in this study, critical components of information can be lost to generations of students working on the Project. This can result in repetition of work or a lack of understanding of Project evolution.

## Future Work

An evaluative study such as this would always benefit by becoming a longitudinal study where monitoring in the future occurs at set intervals to track the real long-term evolution of the Programs evaluated in these case studies. To expand the work in identifying best practices conducted at the Chapter level, a broader range of Programs needs to be evaluated across a range of Project types, locations, and student/professional Chapters. This would help identify common themes within the Programs that could be enhanced or supported with initiatives from EWB-USA. This would allow for the identification of emergent patterns in the way Projects are run successfully at a both the Chapter and Program level and where they struggle and those levels. A larger cross-sectional study would also allow for the development of more defined recommendations for improvement of the EWB-USA process and allow EWB-USA to determine how they can best serve their member Chapters and the communities in which they are working.

# Appendix A – Reference Monitoring & Evaluation Form From EWB-USA

## Document 531 – Post-Monitoring Report Instructions for Report Preparation

*Please go to the EWB-USA website to make sure that you are using the most current version of this document.*

The monitoring activities of the project are archived, presented and summarized in this document. All information gathered should be included as appendices to this document. This includes notes, photographs, and any other pertinent data. The data should also be summarized as appropriate. This report should be prepared and submitted to EWB-USA National Staff while the information is fresh in your minds. This report will be reviewed by EWB-USA National Staff to assess appropriate next steps for the program in the subject community. The 531 – Post-Monitoring Report will follow the same review cycle as the pre-trip reports. The document should be submitted by the deadline that lies between 60 and 90 days of your return from the site. The deadlines are listed on the submittal deadlines table on our website (Member Pages – Project Process – Submittal Deadlines).

Note: Use this report if your chapter is ***only*** conducting a monitoring trip. The 530 – Pre-Monitoring Report and 531 – Post-Monitoring Report are intended for chapters who are conducting a monitoring trip of past projects and no other project work. If you collected information on past projects while on an assessment or implementation trip for a different project, you should use only the 522 or 526 reports, respectively.

Formatting – Please ensure correct page numbering in your document, and include a Table of Contents. Also, please minimize the number of documents submitted. Multiple documents are unprofessional and confusing. If multiple documents are submitted, the document name for each must be self-explanatory. The contents of the file must be obvious without opening the file.

Size Limit (10MB) - Please limit the size of the reports submitted to the National Office to a maximum size of 10MB. If you compress the photos within the document, this will help reduce the size of the entire document. If you do not know how to compress photos, please **see our website for instructions**. Please contact projects@ewb-usa.org if you have special circumstances that may require a larger report submittal.

There are two parts to the post-monitoring trip report: Part 1 includes the administrative information for the trip and Part 2 includes the technical information.

Part 1 is a fill-in-the-blank exercise that provides the EWB-USA National Office with specific information about chapter and project in a specific format. The information should be provided in the exact format requested without deviation. If you have questions about completing Part 1 of the report contact your Chapter Relations Manager (CRM) at the EWB-USA National Office.

Part 2 of the report is not a fill-in-the-blank exercise. This is the portion of the report where your chapter provides all the detailed information about the project as completed. The outline of this portion of the report can be modified by the chapter if necessary to present the project more clearly. It is your chapter's responsibility to clearly and thoroughly present your project. Note that you may need to include additional information that is not listed depending on the specifics of your project. If you have questions about completing Part 2 of the report, contact one of the Project Managers (PM) at the EWB-USA National Office.

## Part 1: Administrative Information – Instructions

1.0 Contact Information – Fill in the table completely with updated contact information for current project leaders. This information will be used by EWB-USA National Office staff to contact your project team throughout the review process.

2.0 Travel History – Show every trip that your chapter has taken for this program.

3.0 Travel Team – Include information for all the travel team members that actually traveled on the trip.

4.0 Health and Safety

4.1 Incident Reports – If there were any health and safety incidents during the trip, check "Yes" and submit your completed 612 - Incident Report document as a separate attachment with this report. An incident report should be submitted anytime an incident occurs during an EWB-USA trip. If the HSO is uncertain about the type of incidents that would necessitate the submittal of this report, please see the list in document 612 – Incident Report. Please note that the submittal of incident reports is strongly encouraged by EWB-USA. EWB-USA uses the information and lessons learned from the incident reports to create more comprehensive procedures and policies. The chapter will not be penalized in any way for submitting an incident report. If your HSO has not yet filled out the Incident Report, a blank form can be found on the EWB-USA website – Member Pages – Project Process – Health and Safety Program. If there were no incidents, check "No".

5.0 Monitoring – Past-Implemented Project Status Table: Complete the following information for each project. Use the table provided in the template that corresponds to these instructions.

Project Type – State the type of the past-implemented project you monitored. Use only the Project Type terms that are bold listed in Part 1, Section 7.0.

Project Discipline(s) – State the primary discipline(s) of the past-implemented project you monitored. Use only the terms listed in Part 1, Section 7.0.

Date of Completion (m/d/y) – What was the date of the completion of the project implementation?

Functionality (0-50%, 50-75%, 75-100%) – Report what percentage of the project implemented is **functioning as designed**. Examples of how teams might assess functionality for different types of projects include: is the water quality at levels that meet your team's goals, is the flow rate of the water system as you designed, is the school being used as a school, is there a decrease in indoor air pollution from improved cook stoves, are the batteries being charged as intended with the new solar system, etc.

Periodic Maintenance (Yes or No) – Indicate whether or not your chapter has **observed evidence** that the responsible parties in the community have been performing periodic maintenance on the project. Examples might include: no erosion around the foundation of a structure, clean gutters on a rainwater catchment system, clean panels on a solar project, clean water storage tanks, bank statement or accounting log that shows maintenance fees are being collected, etc.

Demonstration of Knowledge Transfer (Yes or No) – Indicate whether or not your chapter has **observed evidence** that the technical knowledge has transferred to the responsible parties in the community. Examples might include duplication of the project, execution of a training of trainers where responsible parties trained others with the chapter's oversight to ensure accuracy, completion of major repairs on the project in the absence of the chapter, etc.

6.0 Budget – fill in each of the tables in the report template without modifying any of the headings.

6.1 Project Budget – Use the budget from the 530 Pre-Implementation Report to complete the "Estimated Expenses" column. Complete the "Actual Expenses" column to account for any variance. Include in-kind contributions in the "Non-Budget Items" section. An in-kind donation is a non-monetary contribution to the project, such as donated labor and materials. Funding that is deposited in a 501(c)3 account (EWB-USA or university account) is not an in-kind donation. EWB-USA must account for all costs associated with a project. The budget for should include all costs incurred from the end of the previous trip through the end of the current trip. Please be sure to account for all costs associated with a project without double-counting costs. If you have two separate trip reports that are associated with a single trip in one program, apportion costs between the trips so that you do not double-count the costs.

6.2 Professional Mentor/Technical Lead Hours – For professional service hours, report the hours spent working directly on project work by each Professional Mentor (student chapters) or Technical Lead (professional chapters), calculated at $100/hour. Hours should be counted only for this trip, not for time spent working on the life cycle of the project.

7.0 Project Discipline(s) – The headings in bold are project types, the subheadings are project disciplines. Check all project disciplines addressed in this report. Note that each project type needs to be approved by an EWB-USA Project Manager. If this is a new project that has not previously been approved, your chapter may need to submit a 501B – New Project Within Existing Program Application.

8.0 Project Location – Provide the latitude and longitude of the project location so that the project site can be located using Google Earth.

## Part 2: Technical Information - Instructions

1.0 Executive Summary - Each 531 Post-Monitoring Trip MUST include an executive summary. The executive summary should be two pages long at most. It should be carefully reviewed by your mentor, technical lead and/or faculty advisor. Paragraph 1: Summarize the following trip details - chapter name, project name, project number, travel dates, type of trip. Use a second sentence to clarify any other details of the trip such that are pertinent to understanding the trip. Paragraph 2: State the scope and goal of the project. Paragraph 3: Provide information about the community and NGO. Reference the status of the Memorandum of Understanding. Paragraph 4: Provide background for the program. When did the program start, how many other projects are included in this program. Provide background for the project including a short description of the number and type of previous trips. Paragraph 5: Summarize the specific tasks that were carried out on this trip. Paragraph 6: Summarize the data that were gathered on the trip. Paragraph 7: State clearly whether you now plan to close the program. Paragraph 8: Additional information to clarify the trip (if needed). **The document must include an executive summary. If the executive summary is not included, the document will be considered deficient and will be rejected. The chapter will be required to resubmit the document for review during a later TAC cycle.**

2.0 Introduction – Explain the purpose of the document and clearly list the project and components being addressed in this report. If the project and components being presented in this document are a subset of a larger community program please explain this in the introduction.

3.0 Program Background – Provide the background of the project including a summary of information contained in previous documents for this project. This is an update of the same section in the 530 – Pre-Monitoring Report.

4.0 Project Description – Provide a general description of the project that is the focus of this report. The description should be brief without going into the details of the design. The description should also include a goal statement that is clearly linked to the community-identified needs that the project is attempting to address. Include here or in an appendix any relevant mapping that has been developed for the program.

5.0 Trip Description – Provide a concise description of the trip sufficient for anyone who had not participated on the trip to understand what happened on the trip.

6.0 Community Information

6.1 Description of the Community – Describe the community. This can be based upon the same section of the report in the post implementation document but updated with information gathered during the monitoring trip.

6.2 Community Relations – Describe the relationship with the community during this monitoring phase of the project. Include names of key contributors. Discuss any misunderstandings between your team and the community and how you worked through any challenges. Assess the sense of ownership of the community and include their plans for continued operation and maintenance of the implemented project.

7.0 Monitoring Approach

7.1 Project monitoring methods: For each project, state the three metrics your team previously identified to measure the impact of your project(s) on the community. Include all data, both quantitative and qualitative, that were used to measure the success of your project(s). Also provide details on the methods used for data collection.

7.2 Monitoring of past-implemented projects: Provide supporting information as instructed below to clarify the status of each project listed in Section 5.0, Part 1.0 of this document.

7.2.1 Functionality Status Supporting Information – For each project, provide details about why the project is or is not functioning as designed.

7.2.2 Periodic Maintenance Supporting Information – For each project, list examples of observable evidence that maintenance is being provided by the community.

7.2.3 Demonstration of Knowledge Transfer Supporting Information – For each project, list examples of observable evidence that the knowledge on operating and maintaining the facility has been successfully transferred to the community.

7.3 Resolution of technical problems – For each project, provide a description of any issues identified through communication with the community after construction was completed. Discuss your plans to address the outstanding issues if the community or partnering organization/NGO is not addressing them directly. Include in this discussion your timeline for submitting to the Technical Advisory Committee your design revisions and plans to return to implement the modifications/repairs.

7.4 Capacity and financial assessment – Provide a detailed description of how the implemented infrastructure is managed and financially supported by the community. Provide the results of your evaluation of the performance of the managing group based on your pre-established criteria. Include a detailed description of any changes in the trainings that you developed to improve technical and non-technical capacity.

8.0 Community Agreement/Contract – Provide an English version of the agreement/contract that your team has developed with the community leadership even if your team has submitted this with previous reports. This agreement/contract should include responsibilities relating to community ownership and funding mechanisms for maintenance into the future. If you have previously submitted this agreement/contract, please indicate when it was submitted and refer to it in this section. If this is not available, please explain why not.

9.0 Photo Documentation – Provide a few photographs of relevant parts of the project along with a description for the photograph. Additional photos taken during the project along with a photo log can be included in an appendix.

10.0 Lessons Learned – Provide a list of the lessons learned during this trip. The purpose of this section is to help the chapter in their future trips and also assist other EWB-USA chapters that may read this document. Please use the following format for your lessons learned: One or two word subject (such as travel, health and safety or community engagement) followed by a one sentence summary of the lesson. A more complete description can then be provided if desired. Although the types of lessons learned will vary from trip to trip, please be sure to always include at least one lesson learned relating to health and safety.

11.0 Project Status – To determine the project status consider whether or not additional implementation is required, if the remaining work is only monitoring and/or if the project can be closed as sufficient maintenance is being performed.

Implementation Continues – Select this option if the implementation work is not complete and additional construction work is required to complete the project.

Monitoring – Select this option if the implementation work is complete and the next trip will be to continue to monitor this project.

Complete – Select this option if the chapter has completed a monitoring trip **at least one year after the completion** of the project implementation and if the project is being maintained at that time by the community. Selection of complete indicates that no further construction, repairs or monitoring is required for this project.

12.0 Next Phase of Program – Provide a brief description of the next phase of the program in this community. Include anticipated future travel dates.

13.0 Mentor Assessment – You should discuss the requirement in this section with your Professional Mentor/Technical Lead ahead of time to accommodate their schedule in anticipating the submittal deadline. This section is required for review.

13.1 Professional Mentor/Technical Lead Name – Type the name of the Professional Mentor/Technical Lead who is writing this assessment.

13.2 Professional Mentor/Technical Lead Assessment - The Professional Mentor (for student chapters) or Technical Lead (for professional chapters) should write a short assessment of how the current report came together, and where the project is currently at. The mentor should include overview information here that the chapter may have missed because they were simply following the outline given in the document, without looking at it from a broad, high level perspective. This assessment can include lessons learned, successes, and steps forward for the chapter and the project.

13.3 Professional Mentor/Technical Lead – The mentor should write one sentence here acknowledging their involvement in the monitoring phase and their acceptance of responsibility for the course that the project is taking.

# Appendix B – Microbial Water Sampling Plan

Water Sampling Plan for Ecuador
Travel Dates: Aug 8-27 & Oct 1-6, 2012
Prepared by: Gabrielle String

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**Microbiological Indicator Testing**
Location: La Margarita, El Cristal
Procedure: Membrane Filtration Testing

Description - This sampling procedure will be used for enumeration of total coliform and *E. coli*.

Quality Control Measures – duplicate sampling of all samples and blank sampling every 20th sample

Equipment
- Petri dishes
- Filtration apparatus
- Carbon Fritt
- Pipettes
- Tweezers
- Incubator
- Thermometer
- Magnifying glass
- Cooler
- Data Sheet

Consumables
- Plastic trash bags
- Candle and matches
- Alcohol – isopropyl and hand
- Paper towels
- Ice
- WhirlPak Bags
- Sterile dilution water
- Filters
- Millipore mColiBlue24 media
- Funnels

Sampling Locations

*La Margarita*

75 houses in community
1 pre- and 1 post-filter per house
= 150 baseline samples

8 blank samples
150 duplicate samples
10 samples to check dilution
= 170 quality control samples

*Total: 320 samples*

*El Cristal*

7 source water (1 collected / day)
7 filter water (1 collected / day)
100 household taps
= 115 baseline samples

7 blank samples
115 duplicate samples
10 samples to check dilution
= 135 quality control samples

*Total: 250 samples*

Procedures

Sample Collection

1. Remove WhirlPak sampling bag from larger sealed bag
2. Label WhirlPak bag with date, time, and sample ID # in permanent marker
3. Wash hands with hand alcohol
4. Open WhirlPak bag ***without*** touching the lip of the bag
5. Fill WhirlPak bag with sample without touching anything to the lip of the bag
6. Place WhirlPak bag upright in cooler with ice
7. Must complete analysis within 8 hours of collection

Sample Preparation

1. Wash hands with hand alcohol
2. Place new garbage bag on sampling surface and wipe with isopropyl alcohol
3. Set up filtration apparatus and light candle
4. Remove WhirlPak bags from cooler
5. Wipe down outside of WhirlPak bags with alcohol soaked paper towel ***before*** placing on garbage bag to prevent cross contamination
6. Label disposable petri dishes with date and time of analysis, dilution factor, and sample ID # in permanent marker
7. Arrange lab space with samples and petri dishes lined up ahead of time
8. Complete analysis of each sample
    a. Sterilize tweezers in candle then pick up and sterilize carbon fritt in candle
    b. Sterilize tweezers in candle, open new filter package by pulling away wrapping without the use of hands
        i. Filter must be discarded if touched
    c. Using the tweezers, carefully center the filter on the filtration apparatus
    d. Place new disposable funnel on top of filter and apparatus
    e. Carefully pour sample from WhilrPak into the funnel without touching the bag to the funnel. Close and set aside the rest of the sample for future use.
    f. Some samples will need to be diluted because the concentration of bacteria is too high to count on the filter.
        i. Run multiple dilutions at the beginning of the sampling process in order to 'learn' the local contamination situation
            1. As dilutions are learned over the days of sampling the number of dilutions can be reduced.
            2. Ideally there are 20-80 colonies per plate, thought up to 200 is acceptable
        ii. NEED DILUTION METHOD
    g. Use a pipette and a pipette to add sample to the funnel, then fill the funnel with buffered dilution water to at least 20 mL in order to not concentrate the bacteria in one portion of the filter

h. Filter sample, expelling the wastewater into a bucket or on the ground
i. Open media packet and pour entire packet into petri dish taking care to cover the entire pad with media.
j. Sterilize tweezers, remove filter funnel from apparatus and discard, pick up filter by the edge with tweezers and place in corresponding petri dish.  Avoid air bubbles under the filter

9. Incubate samples for 24 hours
10. Total coliform colonies appear as red and *E. coli* colonies appear as blue. A maximum of 200 colonies should be present. Manually count and record the colonies on a data sheet.

# Appendix C – Chlorine Test Methods

## Free or Total Chlorine Test, 0–3.4 mg/L $Cl_2$

**For Test Kits 223101 (CN-66), 223102 (CN-66F) and 223103 (CN-66T)** DOC326.98.00008

***Note:*** *This product has not been evaluated to test for chlorine and chloramines in medical applications in the United States.*

**Additional copies available on www.hach.com**

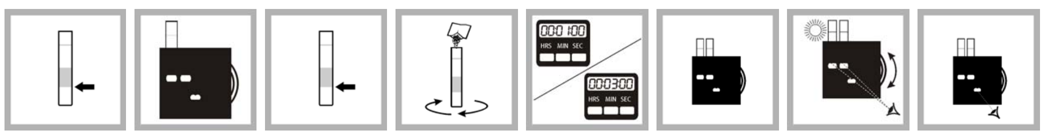
***NOTE: Smallest increment is 0.1 mg/L. See step 7 below for reading instructions.***

### Test preparation

- Assemble the color comparator by placing the color disc on the center pin with the lettering facing out.
- Rinse vials with the sample water before testing. Rinse with deionized water after testing.
- Accuracy is not affected by undissolved powder.
- Monochloramine causes a gradual drift of free chlorine readings to higher values. Read immediately after the addition of the free chlorine reagent. At 3.0 mg/L monochloramine, a 0.1 mg/L increase in the reading will be obtained after 1 minute.
- Read the mg/L chlorine at the matching disc segment or as the value halfway between the two segments closest in color.
- If the disc becomes wet, carefully separate the two halves of the plastic case and dry them and the colored plastic insert with a soft cloth. Reassemble when the parts are completely dry.

***CAUTION: Handle chemical standards and reagents carefully. Review Material Safety Data Sheets before handling chemicals.***

### Free or total chlorine test procedure




**1.** Fill a tube to the first (5-mL) line with sample.

**2.** Insert the tube into the left opening of the comparator.

**3.** Fill another tube to the first (5-mL) line with sample.

**4.** If testing free chlorine, add one DPD Free Chlorine Reagent Powder Pillow to the second tube. Swirl to mix.

If testing total chlorine, add one DPD Total Chlorine Reagent Powder Pillow to the second tube. Swirl to mix.

***Note:*** *If testing free chlorine, complete the test and read the result within one minute of adding the reagent.*

***Note:*** *If testing total chlorine, read the test result after three minutes but before six minutes after adding the reagent.*

**5.** Insert the second tube into the right opening of the comparator.

**6.** Hold the comparator so that daylight or a fluorescent light source is directly behind the tubes. Rotate the color disc until the colors in the front windows match. The best match might occur between two color segments.

**7.** Read the result in mg/L in the scale window. If the best match occurs between two color segments, determine the value halfway between the two printed numbers.

### Replacement items

| Description | Unit | Catalog no. |
|---|---|---|
| Color Comparator Box | each | 173200 |
| Color Disc, DPD Chlorine, 0–3.4 mg/L | each | 990200 |
| Color Viewing Tube, plastic, with cap | 4/pkg | 4660004 |
| DPD Free Chlorine Reagent Powder Pillows | 100/pkg | 1407799 |
| DPD Total Chlorine Reagent Powder Pillows | 100/pkg | 1407699 |

### Optional items

| Description | Unit | Catalog no. |
|---|---|---|
| Caps, for plastic viewing tubes 4660004 | 4/pkg | 4660014 |
| Color Viewing Tube, glass | 6/pkg | 173006 |
| Stoppers, for glass viewing tubes 173006 | 6/pkg | 173106 |
| Deionized Water | 500 mL | 27249 |

 For technical assistance or ordering information: visit www.hach.com, call 800-227-4224 or email techhelp@hach.com

03/2013 Edition 3

# Chlorine, Free

DOC316.53.01023

**USEPA DPD Method[1]** **Method 8021**

**0.02 to 2.00 mg/L $Cl_2$** **Powder Pillows or AccuVac® Ampuls**

**Scope and application:** For testing free chlorine (hypochlorous acid and hypochlorite ion) in water, treated waters, estuary and seawater. USEPA accepted for reporting for drinking water analyses.[2] This product has not been evaluated to test for chlorine and chloramines in medical applications in the United States.

[1] Adapted from Standard Methods for the Examination of Water and Wastewater.
[2] Procedure is equivalent to USEPA and Standard Method 4500-Cl G for drinking water.

## Test preparation

### Instrument-specific information

The tables in this section show all of the instruments that have the program for this test. Table 1 shows sample cell and orientation requirements for reagent addition tests, such as powder pillow or bulk reagent tests. Table 2 shows sample cell and adapter requirements for AccuVac Ampul tests.

To use either table, select an instrument, then read across to find the corresponding information for this test.

**Table 1 Instrument-specific information for powder pillows**

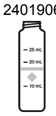
| Instrument | Sample cell orientation | Sample cell |
|---|---|---|
| DR 6000<br>DR 3800<br>DR 2800<br>DR 2700 | The fill line is to the right. | 2495402  |
| DR 5000<br>DR 3900 | The fill line is toward the user. | |
| DR 900 | The orientation mark is toward the user. | 2401906  |

**Table 2 Instrument-specific information for AccuVac Ampuls**

| Instrument | Adapter | Sample cell |
|---|---|---|
| DR 6000<br>DR 5000<br>DR 900 | — | 2427606  |
| DR 3900 | LZV846 (A) | |
| DR 3800<br>DR 2800<br>DR 2700 | LZV584 (C) | 2122800  |

## Before starting

| |
|---|
| Samples must be analyzed immediately after collection and cannot be preserved for later analysis. |
| Install the instrument cap on the DR 900 cell holder before ZERO or READ is pushed. |
| Do not use the same sample cells for free and total chlorine. If trace iodide from the total chlorine reagent is carried over into the free chlorine determination, monochloramine will interfere. It is best to use separate, dedicated sample cells for free and total chlorine measurements. |
| If the test result is over-range, or if the sample temporarily turns yellow after the reagent addition, dilute the sample with a known volume of high quality, chlorine demand-free water and repeat the test. Some loss of chlorine may occur due to the dilution. Multiply the result by the dilution factor. Additional methods are available to measure chlorine without dilution. |
| For best results, measure the reagent blank value for each new lot of reagent. Replace the sample with deionized water in the test procedure to get the reagent blank value. Subtract the reagent blank value from the sample results automatically with the reagent blank adjust option. |
| An AccuVac Ampule for Blanks can be used to zero the instrument in the AccuVac test procedure. |
| Review the Safety Data Sheets (MSDS/SDS) for the chemicals that are used and use any recommended personal protective equipment. |
| Dispose of reacted solutions according to local, state and federal regulations. Use the Safety Data Sheets for disposal information for unused reagents. Consult the environmental, health and safety staff for your facility and/or local regulatory agencies for further disposal information. |
| The SwifTest Dispenser for Free Chlorine can be used in place of the powder pillow in the test procedure. |

## Items to collect

### Powder pillows

| Description | Quantity |
|---|---|
| DPD Free Chlorine Reagent Powder Pillows, 10-mL | 1 |
| Sample cells. (For information about sample cells, adapters or light shields, refer to Instrument-specific information on page 1.) | 2 |

Refer to Consumables and replacement items on page 6 for reorder information.

### AccuVac Ampuls

| Description | Quantity |
|---|---|
| DPD Free Chlorine Reagent AccuVac Ampuls | 1 |
| Beaker, 50-mL | 1 |
| Sample cells (For information about sample cells, adapters or light shields, refer to Instrument-specific information on page 1.) | 1 |
| Stopper for 18-mm tubes and AccuVac Ampuls | 1 |

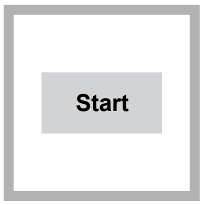
Refer to Consumables and replacement items on page 6 for reorder information.

## Sample collection

- Samples must be analyzed immediately and cannot be preserved for later analysis.
- Chlorine is a strong oxidizing agent and it is unstable in natural waters. It reacts quickly with various inorganic compounds and more slowly with organic compounds. Many factors, including reactant concentrations, sunlight, pH, temperature and salinity influence the decomposition of chlorine in water.
- Collect samples in clean glass bottles. Avoid plastic containers since these may have a large chlorine demand.

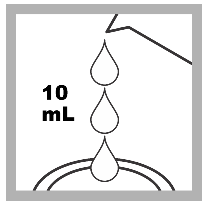
- Pre-treat glass sample containers to remove any chlorine demand. Soak the containers in a dilute bleach solution (1 mL commercial bleach to 1 liter of deionized water) for at least 1 hour. Rinse thoroughly with deionized or distilled water. If sample containers are rinsed thoroughly with deionized or distilled water after use, only occasional pre-treatment is necessary.
- Be sure to get a representative sample. If the sample is taken from a spigot or faucet, let the water flow for at least 5 minutes. Then let the container overflow with the sample several times and then put the cap on the sample container so that there is no headspace (air) above the sample. If a sample cell is used, rinse the cell several times with the sample, then carefully fill to the 10-mL mark.

### Powder pillow procedure

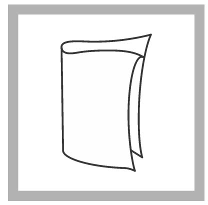



**1.** Start program **80 Chlorine F&T PP**. For information about sample cells, adapters or light shields, refer to Instrument-specific information on page 1.

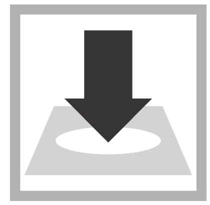
***Note:** Although the program name may vary between instruments, the program number does not change.*



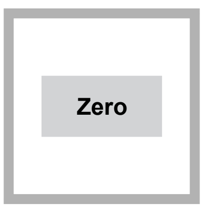

**2. Prepare the blank:** Fill the sample cell with 10 mL of sample.



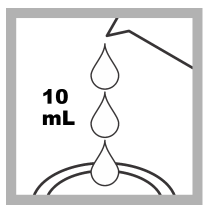
**3.** Clean the prepared sample.



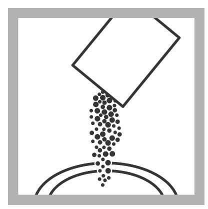
**4.** Insert the blank into the cell holder.



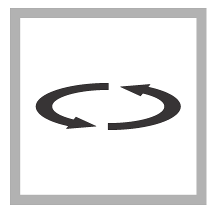

**5.** Push **ZERO**. The display shows 0.00 mg/L.



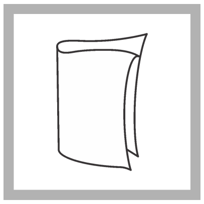

**6. Prepare the sample:** Fill a second sample cell with 10 mL of sample.



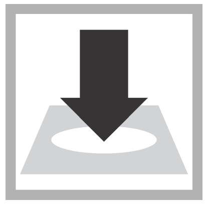
**7.** Add the contents of one powder pillow to the sample cell.



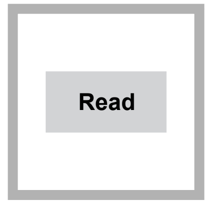
**8.** Swirl the sample cell for 20 seconds to mix.
A pink color will develop if chlorine is present. Proceed to the next step immediately.



**9.** Clean the prepared sample.

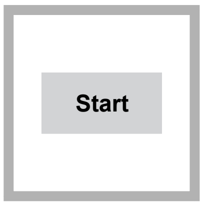


**10.** Within 60 seconds of adding the reagent, insert the prepared sample into the cell holder.



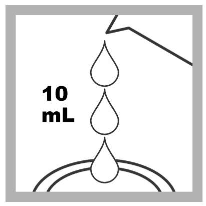

**11.** Push **READ**. Results show in mg/L $Cl_2$.

### AccuVac Ampul procedure

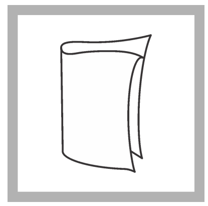



**1.** Start program **85 Chlorine F&T AV**. For information about sample cells, adapters or light shields, refer to Instrument-specific information on page 1.

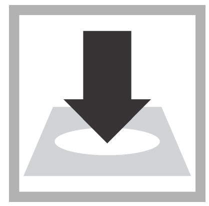
***Note:** Although the program name may vary between instruments, the program number does not change.*



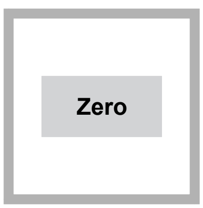

**2. Prepare the blank:** Fill the sample cell with 10 mL of sample.



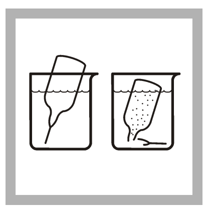
**3.** Clean the blank.



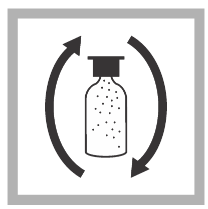
**4.** Insert the blank into the cell holder.



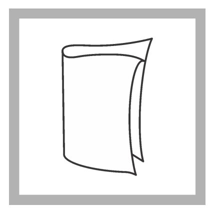

**5.** Push **ZERO**. The display shows 0.00 mg/L.



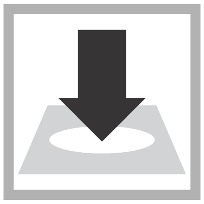
**6. Prepare the sample:** Collect at least 40 mL of sample in a 50-mL beaker. Fill the AccuVac Ampul with sample. Keep the tip immersed while the Ampul fills completely.

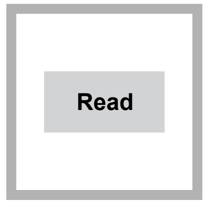


**7.** Quickly invert the Ampul several times to mix.



**8.** Clean the AccuVac Ampul.






**9.** Within 60 seconds of adding the reagent, insert the prepared sample AccuVac Ampul into the cell holder.

**10.** Push **READ**. Results show in mg/L $Cl_2$.

## Interferences

| Interfering substance | Interference level |
|---|---|
| Acidity | More than 150 mg/L $CaCO_3$. The full color may not develop or the color may fade instantly. Adjust to pH 6–7 with 1 N Sodium Hydroxide. Measure the amount to be added on a separate sample aliquot, then add the same amount to the sample that is tested. Correct the test result for the dilution from the volume addition. |
| Alkalinity | More than 250 mg/L $CaCO_3$. The full color may not develop or the color may fade instantly. Adjust to pH 6–7 with 1 N Sulfuric Acid. Measure the amount to add on a separate sample aliquot, then add the same amount to the sample that is tested. Correct the test result for the dilution from the volume addition. |
| Bromine, $Br_2$ | Interferes at all levels |
| Chlorine Dioxide, $ClO_2$ | Interferes at all levels |
| Chloramines, organic | May interfere |
| Hardness | No effect at less than 1000 mg/L as $CaCO_3$ |
| Iodine, $I_2$ | Interferes at all levels |
| Manganese, Oxidized ($Mn^{4+}$, $Mn^{7+}$) or Chromium, Oxidized ($Cr^{6+}$) | Pre-treat the sample as follows:<br>**1.** Adjust the sample pH to 6–7.<br>**2.** Add 3 drops of Potassium Iodide (30-g/L) to 10 mL of sample.<br>**3.** Mix and wait 1 minute.<br>**4.** Add 3 drops of Sodium Arsenite (5-g/L) and mix.<br>**5.** Use the test procedure to measure the concentration of the treated sample.<br>**6.** Subtract this result from the result without the treatment to obtain the correct chlorine concentration. |
| Monochloramine | Causes a gradual drift to higher readings. When read within 1 minute after reagent addition, 3 mg/L monochloramine causes less than a 0.1 mg/L increase in the reading. |
| Ozone | Interferes at all levels |
| Peroxides | May interfere |
| Highly buffered samples or extreme sample pH | Can prevent the correct pH adjustment of the sample by the reagents. Sample pretreatment may be necessary. Adjust to pH 6–7 with acid (Sulfuric Acid, 1.000 N) or base (Sodium Hydroxide, 1.00 N). |

## Pollution prevention and waste management

If sodium arsenite was added to the sample for manganese or chromium interferences, the reacted samples will contain arsenic and must be disposed of as a hazardous waste. Dispose of reacted solutions according to local, state and federal regulations.

## Accuracy check

#### Standard additions method (sample spike)

Use the standard additions method (for applicable instruments) to validate the test procedure, reagents and instrument and to find if there is an interference in the sample.

Items to collect:

- Chlorine Standard Solution, 2-mL PourRite® Ampule, 25–30 mg/L (use mg/L on label)
- Breaker, PourRite Ampules
- Pipet, TenSette®, 0.1–1.0 mL and tips

1. Use the test procedure to measure the concentration of the sample, then keep the (unspiked) sample in the instrument.
2. Go to the Standard Additions option in the instrument menu.
3. Select the values for standard concentration, sample volume and spike volumes.
4. Open the standard solution.
5. Prepare three spiked samples: use the TenSette pipet to add 0.1 mL, 0.2 mL and 0.3 mL of the standard solution, respectively, to three 10-mL portions of fresh sample. Mix well.
   ***Note:** For AccuVac® Ampuls, add 0.4 mL, 0.8 mL and 1.2 mL of the standard solution to three 50-mL portions of fresh sample.*
6. Use the test procedure to measure the concentration of each of the spiked samples. Start with the smallest sample spike. Measure each of the spiked samples in the instrument.
7. Select **Graph** to compare the expected results to the actual results.
   ***Note:** If the actual results are significantly different from the expected results, make sure that the sample volumes and sample spikes are measured accurately. The sample volumes and sample spikes that are used should agree with the selections in the standard additions menu. If the results are not within acceptable limits, the sample may contain an interference.*

## Method performance

The method performance data that follows was derived from laboratory tests that were measured on a spectrophotometer during ideal test conditions. Users may get different results under different test conditions.

| Program | Standard | Precision (95% Confidence Interval) | Sensitivity<br>Concentration change per 0.010 Abs change |
|---|---|---|---|
| 80 | 1.25 mg/L $Cl_2$ | 1.23–1.27 mg/L $Cl_2$ | 0.02 mg/L $Cl_2$ |
| 85 | 1.25 mg/L $Cl_2$ | 1.21–1.29 mg/L $Cl_2$ | 0.02 mg/L $Cl_2$ |

## Summary of method

Chlorine in the sample as hypochlorous acid or hypochlorite ion (free chlorine or free available chlorine) immediately reacts with DPD (N,N-diethyl-p-phenylenediamine) indicator to form a pink color, the intensity of which is proportional to the chlorine concentration. The measurement wavelength is 530 nm for spectrophotometers or 520 nm for colorimeters.

## Consumables and replacement items

#### Required reagents

| Description | Quantity/Test | Unit | Item no. |
|---|---|---|---|
| DPD Free Chlorine Reagent Powder Pillow, 10-mL | 1 | 100/pkg | 2105569 |
| OR | | | |
| DPD Free Chlorine Reagent AccuVac® Ampul | 1 | 25/pkg | 2502025 |

### Required apparatus

| Description | Quantity/Test | Unit | Item no. |
|---|---|---|---|
| AccuVac Snapper | 1 | each | 2405200 |
| Beaker, 50-mL | 1 | each | 50041H |
| Stoppers for 18-mm tubes and AccuVac Ampuls | 2 | 6/pkg | 173106 |

### Recommended standards

| Description | Unit | Item no. |
|---|---|---|
| Chlorine Standard Solution, 2-mL PourRite® Ampules, 25–30 mg/L | 20/pkg | 2630020 |

### Optional reagents and apparatus

| Description | Unit | Item no. |
|---|---|---|
| AccuVac® vials for sample blanks | 25/pkg | 2677925 |
| Ampule Breaker, PourRite® ampules | each | 2484600 |
| Ampule Breaker, Voluette® ampules | each | 2196800 |
| Water, Chlorine-demand Free | 500 mL | 2641549 |
| Cylinder, mixing, 25-mL | each | 2088640 |
| Cylinder, mixing, 50-mL | each | 189641 |
| Chlorine Standard Solution, 2-mL PourRite® Ampules, 50–75 mg/L | 20/pkg | 1426820 |
| Chlorine Standard Solution, 10-mL Voluette® Ampule, 50–75 mg/L | 16/pkg | 1426810 |
| DPD Free Chlorine Reagent Powder Pillows, 10-mL | 1000/pkg | 2105528 |
| DPD Free Chlorine Reagent Powder Pillows, 10-mL | 300/pkg | 2105503 |
| DPD Free Chlorine Reagent, 10 mL, SwifTest™ Dispenser refill vial | 250 tests | 2105560 |
| Paper, pH, 0–14 pH range | 100/pkg | 2601300 |
| Pipet, TenSette®, 0.1–1.0 mL | each | 1970001 |
| Pipet tips for TenSette Pipet 1970001 | 50/pkg | 2185696 |
| Pipet tips for TenSette Pipet 1970001 | 1000/pkg | 2185628 |
| Potassium Iodide, 30 g/L | 100 mL | 34332 |
| Sodium Arsenite, 5 g/L | 100 mL | 104732 |
| Sodium Hydroxide Standard Solution, 1.0 N | 100 mL MDB | 104532 |
| SpecCheck™ Secondary Standard Kit, Chlorine DPD, 0-2.0 mg/L Set | each | 2635300 |
| Sulfuric Acid Standard Solution, 1 N | 100 mL MDB | 127032 |

# Chlorine, Total

DOC316.53.01027

**USEPA DPD Method[1]** **Method 8167**

**0.02 to 2.00 mg/L $Cl_2$** **Powder Pillows or AccuVac® Ampuls**

**Scope and application:** For testing residual chlorine and chloramines in water, wastewater, estuary water and seawater; USEPA-accepted for reporting for drinking and wastewater analyses.[2] This product has not been evaluated to test for chlorine and chloramines in medical applications in the United States.

[1] Adapted from Standard Methods for the Examination of Water and Wastewater.
[2] Procedure is equivalent to USEPA and Standard Method 4500-Cl G for drinking water and wastewater analysis.

## Test preparation

### Instrument-specific information

The tables in this section show all of the instruments that have the program for this test. Table 1 shows sample cell and orientation requirements for reagent addition tests, such as powder pillow or bulk reagent tests. Table 2 shows sample cell and adapter requirements for AccuVac Ampul tests.

To use either table, select an instrument, then read across to find the corresponding information for this test.

**Table 1 Instrument-specific information for powder pillows**

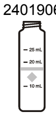
| Instrument | Sample cell orientation | Sample cell |
|---|---|---|
| DR 6000<br>DR 3800<br>DR 2800<br>DR 2700 | The fill line is to the right. | 2495402<br> |
| DR 5000<br>DR 3900 | The fill line is toward the user. | |
| DR 900 | The orientation mark is toward the user. | 2401906<br> |

**Table 2 Instrument-specific information for AccuVac Ampuls**

| Instrument | Adapter | Sample cell |
|---|---|---|
| DR 6000<br>DR 5000<br>DR 900 | — | 2427606<br> |
| DR 3900 | LZV846 (A) | |
| DR 3800<br>DR 2800<br>DR 2700 | LZV584 (C) | 2122800<br> |

## Before starting

| |
|---|
| Samples must be analyzed immediately after collection and cannot be preserved for later analysis. |
| Install the instrument cap on the DR 900 cell holder before ZERO or READ is pushed. |
| If the test result is over-range, or if the sample temporarily turns yellow after the reagent addition, dilute the sample with a known volume of high quality, chlorine demand-free water and repeat the test. Some loss of chlorine may occur due to the dilution. Multiply the result by the dilution factor. Additional methods are available to measure chlorine without dilution. |
| For chloramination disinfection control, use one of the available Chloramine (Mono) methods. |
| For best results, measure the reagent blank value for each new lot of reagent. Replace the sample with deionized water in the test procedure to get the reagent blank value. Subtract the reagent blank value from the sample results automatically with the reagent blank adjust option. |
| Review the Safety Data Sheets (MSDS/SDS) for the chemicals that are used and use any recommended personal protective equipment. |
| Dispose of reacted solutions according to local, state and federal regulations. Use the Safety Data Sheets for disposal information for unused reagents. Consult the environmental, health and safety staff for your facility and/or local regulatory agencies for further disposal information. |
| The SwifTest Dispenser for Total Chlorine can be used in place of the powder pillow in the test procedure. |
| An AccuVac Ampule for Blanks can be used to zero the instrument in the AccuVac test procedure. |

## Items to collect

### Powder pillows

| Description | Quantity |
|---|---|
| DPD Total Chlorine Reagent Powder Pillow, 10-mL | 1 |
| Sample cells. (For information about sample cells, adapters or light shields, refer to Instrument-specific information on page 1.) | 2 |

Refer to Consumables and replacement items on page 7 for reorder information.

### AccuVac Ampuls

| Description | Quantity |
|---|---|
| DPD Total Chlorine Reagent AccuVac® Ampul | 1 |
| Beaker, 50-mL | 1 |
| Sample cells (For information about sample cells, adapters or light shields, refer to Instrument-specific information on page 1.) | 1 |
| Stopper for 18-mm tubes and AccuVac Ampuls | 1 |

Refer to Consumables and replacement items on page 7 for reorder information.

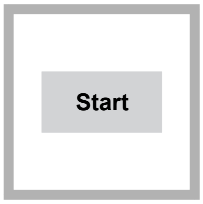
## Sample collection

- Samples must be analyzed immediately and cannot be preserved for later analysis.
- Chlorine is a strong oxidizing agent and it is unstable in natural waters. It reacts quickly with various inorganic compounds and more slowly with organic compounds. Many factors, including reactant concentrations, sunlight, pH, temperature and salinity influence the decomposition of chlorine in water.
- Collect samples in clean glass bottles. Avoid plastic containers since these may have a large chlorine demand.
- Pre-treat glass sample containers to remove any chlorine demand. Soak the containers in a dilute bleach solution (1 mL commercial bleach to 1 liter of deionized water) for at least 1 hour. Rinse thoroughly with deionized or distilled water. If sample

containers are rinsed thoroughly with deionized or distilled water after use, only occasional pre-treatment is necessary.

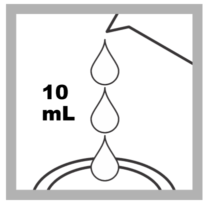
- Be sure to get a representative sample. If the sample is taken from a spigot or faucet, let the water flow for at least 5 minutes. Then let the container overflow with the sample several times and then put the cap on the sample container so that there is no headspace (air) above the sample. If a sample cell is used, rinse the cell several times with the sample, then carefully fill to the 10-mL mark.

### Powder pillow procedure



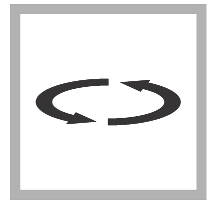

**1.** Start program **80 Chlorine F&T PP**. For information about sample cells, adapters or light shields, refer to Instrument-specific information on page 1.

***Note:*** *Although the program name may vary between instruments, the program number does not change.*




**2.** Fill a sample cell with 10 mL of sample.

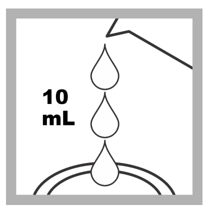
**3. Prepare the sample:** Add the contents of one powder pillow to the sample cell.



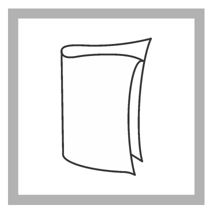
**4.** Swirl the sample cell for 20 seconds to mix. A pink color shows if chlorine is present in the sample.


**5.** Start the instrument timer. A 3-minute reaction time starts.

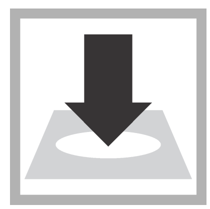
Prepare the sample blank and set the instrument to zero during the reaction time.



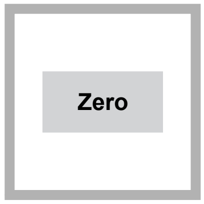

**6. Prepare the blank:** Fill a second sample cell with 10 mL of sample.



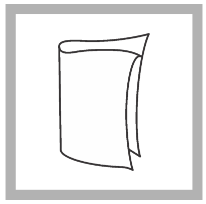
**7.** Clean the blank.



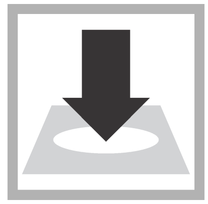
**8.** Insert the blank into the cell holder.



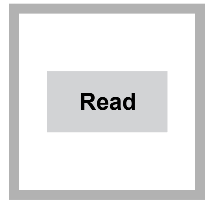

**9.** Push **ZERO**. The display shows 0.00 mg/L $Cl_2$.



**10.** Clean the prepared sample.

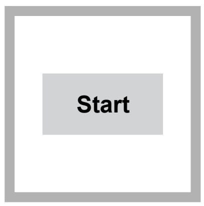


**11.** Within 3 minutes after the timer expires, insert the prepared sample into the cell holder.



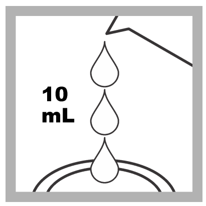

**12.** Push **READ**. Results show in mg/L $Cl_2$.

### AccuVac Ampul procedure

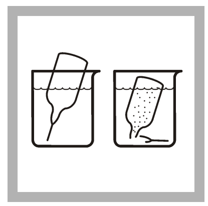



**1.** Start program **85 Chlorine F&T AV**. For information about sample cells, adapters or light shields, refer to Instrument-specific information on page 1.

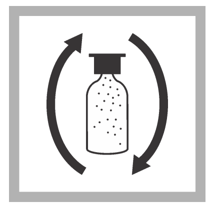
***Note:** Although the program name may vary between instruments, the program number does not change.*




**2. Prepare the blank:** Fill the sample cell with 10 mL of sample.



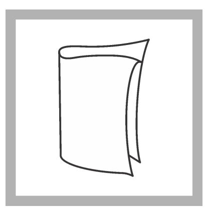
**3. Prepare the sample:** Collect at least 40 mL of sample in a 50-mL beaker. Fill the AccuVac Ampul with sample. Keep the tip immersed while the Ampul fills completely.



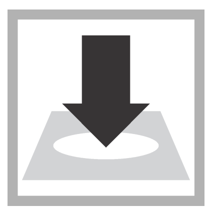
**4.** Quickly invert the Ampul several times to mix.


**5.** Start the instrument timer. A 3-minute reaction time starts.

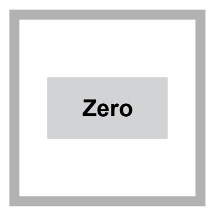
Prepare the sample blank and set the instrument to zero during the reaction time.



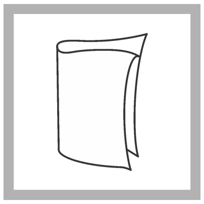
**6.** Clean the blank.



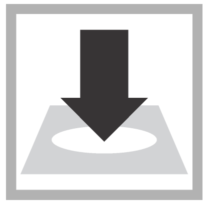
**7.** Insert the blank into the cell holder.



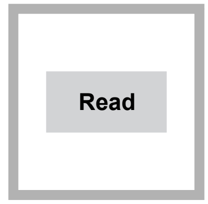

**8.** Push **ZERO**. The display shows 0.00 mg/L $Cl_2$.



**9.** Clean the AccuVac Ampul.



**10.** Within 3 minutes after the timer expires, insert the prepared sample AccuVac Ampul into the cell holder.




**11.** Push **READ**. Results show in mg/L $Cl_2$.

## Interferences

| Interfering substance | Interference level |
|---|---|
| Acidity | More than 150 mg/L $CaCO_3$. The full color may not develop or the color may fade instantly. Adjust to pH 6–7 with 1 N Sodium Hydroxide. Measure the amount to be added on a separate sample aliquot, then add the same amount to the sample that is tested. Correct the test result for the dilution from the volume addition. |
| Alkalinity | More than 250 mg/L $CaCO_3$. The full color may not develop or the color may fade instantly. Adjust to pH 6–7 with 1 N Sulfuric Acid. Measure the amount to add on a separate sample aliquot, then add the same amount to the sample that is tested. Correct the test result for the dilution from the volume addition. |
| Bromine, $Br_2$ | Interferes at all levels |
| Chlorine Dioxide, $ClO_2$ | Interferes at all levels |
| Chloramines, organic | May interfere |
| Hardness | No effect at less than 1000 mg/L as $CaCO_3$ |
| Iodine, $I_2$ | Interferes at all levels |
| Manganese, Oxidized ($Mn^{4+}$, $Mn^{7+}$) or Chromium, Oxidized ($Cr^{6+}$) | Pre-treat the sample as follows:<br>**1.** Adjust the sample pH to 6–7.<br>**2.** Add 3 drops of Potassium Iodide (30-g/L) to 10 mL of sample.<br>**3.** Mix and wait 1 minute.<br>**4.** Add 3 drops of Sodium Arsenite (5-g/L) and mix.<br>**5.** Use the test procedure to measure the concentration of the treated sample.<br>**6.** Subtract this result from the result without the treatment to obtain the correct chlorine concentration. |
| Ozone | Interferes at all levels |
| Peroxides | May interfere |
| Highly buffered samples or extreme sample pH | Can prevent the correct pH adjustment of the sample by the reagents. Sample pretreatment may be necessary. Adjust to pH 6–7 with acid (Sulfuric Acid, 1.000 N) or base (Sodium Hydroxide, 1.00 N). |

## Pollution prevention and waste management

If sodium arsenite was added to the sample for manganese or chromium interferences, the reacted samples will contain arsenic and must be disposed of as a hazardous waste. Dispose of reacted solutions according to local, state and federal regulations.

## Accuracy check

#### Standard additions method (sample spike)

Use the standard additions method (for applicable instruments) to validate the test procedure, reagents and instrument and to find if there is an interference in the sample.

Items to collect:

- Chlorine Standard Solution, 2-mL PourRite® Ampule, 25–30 mg/L (use mg/L on label)
- Breaker, PourRite Ampules
- Pipet, TenSette®, 0.1–1.0 mL and tips

1. Use the test procedure to measure the concentration of the sample, then keep the (unspiked) sample in the instrument.
2. Go to the Standard Additions option in the instrument menu.
3. Select the values for standard concentration, sample volume and spike volumes.
4. Open the standard solution.
5. Prepare three spiked samples: use the TenSette pipet to add 0.1 mL, 0.2 mL and 0.3 mL of the standard solution, respectively, to three 10-mL portions of fresh sample. Mix well.

   ***Note:** For AccuVac® Ampuls, add 0.4 mL, 0.8 mL and 1.2 mL of the standard solution to three 50-mL portions of fresh sample.*
6. Use the test procedure to measure the concentration of each of the spiked samples. Start with the smallest sample spike. Measure each of the spiked samples in the instrument.
7. Select **Graph** to compare the expected results to the actual results.

   ***Note:** If the actual results are significantly different from the expected results, make sure that the sample volumes and sample spikes are measured accurately. The sample volumes and sample spikes that are used should agree with the selections in the standard additions menu. If the results are not within acceptable limits, the sample may contain an interference.*

## Method performance

The method performance data that follows was derived from laboratory tests that were measured on a spectrophotometer during ideal test conditions. Users may get different results under different test conditions.

| Program | Standard | Precision (95% Confidence Interval) | Sensitivity<br>Concentration change per 0.010 Abs change |
|---|---|---|---|
| 80 | 1.25 mg/L $Cl_2$ | 1.23–1.27 mg/L $Cl_2$ | 0.02 mg/L $Cl_2$ |
| 85 | 1.25 mg/L $Cl_2$ | 1.21–1.29 mg/L $Cl_2$ | 0.02 mg/L $Cl_2$ |

## Summary of method

Chlorine can be present in water as free chlorine and as combined chlorine. Both forms can exist in the same water and be determined together as total chlorine. Free chlorine is present as hypochlorous acid and/or hypochlorite ion. Combined chlorine exists as monochloramine, dichloramine, nitrogen trichloride and other chloro derivatives. The combined chlorine oxidizes iodide in the reagent to iodine. The iodine and free chlorine react with DPD (N,N-diethyl-p-phenylenediamine) to form a pink color which is proportional to the total chlorine concentration.

To find the concentration of combined chlorine, run a free chlorine test and a total chlorine test. Subtract the results of the free chlorine test from the total chlorine test to obtain the combined chlorine concentration. The measurement wavelength is 530 nm for spectrophotometers or 520 nm for colorimeters.

## Consumables and replacement items

### Required reagents

| Description | Quantity/Test | Unit | Item no. |
|---|---|---|---|
| DPD Total Chlorine Reagent Powder Pillow, 10-mL | 1 | 100/pkg | 2105669 |
| OR | | | |
| DPD Total Chlorine Reagent AccuVac® Ampul | 1 | 25/pkg | 2503025 |

### Required apparatus

| Description | Quantity/Test | Unit | Item no. |
|---|---|---|---|
| AccuVac Snapper | 1 | each | 2405200 |
| Beaker, 50-mL | 1 | each | 50041H |
| Stoppers for 18-mm tubes and AccuVac Ampuls | 2 | 6/pkg | 173106 |

### Recommended standards

| Description | Unit | Item no. |
|---|---|---|
| Chlorine Standard Solution, 10-mL Voluette® Ampule, 50–75 mg/L | 16/pkg | 1426810 |
| Chlorine Standard Solution, 2-mL PourRite® Ampules, 50–75 mg/L | 20/pkg | 1426820 |
| Chlorine Standard Solution, 2-mL PourRite® Ampules, 25–30 mg/L | 20/pkg | 2630020 |

### Optional reagents and apparatus

| Description | Unit | Item no. |
|---|---|---|
| AccuVac® vials for sample blanks | 25/pkg | 2677925 |
| Ampule Breaker, PourRite® ampules | each | 2484600 |
| Ampule Breaker, Voluette® ampules | each | 2196800 |
| Water, Chlorine-demand Free | 500 mL | 2641549 |
| Cylinder, mixing, 25-mL | each | 2088640 |
| Cylinder, mixing, 50-mL | each | 189641 |
| Chlorine Standard Solution, 2-mL PourRite® Ampules, 50–75 mg/L | 20/pkg | 1426820 |
| Chlorine Standard Solution, 10-mL Voluette® Ampule, 50–75 mg/L | 16/pkg | 1426810 |
| DPD Total Chlorine Reagent Powder Pillows, 10-mL | 1000/pkg | 2105628 |
| DPD Total Chlorine Reagent Powder Pillows, 10-mL | 300/pkg | 2105603 |
| DPD Total Chlorine Reagent, 10 mL, SwifTest™ Dispenser refill vial | 250 tests | 2105660 |
| Paper, pH, 0–14 pH range | 100/pkg | 2601300 |
| Pipet, TenSette®, 0.1–1.0 mL | each | 1970001 |
| Pipet tips for TenSette Pipet 1970001 | 50/pkg | 2185696 |
| Pipet tips for TenSette Pipet 1970001 | 1000/pkg | 2185628 |
| Potassium Iodide, 30 g/L | 100 mL | 34332 |
| Sodium Arsenite, 5 g/L | 100 mL | 104732 |
| Sodium Hydroxide Standard Solution, 1.0 N | 100 mL MDB | 104532 |
| SpecCheck™ Secondary Standard Kit, Chlorine DPD, 0-2.0 mg/L Set | each | 2635300 |

# Appendix D – Turbidity Test Methods

LaMotte

## TURBIDITY IN WATER TEST KIT

**CODE 7519**

| QUANTITY | CONTENTS | CODE |
|---|---|---|
| 60 mL | Standard Turbidity Reagent | 7520-H |
| 2 | Turbidity Columns | 0835 |
| 1 | Brush, Test Tube | 0513 |
| 1 | Pipet, 0.5 mL, plastic, w/cap | 0369 |
| 1 | Rod, plastic, stirring | 1114 |

To order refill reagents or test kit components, use the specified code number.

WARNING! This set contains chemicals that may be harmful if misused. Read cautions on individual containers carefully. Not to be used by children except under adult supervision

### PROCEDURE

This test is performed by comparing the turbidity of a measured amount of the sample with an identical amount of turbidity-free water containing a measured amount of standardized turbidity reagent. The readings are made by looking down through the column of liquid at a black dot. If turbidity is present, it will interfere with the passage of light through the column of liquid. Small amounts of turbidity will cause a "blurring" of the black dot in the bottom of the tube. Large amounts of turbidity may provide sufficient "cloudiness" so that it is not possible to see the black dot when looking down through the column. Any color that may be present in the sample should be disregarded. This determination is concerned only with the haziness or cloudy nature of the sample.

1. Fill one Turbidity Column (0835) to the 50 mL line with the sample water. If the black dot on the bottom of the tube is not visible when looking down through the column of liquid, pour out a sufficient amount of the test sample so that the tube is filled to the 25 mL line.
2. Fill the second Turbidity Column (0835) with an amount of turbidity-free water that is equal to the amount of sample being measured. Distilled water is preferred; however, clear tap water may be used. This is the "clear water" tube.
3. Place the two tubes side by side and note the difference in clarity. If the black dot is equally clear in both tubes, the turbidity is zero. If the black dot in the sample tube is less clear, proceed to Step 4.
4. Shake the Standard Turbidity Reagent (7520) vigorously. Add 0.5 mL to the "clear water" tube. Use the stirring rod (1114) to stir contents of both tubes to equally distribute turbid particles. Check for amount of turbidity by looking down through the solution at the black dot. If the turbidity of the sample water is greater than that of the "clear water", continue to add Standard Turbidity Reagent in 0.5 mL increments to the "clear water" tube, mixing after each addition until the turbidity equals that of the sample. Record total amount of Standard Turbidity Reagent added.
5. Each 0.5 mL addition to the 50 mL size sample is equal to 5 Jackson Turbidity Units (JTUs). If a 25 mL sample size is used, each 0.5 mL addition of the Standard Turbidity Reagent is equal to 10 Jackson Turbidity Units (JTUs). See the table below. Rinse both tubes carefully after each determination.

**TURBITITY TEST RESULTS**

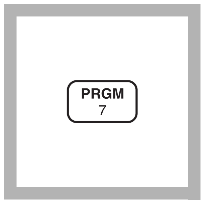
| Number of Measured Additions | Amount in mL | 50 mL Graduation | 25 mL Graduation |
|---|---|---|---|
| 1 | 0.5 | 5 JTU | 10 JTU |
| 2 | 1.0 | 10 JTU | 20 JTU |
| 3 | 1.5 | 15 JTU | 30 JTU |
| 4 | 2.0 | 20 JTU | 40 JTU |
| 5 | 2.5 | 25 JTU | 50 JTU |
| 6 | 3.0 | 30 JTU | 60 JTU |
| 7 | 3.5 | 35 JTU | 70 JTU |
| 8 | 4.0 | 40 JTU | 80 JTU |
| 9 | 4.5 | 45 JTU | 90 JTU |
| 10 | 5.0 | 50 JTU | 100 JTU |
| 15 | 7.5 | 75 JTU | 150 JTU |
| 20 | 10.0 | 100 JTU | 200 JTU |

**Method 8237**

# TURBIDITY (0 to 1000 FAU)

**For water, wastewater, and seawater**

## Absorptometric Method*



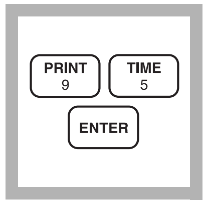

**1.** Enter the stored program number for turbidity.

Press: **PRGM**

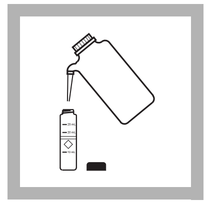
The display will show:

**PRGM ?**

***Note:***
*1 FAU=1 NTU=1 FTU when measuring formazin. These are not equivalent when measuring other types of standards or samples.*



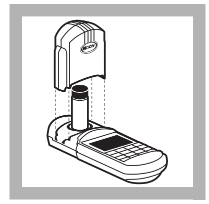

**2.** Press: **95 ENTER**
The display will show **FAU** and the **ZERO** icon.



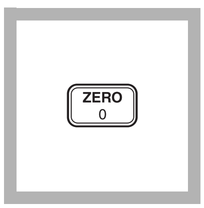
**3.** Fill a sample cell with 10 mL of deionized water (the blank).

***Note:*** *Wipe the surface of the cell with a soft cloth.*

***Note:*** *For highly colored samples, use a filtered portion of sample in place of the deionized water.*



**4.** Place the blank into the cell holder. Tightly cover the sample cell with the instrument cap.




**5.** Press: **ZERO**

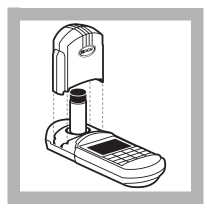
The cursor will move to the right, then the display will show:

**0 FAU**

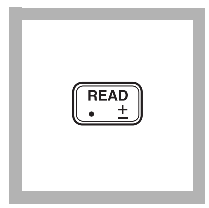
**6.** Fill another sample cell with 10 mL of sample.

***Note:*** *Mix the sample well before transferring it to the sample cell.*

***Note:*** *Wipe the surface of the cell with a soft cloth.*



**7.** Place the sample cell into the cell holder. Tightly cover the sample cell with the instrument cap.




**8.** Press: **READ**

The cursor will move to the right, then the result in Formazin Attenuation Units (FAU) will be displayed.

***Note:*** *Standard Adjust may be performed using a prepared standard (see Section I).*

---

* Adapted from FWPCA *Methods for Chemical Analysis of Water and Wastes*, 275 (1969)

## Sampling and Storage

Collect samples in clean plastic or glass bottles. Analyze samples as soon as possible. Store samples up to 48 hours by cooling to 4 °C (39 °F). Analyze the sample at the same temperature as it was collected.

## Accuracy Check

**Standard Solution Method**
The stored program has been calibrated using formazin, the primary standard for turbidity. A 200 FAU formazin solution for checking the accuracy of the test can be prepared using the following procedure.

1. Pipet 5.00 mL of a 4000 NTU Formazin stock solution into a 100-mL volumetric flask.

2. Dilute to the mark with deionized water. Prepare this daily.

Convenient stabilized turbidity stock solution (200 NTU StablCal™ Standard) is available from Hach.

**Standard Adjust**
To adjust the calibration curve using the reading obtained with the
200 FAU formazin standard, press the **SETUP** key and scroll (using the arrow keys) to the STD setup option. Press **ENTER** to activate the standard adjust option. Then enter **200** to edit the standard concentration to match that of the standard used. Press **ENTER** to complete the adjustment. See *Section 1, Standard Curve Adjustment* for more information.

## Method Precision

**Precision**
In a single laboratory, using a turbidity standard solution of 200 FAU with the instrument, a single operator obtained a standard deviation of ±2 FAU.

**Estimated Detection Limit**
The estimated detection limit for program 95 is 21 FAU. For more information on the estimated detection limit, see *Section 1*.

## Interferences

| Interfering Substance | Interference Levels and Treatments |
|---|---|
| Air Bubbles | Interfere at all levels. Degass samples using the Degassing Kit or an ultrasonic bath. |
| Color | Interferes if the color absorbs light at 520 nm. |
| Temperature extremes | May interfere by changing the turbidity of the sample. Analyze samples as soon as possible after collection. Analyze at the same temperature as the original sample. |

## Summary of Method

This turbidity test measures an optical property of the sample which results from scattering and absorption of light by particles in the sample. The amount of turbidity measured depends on variables such as the size, shape, color, and refractive properties of the particles.

This procedure is calibrated using formazin turbidity standards and the readings are in terms of Formazin Attenuation Units (FAU). This test cannot be used for USEPA reporting purposes, but it may be used for daily in-plant monitoring. One FAU is equivalent to one Nephelometric Turbidity Unit (NTU) of Formazin. However, the optical method of measurement for FAU is very different than the NTU method (1 NTU = 1 FTU = 1 FAU when traced to formazin primary standards.)

**REQUIRED APPARATUS**

| Description | Quantity Required Per Test | Unit | Cat. No. |
|---|---|---|---|
| Sample Cell, 10-20-25 mL, w/cap | 2 | 6/pkg | 24019-06 |

**REQUIRED REAGENTS**

| Description | Units | Cat. No. |
|---|---|---|
| Formazin Stock Solution, 4000 NTU | 500 mL | 2461-49 |
| Silicone Oil | 15 mL DB | 1269-36 |
| StablCal Stabilized Turbidity Standard, 200 NTU | 500 mL | 26604-49 |
| Water, deionized | 4 L | 272-56 |

# Appendix E – Household Surveys in English and Spanish

## El Cristal Household Survey

Good morning / good afternoon. My name is _____. I am part of Engineers Without Borders and am conducting research on drinking water during this project. The purpose of the study is to understand the use and safety of water after sand filtration and chlorination. Our team will interview a representative from every willing household in this community. If you participate, I will ask you questions about your drinking water and collect a sample of your water. The interview will take approximately 10 minutes. No one except the researcher will know that it was you who provided these answers. Are you willing to participate? If so, I will sign this form to indicate that you are a participant.

________________________________
Person Obtaining Consent

HH Number

| | | |
|---|---|---|
| | | |

| | | |
|---|---|---|
| A | Interviewer | |
| B | Date | |
| C | Time | |

Q1. Circle respondents' gender.

| Male | 1 | Female | 0 |
|---|---|---|---|

Q2. How old are you?

Q3. Did you go to school?

| Yes | 1 | No [GOTO Q5] | 0 |
|---|---|---|---|

Q4. How many years did you go to school?

Q5. How many people are in this household?

Q6. Where do you collect your primary drinking water from?

| Tap [GOTO Q7] | 1 | Irrigation | 2 | Stream | 3 | Other: |
|---|---|---|---|---|---|---|

Q7. Where does your tap water come from?

| Water Filter | 1 | Irrigation | 2 | Stream | 3 | Other |
|---|---|---|---|---|---|---|

Q8. Do you treat your drinking water in the house?

| Yes [GOTO Q9] | 1 | No [GOTO Q13] | 0 |
|---|---|---|---|

Q9.

| Q9.a What was the water treated with? | Q9.b Circle: primary drinking water? | | Q9.c Is it covered? | | Q9.d What container is water stored in? | Q9.e Is the water in the container currently treated? | | Q9.f How many liters is stored? | Q9.g How many hours ago was it treated? |
|---|---|---|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | | Yes | No | | |
| | 1 | 0 | 1 | 0 | | 1 | 0 | | |

Q9.a

| Chlorine [GOTO Q10] | 1 | Boiling | 2 | Filter only | 3 | Filter+boiling | 4 |
|---|---|---|---|---|---|---|---|
| Filter+ chlorine | 5 | Other: | | | | | |

1

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Q9.d | Jerry can | 1 | Bucket | 2 | Filter bucket | 3 | Ceramic Pot | 4 | Other: |

Q10. How do you know you have dosed the chlorine correctly?

| | | | | | | |
|---|---|---|---|---|---|---|
| Followed dosage instructions on package | 1 | Minimal chlorine taste | 2 | Color Test / Wheel Test / Color Strips | 3 | Other: |

Q11. How much do you spend on chlorine?

| | |
|---|---|
| US Dollars | Per: |

Q12. How often do you treat the water?

| | | | | | | |
|---|---|---|---|---|---|---|
| Rarely | 1 | 1/week | 2 | Daily | 3 | Other: |

Q13. Do you believe your current drinking water is safe to drink?

| | | | | | |
|---|---|---|---|---|---|
| Yes | 1 | No [GOTO Q15] | 2 | Don't know [GOTO Q16] | 99 |

Q14. How do you know that your water is safe to drink? [GOTO Q16]

| | | | |
|---|---|---|---|
| Water clear | 1 | From protected source: | 2 |
| Chlorinated | 3 | Other: | |

Q15. How do you know when your water is not safe to drink?

| | | | | | |
|---|---|---|---|---|---|
| Has suspended materials | 1 | Water cloudy | 2 | Has color | 3 |
| From unprotected source | 4 | Normal to use | 5 | Other: | |

Q16. How much do you spend on water?

| | |
|---|---|
| US Dollars | Per: |

Q17. For what do you use the tap water (or water you treat)? **[prompt 'any more']**

| | | | | | |
|---|---|---|---|---|---|
| Drinking | 1 | Cooking | 2 | Bathing | 3 |
| Washing hands | 4 | Washing dishes | 5 | Washing clothes | 6 |
| Washing fruits/vegetables | 7 | Watering the garden | 8 | Other: | |

Q18. What information have you received on the sand filter? How many times did you receive that information? Who gave it? **[prompt 'any more']**

| Type | Received | Number | Who gave? |
|---|---|---|---|
| Poster/pamphlet | 1 | | |
| Household visit | 2 | | |
| Group training | 3 | | |
| Health promotion | 4 | | |
| Other: | 5 | | |

Q19. May I collect a sample of the treated water?

| | | | |
|---|---|---|---|
| Yes [Collect] | 1 | No | 0 |

Q20. Can you give me untreated water (only if not using water from the sand filter)?

| | | | | | |
|---|---|---|---|---|---|
| From house [Collect, FINISH] | 1 | From source [Collect, Record Source, FINISH] | 2 | No [FINISH] | 0 |

## El Cristal: Estudio de Hogares

Buenos días / buenas tardes. Mi nombre es _____. Yo soy parte de Ingenieros sin Fronteras y estoy realizando una investigación sobre el agua potable durante este proyecto. El propósito del estudio es comprender el uso y la seguridad de agua después de la filtración de arena y cloración. Nuestro equipo se entrevistará con un representante de cada hogar dispuesto en esta comunidad. Si usted participa, voy a hacer preguntas acerca de su agua potable y recoger una muestra de su agua. La entrevista tendrá una duración aproximada de 10 minutos. Nadie, excepto el investigador va a saber que eras tú el que siempre estas respuestas. ¿Está usted dispuesto a participar? Si es así, voy a firmar este formulario para indicar que usted es un participante.

________________________________
Persona que obtiene el consentimiento

Número de Identificación | | |

| | | |
|---|---|---|
| A | Entrevistador | |
| B | Fecha | |
| C | Hora | |

Q1. Sexo de los encuestados del círculo.

| Masculino | 1 | Femenino | 0 |
|---|---|---|---|

Q2. ¿Qué edad tienes?

Q3. ¿Fuiste a la escuela?

| Sí | 1 | No [IR A Q5] | 0 |
|---|---|---|---|

Q4. ¿Cuántos años vas a la escuela?

Q5. ¿Cuántas personas viven en este hogar?

Q6. ¿Dónde recoger el agua potable de la primaria?

| Grifo [IR A Q7] | 1 | Riego | 2 | Arroyo | 3 | Otros: |
|---|---|---|---|---|---|---|

Q7. ¿De dónde viene el agua del grifo viene?

| Filtro de agua | 1 | Riego | 2 | Arroyo | 3 | Otros: |
|---|---|---|---|---|---|---|

Q8. ¿Trata usted a su agua potable en la casa?

| Sí [IR A Q9] | 1 | No [IR A Q13] | 0 |
|---|---|---|---|

Q9.

| Q9.a ¿Cuál fue el agua tratada con? | Q9.b Círculo: el agua potable primaria? | | Q9.c ¿Está cubierto? | | Q9.d ¿Cuál es el recipiente del agua almacenada en? | Q9.e ¿Es el agua en el recipiente en la actualidad el tratamiento? | | Q9.f ¿Cuántos litros se almacenan? | Q9.g ¿Cuántas horas se trata? |
|---|---|---|---|---|---|---|---|---|---|
| | Sí | No | Sí | No | | Sí | No | | |
| | 1 | 0 | 1 | 0 | | 1 | 0 | | |

Q9.a

| Cloro [IR A Q10] | 1 | Hirviendo | 2 | Filtrar sólo | 3 | Filtro + Hirviendo | 4 |
|---|---|---|---|---|---|---|---|
| Filtro + Cloro | 5 | Otros: | | | | | |

1

Q9.d

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lata de gasolina | 1 | Balde | 2 | Balde de filtro | 3 | Olla de cerámica | 4 | Otros: |

Q10. ¿Cómo usted sabe que ha dosificado correctamente el cloro?

| | | | | | | |
|---|---|---|---|---|---|---|
| Siguió las instrucciones de dosis en el envase | 1 | El sabor a cloro mínimo | 2 | Prueba de color / rueda de ensayo / tiras de color | 3 | Otros: |

Q11. ¿Cuánto gasta en cloro?

| | |
|---|---|
| US Dólares | Por: |

Q12. ¿Con qué frecuencia el tratamiento del agua?

| | | | | | | |
|---|---|---|---|---|---|---|
| Raramente | 1 | 1/ semana | 2 | Diario | 3 | Otros: |

Q13. ¿Cree usted que el agua potable corriente es segura para beber?

| | | | | | |
|---|---|---|---|---|---|
| Sí | 1 | No [IR A Q15] | 2 | Yo no sé [IR A Q16] | 99 |

Q14. ¿Cómo sabes que el agua es segura para beber? [IR A Q16]

| | | | |
|---|---|---|---|
| El agua es clara | 1 | Desde la fuente protegida | 2 |
| Clorada | 3 | Otros: | |

Q15. ¿Cómo sabes cuando el agua no es segura para beber?

| | | | | | |
|---|---|---|---|---|---|
| Ha suspendido los materiales | 1 | Agua turbia | 2 | Tiene un color | 3 |
| De la fuente sin protección | 4 | Normal para usar | 5 | Otros: | |

Q16. ¿Cuánto gasta en agua?

| | |
|---|---|
| US Dólares | Por: |

Q17. ¿Para qué se utiliza el agua de la llave (o el agua a tratar)? **[pedirá 'más']**

| | | | | | |
|---|---|---|---|---|---|
| Beber | 1 | Cocina | 2 | Baños | 3 |
| Lavarse las manos | 4 | Lavar los platos | 5 | Lavar la ropa | 6 |
| Lavar las frutas y verduras | 7 | Regar el jardín | 8 | Otros: | |

Q18. ¿Qué información ha recibido en el filtro de arena? ¿Cuántas veces recibió usted esa información? ¿Quién lo dio? **[pedirá 'más']**

| Tipo | Recibido | Número | ¿Quién le dio? |
|---|---|---|---|
| Cartel / folleto | 1 | | |
| Hogares visita | 2 | | |
| Grupo de la formación | 3 | | |
| Promoción de la salud | 4 | | |
| Otros: | 5 | | |

Q19. ¿Puedo recoger una muestra de que el agua tratada?

| | | | |
|---|---|---|---|
| Sí [Recoger] | 1 | No | 0 |

2

# La Margarita Household Survey

Good morning / good afternoon. My name is _____. I am part of a team of people who are conducting research on drinking water during this project. The purpose of the study is to understand the use and safety of water after ceramic filtration. Our team will interview a representative from every willing household in this community. If you participate, I will ask you questions about your drinking water, your ceramic filter and collect a sample of your water. The interview will take approximately 15 minutes. No one except the researcher will know that it was you who provided these answers. Are you willing to participate? If so, I will sign this form to indicate that you are a participant.

______________________________
Person Obtaining Consent

HH Number

| | | |
|---|---|---|
| | | |

| | | |
|---|---|---|
| A | Interviewer | |
| B | Date | |
| C | Time | |

Q1. Circle respondents' gender.

| | | | |
|---|---|---|---|
| Male | 1 | Female | 0 |

Q2. How old are you?

Q3. Did you go to school?

| | | | |
|---|---|---|---|
| Yes | 1 | No [GOTO Q5] | 0 |

Q4. How many years did you go to school?

Q5. How many people are in this household?

Q6. Where do you collect your primary drinking water from?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Los Tintos [GOTO Q8] | 1 | Tap [GOTO Q7] | 2 | Rice Fields [GOTO Q8] | 3 | Pond [GOTO Q8] | 4 |
| Well [GOTO Q8] | 5 | Truck [GOTO Q8] | 6 | Bottled Water [GOTO Q8] | 7 | Other: [GOTO Q8] | |

Q7. Where does your tap water come from?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Los Tintos | 1 | Well | 2 | Rice Fields | 3 | Pond | 4 |
| Other: | | | | | | | |

Q8. How long does it take to go to your primary drinking water source, collect water, and come back? [If not using tap]

| |
|---|
| Minutes |

Q9. Please tell me all of the different methods for treating water at the household level you know of ***[prompt "any more"]***.

Did you use any of these methods – and how often? ***[Circle to indicate frequency]***

| Type | Knew | Used | | | |
|---|---|---|---|---|---|
| Boiling | 1 | Never | Rarely | 1/week | Daily |
| Chlorine | 2 | Never | Rarely | 1/week | Daily |
| Ceramic Filter | 3 | Never | Rarely | 1/week | Daily |
| Other Filter: Type: ______ | 4 | Never | Rarely | 1/week | Daily |
| Other: | | Never | Rarely | 1/week | Daily |

Q10. Do you believe your current drinking water is safe to drink?

| | | | | | |
|---|---|---|---|---|---|
| Yes | 1 | No [GOTO Q12] | 2 | Don't know [GOTO Q13] | 99 |

Q11. How do you know that your water is safe to drink? [GOTO Q13]

| | | | |
|---|---|---|---|
| Water clear | 1 | From protected source: | 2 |
| Normal to use | 3 | Other: | |

Q12. How do you know that your water is not safe to drink?

| | | | | | |
|---|---|---|---|---|---|
| Has suspended materials | 1 | Water cloudy | 2 | Has color | 3 |
| From unprotected source | 4 | Normal to use | 5 | Other: | |

| | | | |
|---|---|---|---|
| Q13. When did you receive your filter? | | Month | Year |
| Q14. How much did your filter cost? | | US Dollars | |
| Q15. Where do you get replacement parts? | Filter: | Bucket: | |

Q16. What do replacement parts cost?

| | | |
|---|---|---|
| Filter: | Bucket: | Other: |

Q17. What training/promotions/ monitorings did you receive on the ceramic filter? How many times did you receive that training? Who gave it? **[prompt 'any more']**

| Type | Received | Number | Who gave? |
|---|---|---|---|
| Poster/pamphlet | 1 | | |
| Household visit | 2 | | |
| Group training | 3 | | |
| Health promotion | 4 | | |
| Other: | 5 | | |

Q18. Can you show us written materials you received?

| | | | |
|---|---|---|---|
| Yes | 1 | No | 0 |

Q19. Did you ever use the ceramic filter?

| | | | | | |
|---|---|---|---|---|---|
| Yes | 1 | No | 0 | Don't know [GOTO Q32] | 99 |

Q20. For how many months have you used the filter ?

| | |
|---|---|
| | months |

Q21. Are you still using the ceramic filter?

| | | | | | |
|---|---|---|---|---|---|
| Yes | 1 | No [GOTO Q23] | 0 | Don't know [GOTO Q24] | 99 |

Q22. Why? [GOTO Q24]

| | | | | | |
|---|---|---|---|---|---|
| Cleans water | 1 | Prevents disease | 2 | Makes water cool | 3 |
| Easy to use | 4 | Tastes better | 5 | Other: | |

Q23. Why not?

| | | | | | |
|---|---|---|---|---|---|
| Broken | 1 | Flow rate too slow | 2 | Bad taste | 3 |
| Too much time | 4 | DK how to use | 5 | Other: | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Q24. | Did you receive enough education about how to install your filter? | Yes | 1 | No | 0 | DK | 99 |
| Q25. | Did you receive enough education about how to maintain your filter? | Yes | 1 | No | 0 | DK | 99 |
| Q26. | Do you plan to keep using your filter? | Yes | 1 | No | 0 | DK | 99 |
| Q27. | Do you clean your filter? | Yes | 1 | No | 0 | DK | 99 |
| Q28. | Do you share filtered water with others outside the family? | Yes | 1 | No | 0 | DK | 99 |

Q29. Can you describe how you clean/maintain your filter ? **[prompt 'any more']**

| | | | | | |
|---|---|---|---|---|---|
| Scrub inside of pot | 1 | Clean bucket | 2 | Clean outside only | 3 |
| Clean taps | 4 | Never clean [GOTO Q31] | 5 | Other: | |

Q30. How often do you clean your filter?

| | | | |
|---|---|---|---|
| | Times | per | |

Q31. What problems have you had with the filter? **[prompt 'any more']**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Slow flow/clogging | 1 | Cracks | 2 | Broken bucket | 3 | Odor | 4 |
| Broken taps | 5 | No problems | 6 | Other: | | | |

Q32. For what do you use the water you treat? **[prompt 'any more']**

| | | | | | |
|---|---|---|---|---|---|
| Drinking | 1 | Cooking | 2 | Bathing | 3 |
| Washing hands | 4 | Washing dishes | 5 | Washing clothes | 6 |
| Washing fruits/vegetables | 7 | Watering the garden | 8 | Other: | |

Q33. OBSERVE : Is the filter wet ?

| | | | | | |
|---|---|---|---|---|---|
| Yes | 1 | No | 0 | No filter | 99 |

Q34.

| Q34.a How many liters is the storage container? | Q34.b Circle primary drinking water? | | Q34.c Is it covered? | | Q34.d What container is water stored in? | Q34.e Is the water treated? | | Q34.f What was it treated with? | Q34.g How many hours ago? |
|---|---|---|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | | Yes | No [GOTO Q35] | | |
| | 1 | 0 | 1 | 0 | | 1 | 0 | | |

Q34.d

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Jerry can | 1 | Bucket | 2 | Filter bucket | 3 | Ceramic Pot | 4 | Other: |

Q34.f

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ceramic Filter | 1 | CF + boiling | 2 | CF + chlorine | 3 | Boiling | 4 |
| Chlorine | 5 | Other: | | | | | |

3

Q35. Can you give me some of the treated water?

| | | | |
|---|---|---|---|
| Yes [Collect] | 1 | No | 0 |

Q36. Can you give me untreated water (if treated water in house, make sure untreated is from the same source as treated)?

| | | | | | |
|---|---|---|---|---|---|
| From house [Collect, FINISH] | 1 | From source [Collect, FINISH] | 2 | No [FINISH] | 0 |

Workflow questions
Look at NASA TLX workload scale to provide numerical results
Do you think your average neighbor would understand this? Helps to explain difficult questions and knowledge so they don't blame themselves.

SPSS has become expensive
R is an open source with a command line interface
Email Dan and he will email non-parametric data transform "assigned rank" allows you to do analysis of variance
Need to test for interactions using this transform and an analysis of variance PSY107: Rich Cagley, prof. Binomial distribution oriented
Who is responsible for maintaining the system in this home?
What grade level is required to read this label?

INSTALLATION NOTES

Measure water depth in pot: _________________

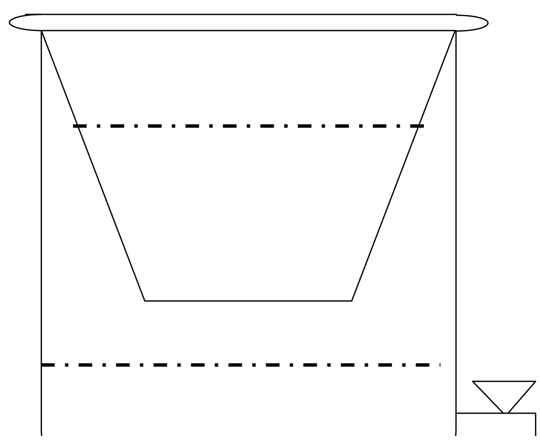
Measure water depth in bucket: _______________

**Note any leaks, cracks, problems, other….**

**Is it clean:** **YES** **NO**

**Does it smell:** **YES** **NO**

**Is the lid in use:** **YES** **NO**



# La Margarita: Estudio de Hogares

Buenos días / buenas tardes. Mi nombre es _____. Yo soy parte de un equipo de personas que están llevando a cabo la investigación sobre el agua potable durante este proyecto. El propósito del estudio es comprender el uso y la seguridad de agua después de la filtración de cerámica. Nuestro equipo se entrevistará con un representante de cada hogar dispuesto en esta comunidad. Si usted participa, voy a hacer preguntas acerca de su agua de beber, los filtros de cerámica y recoger una muestra de su agua. La entrevista tendrá una duración aproximada de 15 minutos. Nadie, excepto el investigador va a saber que eras tú el que siempre estas respuestas. ¿Está usted dispuesto a participar? Si es así, voy a firmar este formulario para indicar que usted es un participante.

_______________________________
Persona que obtiene el consentimiento

Número de Identificación

| | | |
|---|---|---|
| | | |

| | | |
|---|---|---|
| A | Entrevistador | |
| B | Fecha | |
| C | Hora | |

Q1. Sexo de los encuestados del círculo.

| | | | |
|---|---|---|---|
| Masculino | 1 | Femenino | 0 |

Q2. ¿Qué edad tienes?

Q3. ¿Fuiste a la escuela?

| | | | |
|---|---|---|---|
| Sí | 1 | No [IR A Q5] | 0 |

Q4. ¿Cuántos años vas a la escuela?

Q5. ¿Cuántas personas viven en este hogar?

Q6. ¿Dónde recoger el agua potable de la primaria?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Los Tintos [IR A Q8] | 1 | Grifo [IR A Q7] | 2 | Los campos de arroz [IR A Q8] | 3 | Estanque [IR A Q8] | 4 |
| Pozo [IR A Q8] | 5 | Camión [IR A Q8] | 6 | Agua embotellada [IR A Q8] | 7 | Otros: [IR A Q8] | |

Q7. ¿De dónde viene el agua del grifo viene?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Los Tintos | 1 | Pozo | 2 | Los campos de arroz | 3 | Estanque | 4 |
| Otros: | | | | | | | |

Q8. ¿Cuánto tiempo se tarda en ir a su fuente primaria de agua potable, recoger agua y volver? [Si no se usa grifo]

Minutos

Q9. Por favor, dígame todos los diferentes métodos de tratamiento de agua en los hogares sabes de **[mensaje 'más'].**

¿Ha utilizado alguno de estos métodos y con qué frecuencia? **[Frecuencia círculo]**

| Tipo | Sabía | Utilizado | | | |
|---|---|---|---|---|---|
| Hirviendo | 1 | Nunca | Raramente | 1/semana | Diario |
| Cloro | 2 | Nunca | Raramente | 1/semana | Diario |
| Filtro de cerámica | 3 | Nunca | Raramente | 1/semana | Diario |
| Otros Filtros: Tipo: ______ | 4 | Nunca | Raramente | 1/semana | Diario |
| Otros: | | Nunca | Raramente | 1/semana | Diario |

1

Q10. ¿Cree usted que el agua potable corriente es segura para beber?

| | | | | | |
|---|---|---|---|---|---|
| Sí | 1 | No [IR A Q12] | 2 | Yo no sé [IR A Q13] | 99 |

Q11. ¿Cómo sabes que el agua es segura para beber? [IR A Q13]

| | | | |
|---|---|---|---|
| El agua es clara | 1 | Desde la fuente protegida | 2 |
| Clorada/Hirvido | 3 | Otros: | |

Q12. ¿Cómo sabes cuando el agua no es segura para beber?

| | | | | | |
|---|---|---|---|---|---|
| Ha suspendido los materiales | 1 | Agua turbia | 2 | Tiene un color | 3 |
| De la fuente sin protección | 4 | Normal para usar | 5 | Otros: | |

Q13. ¿Cuándo recibió su filtro?

Q14. ¿En qué medida el coste del filtro?

Q15. ¿De dónde sacas las piezas de repuesto?

| | | | |
|---|---|---|---|
| | Mes | | Año |
| | US Dólares | | |
| Filtro: | | Balde: | |

Q16. ¿Qué partes del costo de reemplazo?

| | | |
|---|---|---|
| Filtro: | Balde: | Otros: |

Q17. ¿Qué información ha recibido en el filtro de arena? ¿Cuántas veces recibió usted esa información? ¿Quién lo dio? **[pedirá 'más']**

| Tipo | Recibido | Número | ¿Quién le dio? |
|---|---|---|---|
| Cartel / folleto | 1 | | |
| Hogares visita | 2 | | |
| Grupo de la formación | 3 | | |
| Promoción de la salud | 4 | | |
| Otros: | 5 | | |

Q18. ¿Nos puedes mostrar material escrito que usted recibió?

| | | | |
|---|---|---|---|
| Sí | 1 | No | 0 |

Q19. ¿Alguna vez se utiliza el filtro de cerámica?

| | | | | | |
|---|---|---|---|---|---|
| Sí | 1 | No | 0 | Yo no sé [IR A Q32] | 99 |

Q20. ¿Por cuántos meses ha usado el filtro?

| | |
|---|---|
| | mes |

Q21. ¿Sigues usando el filtro de cerámica?

| | | | | | |
|---|---|---|---|---|---|
| Sí | 1 | No [IR A Q23] | 0 | Yo no sé [IR A Q24] | 99 |

Q22. ¿Por qué? [IR A Q24]

| | | | | | |
|---|---|---|---|---|---|
| Limpia el agua | 1 | Previene enfermedades | 2 | Hace agua fría | 3 |
| Fácil de usar | 4 | Mejor los gustos | 5 | Otros: | |

Q23. ¿Por qué no?

| | | | | | |
|---|---|---|---|---|---|
| Roto | 1 | Flujo demasiado lenta tasa de | 2 | Mal sabor | 3 |
| Demasiado tiempo | 4 | No sabe cómo utilizar | 5 | Otros: | |

Q24. ¿Ha recibido suficiente educación acerca de cómo instalar el filtro?

Q25. ¿Recibió la educación suficiente sobre cómo mantener su filtro?

Q26. ¿Tiene planes de seguir usando el filtro?

Q27. ¿Cómo se limpia el filtro?

Q28. ¿Usted comparte el agua filtrada con los demás fuera de la familia?

| | | | | | | |
|---|---|---|---|---|---|---|
| Q24. ¿Ha recibido suficiente educación acerca de cómo instalar el filtro? | Sí | 1 | No | 0 | Yo no sé | 99 |
| Q25. ¿Recibió la educación suficiente sobre cómo mantener su filtro? | Sí | 1 | No | 0 | Yo no sé | 99 |
| Q26. ¿Tiene planes de seguir usando el filtro? | Sí | 1 | No | 0 | Yo no sé | 99 |
| Q27. ¿Cómo se limpia el filtro? | Sí | 1 | No | 0 | Yo no sé | 99 |
| Q28. ¿Usted comparte el agua filtrada con los demás fuera de la familia? | Sí | 1 | No | 0 | Yo no sé | 99 |

Q29. ¿Puede describir cómo limpiar / mantener el filtro? **[pedirá 'más']**

| | | | | | |
|---|---|---|---|---|---|
| Frote el interior de la olla | 1 | Balde limpio | 2 | Limpie el exterior sólo se | 3 |
| Limpia del grifo | 4 | Nunca limpie [IR A Q31] | 5 | Otros: | |

Q30. ¿Con qué frecuencia se limpia el filtro?

| | | | |
|---|---|---|---|
| | veces | por | |

Q31. ¿Qué problemas ha tenido con el filtro? **[pedirá 'más']**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Reduzca la velocidad de flujo / obstrucción | 1 | Grietas | 2 | Balde roto | 3 | Olor | 4 |
| Grifo roto | 5 | No hay problemas | 6 | Otros: | | | |

Q32. ¿Para qué se utiliza el agua a tratar? **[pedirá 'más']**

| | | | | | |
|---|---|---|---|---|---|
| Beber | 1 | Cocina | 2 | Baños | 3 |
| Lavarse las manos | 4 | Lavar los platos | 5 | Lavar la ropa | 6 |
| Lavar las frutas y verduras | 7 | Regar el jardín | 8 | Otros: | |

Q33. OBSERVAR: Es el filtro húmedo?

| | | | | | |
|---|---|---|---|---|---|
| Sí | 1 | No | 0 | No filter | 99 |

Q34.

| Q34.a ¿Cuántos litros es el recipiente de almacenamiento? | Q34.b Círculo: de agua potable primaria? | | Q34.c ¿Está cubierto? | | Q34.d Lo que el recipiente se almacena el agua en el? | Q34.e ¿Está el agua tratada? | | Q34.f ¿Cómo fue tratado con? | Q34.g ¿Cuántas horas? |
|---|---|---|---|---|---|---|---|---|---|
| | Sí | No | Sí | No | | Sí | No [GOTO Q35] | | |
| | 1 | 0 | 1 | 0 | | 1 | 0 | | |

Q34.d

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lata de gasolina | 1 | Balde | 2 | Balde de filtro | 3 | Olla de cerámica | 4 | Otros: |

Q34.f

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Filtro de ceramica | 1 | CF + hirviendo | 2 | CF + cloro | 3 | Hirviendo | 4 |
| Cloro | 5 | Other: | | | | | |

3

Q35. ¿Me puede dar un poco de agua tratada?

| | | | |
|---|---|---|---|
| Sí [Recoger] | 1 | No | 0 |

Q36. ¿Me puede dar agua sin tratar (si el agua tratada en la casa, asegúrese de que no se trata es de la misma fuente que trata)?

| | | | | | |
|---|---|---|---|---|---|
| Desde la casa de [Recoger, TERMINA] | 1 | From source [Recopilar, TERMINA] | 2 | No [TERMINA] | 0 |

NOTAS DE INSTALACIÓN

Medir la profundidad del agua en la olla:________________

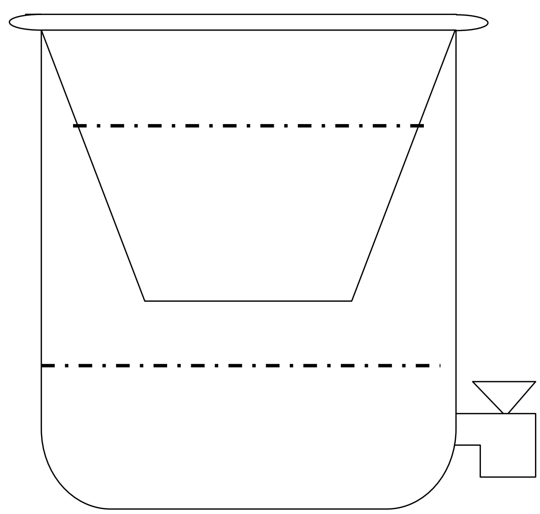
Medir la profundidad del agua en un balde:_______________

**Tenga en cuenta las fugas, grietas, problemas, otros ....**

**¿Está limpia? SI NO**

**¿Huele? SI NO**

**Es la tapa en su uso? SI NO**



4

# Appendix F – Operator Surveys in English and Spanish

## El Cristal Slow Sand Filter Operator Survey

Good morning / good afternoon. My name is _____. I am part of a team of people who are conducting research on drinking water during this project. The purpose of the study is to understand the use and safety of water after sand filtration and chlorination. If you participate, I will ask you questions about your filter operations and collect samples of the water. No one except the researcher will know that it was you who provided these answers. Are you willing to participate? If so, I will sign this form to indicate that you are a participant.

______________________________
Person Obtaining Consent

ID Number | | |

| | | |
|---|---|---|
| A | Interviewer | |
| B | Date | |
| C | Time | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Q1. | Circle respondents' gender. | Male | 1 | Female | 0 | |
| Q2. | How old are you? | | | | | |
| Q3. | Did you go to school? | Yes | 1 | No [GOTO Q5] | 0 | |
| Q4. | How many years did you go to school? | | | | | |
| Q5. | How long have you been working as an operator? | | | | | |
| Q6. | Did you receive training on the filter operation? | Yes | 1 | No [GOTO Q9] | 0 | |
| Q7. | From whom did you receive training on filter operation? | Tufts University | 1 | Previous Operator | 2 | Other: |
| Q8. | When did you receive training? | | | | | |
| Q9. | Did you receive training on the chlorination system? | Yes | 1 | No [GOTO Q9] | 0 | |
| Q10. | From whom did you receive training on the chlorination system? | Tufts University | 1 | Previous Operator | 2 | Other: |
| Q11. | When did you receive this training? | | | | | |
| Q12. | How many hours per week do you work? | | | | | |

NOTE: Please refer to the supplemental sheet at this time and complete

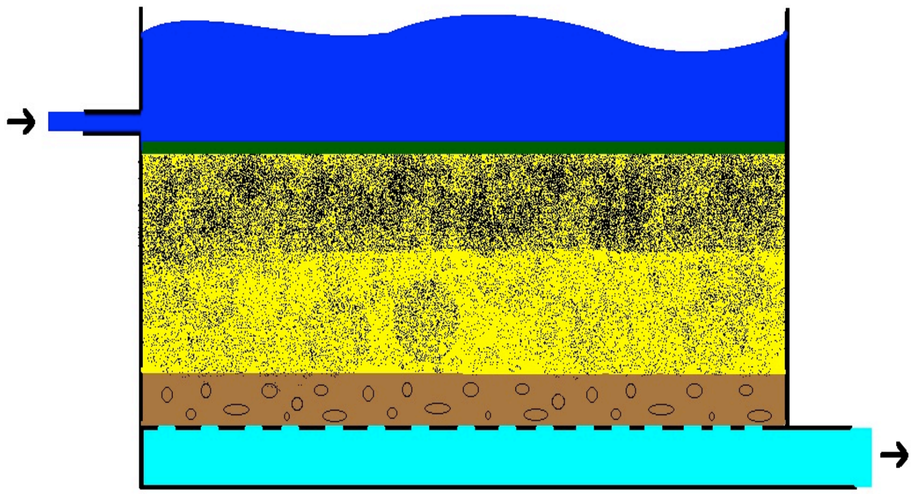
Ask them to clean the filter and record notes on this operation. Also ask to see the chlorination system and record notes on this operation as well.

**OPEN ENDED FOCUS GROUP DISCUSSION QUESTIONS WITH THE OPERATORS**

Choose questions to ask based on operation and maintenance processes that have been observed.

1) Describe the process of how you identify and react to abnormal operating conditions
2) Do you believe you have enough information to run the system smoothly?
3) Are you ever forced to take short-cuts in your work? Why do these have to be made?
4) What is your process for training a new operator?
5) How is a new operator selected?
6) Do you believe your compensation is equal to the amount of work you put in?
7) Did you feel like you were prepared enough by Tufts on the operation and maintenance of the system?
8) How confident are you in your abilities as an operator?
9) What is the most difficult task you are asked to perform? What makes it so?
10) Are there specific duties assigned to each operator? How do you decide how to share the work load?

Please identify the different components of the slow sand filter and explain how it works:



Q1. Mark everything that they correctly identify.

| Type | Received |
|---|---|
| Inlet | 1 |
| Water head | 2 |
| Biological layer | 3 |
| Fine Sand | 4 |
| Large Sand | 5 |
| Sand (not size specified) | 6 |
| Gravel | 7 |
| Outlet | 8 |
| Other: | |

Q2. Please record their explanation of the filtration process:

## El Cristal: Estudio de filtro lento de arena operador

Buenos días / buenas tardes. Mi nombre es _____. Yo soy parte de un equipo de personas que están llevando a cabo la investigación sobre el agua potable durante este proyecto. El propósito del estudio es comprender el uso y la seguridad de agua después de la filtración de arena y cloración. Si usted participa, voy a hacer preguntas acerca de sus operaciones de filtrado y recoger muestras del agua. Nadie, excepto el investigador va a saber que eras tú el que siempre estas respuestas. ¿Está usted dispuesto a participar? Si es así, voy a firmar este formulario para indicar que usted es un participante.

_______________________________
Persona que obtiene el consentimiento

| | | | |
|---|---|---|---|
| Número de Identificación | | | |

| | | |
|---|---|---|
| A | Entrevistador | |
| B | Fecha | |
| C | Hora | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Q1. | Sexo de los encuestados del círculo. | Masculino | 1 | Femenino | 0 | |
| Q2. | ¿Qué edad tienes? | | | | | |
| Q3. | ¿Fuiste a la escuela? | Sí | 1 | No [IR A Q5] | 0 | |
| Q4. | ¿Cuántos años vas a la escuela? | | | | | |
| Q5. | ¿Cuánto tiempo ha estado trabajando como un operador? | | | | | |
| Q6. | ¿Ha recibido capacitación sobre el funcionamiento del filtro? | Sí | 1 | No [IR A Q9] | 0 | |
| Q7. | ¿De quién reciben capacitación sobre el funcionamiento del filtro? | Universidad de Tufts | 1 | Operador anterior | 2 | Otros: |
| Q8. | ¿Cuándo recibió la capacitación? | | | | | |
| Q9. | ¿Ha recibido capacitación sobre el sistema de cloración? | Sí | 1 | No [IR A Q9] | 0 | |
| Q10. | ¿De quién reciben capacitación sobre el sistema de cloración? | Universidad de Tufts | 1 | Operador anterior | 2 | Otros: |
| Q11. | ¿Cuándo recibió esta capacitación? | | | | | |
| Q12. | ¿Cuántas horas por semana trabaja usted? | | | | | |

NOTA: Por favor consulte la hoja adicional en este momento y completa

Pídales que limpiar los filtros de notas y registrar en esta operación. También pida ver el sistema de cloración y grabar notas de esta operación así.

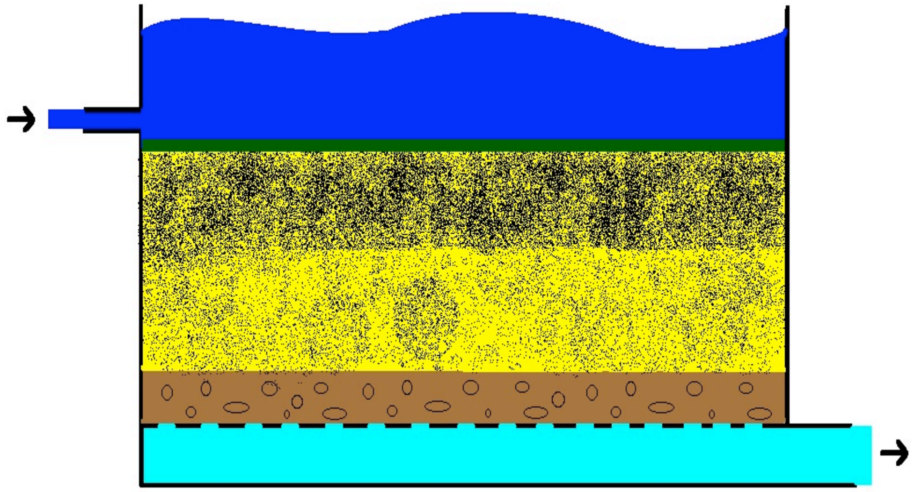
1

FOCUS PREGUNTAS DE DISCUSIÓN PARA GRUPOS CON LOS OPERADORES

Elija preguntas que hacer sobre la base de los procesos de operación y mantenimiento que se han observado.

1) Describir el proceso de cómo identificar y reaccionar ante condiciones anormales de funcionamiento
2) ¿Cree usted que tiene la información suficiente para hacer funcionar el sistema sin problemas?
3) ¿Alguna vez vio obligado a tomar atajos en su trabajo? ¿Por qué ellos tienen que hacer?
4) ¿Cuál es su proceso de formación de un nuevo operador?
5) ¿Cómo se selecciona un nuevo operador?
6) ¿Cree que su remuneración es igual a la cantidad de trabajo que poner?
7) ¿Te sientes como si se prepararon lo suficiente por la Tufts sobre el funcionamiento y mantenimiento del sistema?
8) ¿Qué tan seguro se encuentra en sus habilidades como operador?
9) ¿Cuál es la tarea más difícil se le pide que realice? Lo que lo hace?
10) ¿Existen funciones específicas asignadas a cada operador? ¿Cómo se decide cómo compartir la carga de trabajo?

Por favor, identifique los diferentes componentes del filtro lento de arena y explicar cómo funciona:



Q1. Mark everything that they correctly identify.

| Type | Received |
|---|---|
| Inlet | 1 |
| Water head | 2 |
| Biological layer | 3 |
| Fine Sand | 4 |
| Large Sand | 5 |
| Sand (not size specified) | 6 |
| Gravel | 7 |
| Outlet | 8 |
| Other: | |

Q2. Please record their explanation of the filtration process:

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