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Investigation of the Potters for Peace Colloidal Silver Impregnated Ceramic Filter

Report 2: Field Investigations

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1 Project Background

1.1 Hurricane Mitch, USAID, and CACEDRF

In October 1998, Hurricane Mitch devastated Central America, causing over 3,000 deaths in Nicaragua alone (USAID 2001, 2001a). An estimated 18 percent of the population of Nicaragua was affected by Mitch, and water and wastewater systems serving 804,000 people suffered over US$560 million in damage. The Unites States provided US$22 million in immediate humanitarian and food aid, and an additional US$8 million to start reconstruction activities in health, agriculture, and micro-finance.

In May 1999, the United States Congress authorized US$621 million in aid under the Emergency Supplemental Appropriations Act (USAID, 2001). These funds were authorized to support reconstruction in countries affected by Hurricanes George and Mitch, and were later authorized to cover Hurricanes Floyd and Lenny, as well as the earthquake of January 1999. This appropriation created an account named the Central American and Caribbean Emergency Disaster Recovery Funds (CACEDRF).

USAID is responsible for administering US$586.8 million of the US$621 million allocated under CACEDRF (USAID, 2001a). Of the total funds, US$94.1 million was allocated for economic reactivation, public health, school rehabilitation, disaster mitigation, and municipal restoration in Nicaragua. As of June 30, 2001, a significant amount of progress on projects relating to water supply and sanitation had already occurred (Table 1-1).

Table 1-1: CACEDRF Successes Relating to Water Supply and Sanitation in Nicaragua

Category	Success
Economic Reactivation	57,000 households incorporated environmentally sustainable practices on their farms 8,000 hectares of watershed area protected
Public Health	2,440 wells rehabilitated or built 5,740 latrines constructed 600 seepage pits constructed 175 deep wells drilled in rural areas 10,000 training visits held to improve health behavior related to new water and sanitation infrastructure 6 health clinics constructed
School Rehabilitation	196 schools scheduled for rehabilitation of wells and latrines
Disaster Mitigation	Cleaning and stabilizing stream channels Construction of drainage channels
Municipal Restoration	Projects with local governments on storm drain systems, flood control, river deck construction

An additional goal of the rehabilitation program in Nicaragua is to investigate point-of-use household water filtration systems (USAID, 2001b). To this end, USAID worked to install 40,000 sand filtration units, supervised by Maria Alejandra Bosche. Ms. Bosche found that follow-up education was critical to the correct and continued use of the filter system (Bosche, personal conversation).

Secondly, USAID contracted with Jubilee House Community (JHC) to study the Potters for Peace (PFP) ceramic water filtration system. JHC, an intentional Christian community, is a 501(c)3 organization in North Carolina (JHC-CDCA, 2001). From 1979 – 1994, members of the community worked on shelters for homeless and battered women, as well as other social and justice issues, in North Carolina. In 1994, the community moved to Nicaragua, established the Center for Development in Central America (CDCA), and began working with communities in Nicaragua. After Hurricane Mitch, JHC-CDCA began to work on reconstruction projects in Nueva Vida, a nearby community swelled with displaced persons. USAID provided funding and supplies to build housing, a medical clinic, and latrines (USAID, 2001c). JHC and a group of volunteers worked with the community to build these facilities, in addition to a number of other projects. One of these other projects is the promotion of the Potters for Peace water filtration system to provide safe drinking water for families in Nueva Vida.

JHC worked with PFP to contract Daniele Lantagne, Principal of Alethia Environmental and Lecturer in Civil and Environmental Engineering at the Massachusetts Institute of Technology, to complete the project. The project was divided into two deliverables, one addressing the intrinsic effectiveness of the filter, and the other addressing the performance of the filters under field conditions. Specifically the reports are to address the following:

Report 1: Intrinsic Effectiveness of the Potters for Peace Ceramic Filter

- Best practices for colloidal silver application.
- Expected filter flow rates with and without colloidal silver.
- Expected lifetime per application of colloidal silver.
- Concentration of silver in filtered water.
- Effects of ingestion of the silver.
- Inactivation of microbes as a function of the concentration of silver.
- Effectiveness of silver in removing other pollutants commonly found in the area of interest.

Completion Deadline: December 21, 2001

Report 2: Field Testing of the Potters for Peace Ceramic Filter

- Discussion of the performance of the filters under field conditions.
- Comparison of filter performance with other commonly used methods of treatment.

Completion Deadline: November 16, 2001

This report, Report 2, details the data obtained on a three-week field study in rural Nicaraguan communities utilizing the PFP filtering system. The report begins with water supply and sanitation indicators in Nicaragua, and a discussion of the history of PFP and the development of the filtering system. Then, the mechanism of filtration and disinfection is discussed, followed by the results of previous studies conducted on the use of the filtering system. Results of the field study are then presented, and the report concludes with recommendations and conclusions.

1.2 Water Supply and Sanitation in Nicaragua

Nicaragua is located in the center of the Central American isthmus and is the largest country in the region, with a surface area of 130,682 km^2 (PAHO, 1999). Nicaragua has three distinct topographical regions – the Pacific, Atlantic, and Central regions. The greatest percentage of the population lives on the Pacific coast and the lowest percentage lives on the Atlantic coast. Recovery from the devastation of Hurricane Mitch is ongoing. Although many roads and water supply systems have been repaired or replaced, some rural areas of the country have still not recovered to pre-Mitch levels of infrastructure.

Although most people living in urban areas have access to safe water and sanitation, a significant percentage of people in rural areas do not (Table 1-2). In addition, and possibly as a result, infant and under-5 mortality is high. Over half of the population lives in poverty, and the illiteracy rate is around 40 percent.

Table 1-2: Water Supply and Sanitation Indicators in Nicaragua

	World Bank (1999)	PAHO (2000)	PAHO (1999)	UNICEF (2000)
Population (millions)	4.9	5.1	4.5	4.9
Urban population (%)	55.8		63.7	
GNI per capita	US$410			US$430
Access to safe water	79%		37%	79%
Access to safe water (urban)	95%		93%	95%
Access to safe water (rural)	59%		12%	59%
Access to sanitation				84%
Access to sanitation (urban)	96%			96%
Access to sanitation (rural)	68%			68%
Under-5 mortality rate (per 1,000 live births)	43	55.8	66	
Infant mortality (per 1,000 live births)		45.2	47	
Maternal mortality (per 100,000 live births)		102	124	150
Life Expectancy (years)			68.4	
Population in poverty		50.3%	63%	
Literacy Rate – Women		69%	66%	
Literacy Rate – Men		50.3%		

A number of different international and national development organizations have worked in Nicaragua to increase access to safe water and sanitation. Many of the wells installed for water supply are Nicaraguan rope pump wells. These are an appropriate technology design utilizing a rope pulley to lift groundwater up to 6 meters (Sandiford, 1993). The systems are easy to use, low cost, simple to maintain, and made of locally available parts. In addition, rope pump wells show a 62 percent reduction in fecal coliform as compared to bucket wells. Currently, Bombas de Mecate markets the wells commercially in Nicaragua, without the need for external subsidies.

Anna Gorter conducted a series of studies on childhood diarrhea in Villa Carlos Fonseca, and published them in her book Childhood Diarhhoea and its Prevention in Nicaragua (1995). She investigated a series of variables and their relationship to childhood diarrhea and found the following:

Variables Reducing Childhood Diarrhea	Variables Increasing Childhood Diarrhea	No Relationship to Childhood Diarrhea
Distance to water supply Increased schooling of mother Hand-washing Domestic cleanliness Use of diapers in children	Increased number of children under 5	Ownership of latrine

After years of study, Gorter (1995) concluded that

> There are interactions among interventions, and therefore the effect of a particular intervention will not only depend on its own merit, but also on those of the other interventions with which it interacts. Theoretical models suggest that such interactions exist between water supply, sanitation and hygiene interventions. The impact of improvements in water supply, sanitation and hygiene together are greater than the sum of the effects of the interventions alone. Furthermore, if the interactions are strong, the health impact from an improved water supply may depend critically on whether sanitation and hygiene conditions are good or poor. The Villa Carlos Fonseca studies have made it clear that supplying only hardware is not sufficient to reduce the incidence of diarrhoea. Personal, domestic and especially community hygiene plays a crucial role in the transmission of diarrhoeal pathogens.

The conclusion of Gorter's research highlights the need for coordinated water supply, water treatment, and education programs in order to achieve the greatest improvement in human health.

2 The PFP Filter

2.1 Initial Filter Design

In 1981 the InterAmerican Bank financed a comparative study designed to determine which of 10 appropriate technology filters could be best adapted to the objectives of the project, which were (ICAITI, 1994):

1. to produce a domestic filter of suitable capacity;
2. in a self-supporting manner;
3. whose production would foster economic activity at low income levels; and
4. foster artisan activity.

ICAITI, an industrial research institute in Guatemala supported by the Organization for American States, was contracted to complete the research and to choose a model. Ten models were evaluated based on filtration flow, bacteriological efficiency, ease of manufacture, availability of materials, final cost, contribution to artisan activity, and ease of distribution. All but two models were discarded after initial review because they did not meet basic criteria. The two models not discarded were:

1. Lathed clay filter with feldspar, sawdust, and colloidal silver impregnation; and
2. Lathed clay filter with sand, sawdust, and colloidal silver impregnation.

None of the ten models investigated utilized chlorine as a disinfectant.

Further research was then conducted on the two models that met the basic criteria. This research, led by Fernando Mazareigos, did extensive bacteriological testing over a 3 to 10 month period. Results of this research include:

1. Of 302 filtered samples analyzed, only 6.3 percent were above 1.0 coliforms per 100 mL of water. The method used for analysis was most probable number.
2. Application of silver was determined to be more uniform when applied by brush as opposed to filtering water containing colloidal silver through the filtering element.
3. Frequent contamination was found both in the first few runs of the filter (41 percent contaminated) and after handling the element during sampling. This was attributed to handling the filter and ICAITI recommended that users refrain from touching the element during its useful life. Due to the omnipresent bacteria in the environment "usage of the filter must be accompanied by sanitary and hygienic practices in order to maximize the potential benefits to health."
4. Flow in the filters gradually declined from 3.5 liters per hour on Day 1 to 1.97 liters per hour on Day 365. The report contained no information on turbidity of the raw water supply.
5. ICAITI recommended not using the filter with chlorinated water. No reason was given.

Based on these results, ICAITI concluded that a colloidal silver impregnated ceramic filter was the only design that met all established criteria of the study. The United Nations then included this filter in their

Appropriate Technology Resource Material Manual. ICAITI concluded its study by producing a "Manual Para La Fabricacion De Filtros Artesanales De Agua Potable."

2.2 Filter Implementation

After a visit from Fernando Mazariegos, MAP International in Quito, Ecuador applied for funding to develop a factory in indigenous lands that would produce and market the water filter (MAP International, 1985). In 1983, USAID granted the funding, and, using that initial and then a second grant, MAP International worked with the local community to establish a factory.

A number of technical difficulties were encountered and solved during the establishment of the factory. These included:

1. Adaptations to the sand, clay and sawdust mixture were necessary to obtain the correct porosity.
2. It was difficult to make the external finished water receptacle impermeable.
3. It was difficult to find a supplier of colloidal silver in Mexico.
4. Adaptation of the kiln was necessary so that it could be hot enough to fire the filters.

In addition, laboratory tests with the filter indicated that with lower turbidity, flow rates would be more rapid. Thus, control of the filter production was deemed crucial to ensuring enough colloidal silver contact time to effectively reduce bacteriological contamination (IEOS, 1985; 1985a). Due to these issues, Ron Rivera, a ceramics consultant, was brought in to provide technical assistance.

These problems were solved, and the factory was completed. However, the majority of the grant resources were expended solving the problems, and not enough money was spent on development of the market. In the final report, MAP International (1985) stated that "the end of the project status can best be described as a water filter production unit that is capable of producing a quality product buy lacks a marketing unit that is capable of generating sales that are sufficient to enable the operation to sustain itself at a breakeven point of 83 units per month."

Although the MAP International project ended less than ideally, Ron Rivera continued to consult on other projects and proceeded to introduce the filter to potters in Ecuador, Bolivia, and Nicaragua (Rivera, personal communication). In addition, ICAITI continued to support the one family of potters making filters in the small village of Rabinal, Guatemala.

The next major step in the history of the filter came when Dominique Wilson, of AFAGuatemala, became interested in the filter. She was researching water purification and found that people were not using chlorine correctly and also were not boiling water long enough to ensure disinfection. Wilson received funding to investigate the ICAITI filter, and determined that health education and the filter could reduce childhood diarrhea (see Section 5.1 for detailed results). Unfortunately, the project ended with that study, as the NGO did not have a marketing strategy and discontinued work with the filter.

The next step in the history of the filter came when Ron Rivera was hired by Potters for Peace as their in-country supervisor in Nicaragua.

2.3 Potters for Peace

Potters for Peace (PFP) "seeks to build an independent, non-profit, international network of potters concerned with peace and justice issues. We will maintain this concern principally through interchanges involving potters of the (overdeveloped) North and (underdeveloped) South. PFP aims to provide socially responsible assistance to pottery groups and individuals in their search for stability and improvement of ceramic production, and in the preservation of their cultural inheritance (PFP, 2001)."

The PFP in-country supervisor, Ron Rivera, works with individuals, communities, and North American volunteers to learn and teach pottery techniques, and to market indigenous Nicaraguan pottery in the United States. PFP is recognized by Global Exchange as a fair trade company, and PFP associated ceramics are sold in fair trade stores across North America and Europe. The description on the Global Exchange web site (2001) describes PFP as an "international crafts solidarity organization of North American potters working to provide product development and export assistance to ceramic cooperatives in Nicaragua."

In addition, Ron has used his previous experience with the filter to develop filter factories and filter sales both in Nicaragua and around the world. Even though the filter factory in Nicaragua is successful and the filtration system is in high demand across the globe there has been some questioning of the PFP board as to whether this focus matches with their original goal (Rivera, personal communication). At the last PFP board meeting, it was decided that the current intense focus on the filtration system is something they want to continue to support. However, the board has established a mechanism for donors to contribute to only non-filtration system projects, if donors desire to support only the fair trade aspect of the organization.

Thus, PFP and Ron Rivera work to introduce the filter for general use in developing countries by establishing micro-enterprises of artisans making the filters and receptacles, and by partnering with NGOs that distribute the filter and provide education. From here on in the report, the ICAITI / PFP filter will be referred to simply as the PFP filter.

2.4 The PFP Filter Factory

The PFP water filters are produced in a factory in Managua, Nicaragua that employs four male staff ceramicists and one female part-time administrative assistant. The factory is in the process of becoming a legally recognized cooperative, owned by the workers and other interested parties to make up the requisite number of 10 for a cooperative in Nicaragua. The factory workers maintain their own Quicken files, and operate fairly independently, with some technical oversight from Ron Rivera. There has been a woman employee at the factory, but she resigned because of the difficulty of the labor.

The filter itself is 31 cm in diameter, 24 cm high, holds 7.1 liters of water, and is shaped "like a coned flower pot (PFP, 2001)." The filter sits inside the receptacle like a vegetable steamer sits inside the steaming pot. Receptacles for the filter are either 20-liter plastic buckets or thrown ceramic pots. A plastic (or in the past bronze) spigot attaches at the bottom of the receptacle. A plastic or ceramic lid is placed on top.

The process for making the filter is as follows:

1. 60 percent dry pulverized clay (including brick scraps that are not acceptable to bricklayers) and 40 percent screened sawdust are mixed together in a mixer.
2. Water is added to the mix to obtain the correct consistency.
3. The filters are then formed by hand, turned on a potter's wheel, or press-molded. In the Managua factory, filters are press molded using a 10-ton hydraulic jack.
4. Filters are fired at 887 degrees centigrade in a brick kiln using wood scraps from industry as the fuel source.
5. Filters are allowed to cool.
6. Filters are soaked for 24 hours to saturate the filter before flow testing.
7. The flow rate of each filter is tested to ensure a rate of between one and two liters per hour – filters outside this range are discarded.
8. Filters are allowed to dry again.
9. 2 mL of 3.2 percent colloidal silver in 250 mL of filtered water are applied with a brush to each filter.
10. Filters are dried and sold.

Factory costs are calculated based on a daily output of 40 filters. The filters are sold for US$4.00 per filter to primarily NGOs interested in establishing their own water filtration program. Filters are sold without packaging or a finished water receptacle. The NGOs purchasing the filters bring cardboard boxes and trucks for delivery. Receptacles range from 20 liter plastic buckets at US$3.00 each, to a basic ceramic model at US$8 each, to a very elaborate painted ceramic model at US$60.00 each. NGOs primarily purchase the basic plastic model because of ease of transport, light weight, non-breakable material, and lower cost.

In total, approximately 12,000 filters have been sold to organizations that then distribute and support the filters in the communities. The largest purchasers buy 600 – 1,000 filters at a time. Organizations which have purchased large numbers of filters include: Red Cross Nicaragua, Plan International, Accíon Medíca Christiana, ADOVEC, PRONICA, and Médicos del Mundo. Most organizations receive funding from a donor or a grant to purchase the filters, and then distribute the filters in the communities. Because these are often one-time grant funded purchases, money is often not allocated for staff time in training and follow-up with families on filter system use.

Organizations which have purchased the filter from the factory in Managua include:

Federación Internacional de la Cruz Roja
ACSUR (Las Segovias – Cruz Roja Española)
Médicos del Mundo (Spain)
Médicos sin Fronteras (Belgium)
ENACAL – UNICEF (Matagalpa, Nicaragua)
SILAIS (Jinotega, Nicaragua)
Plan International
Project Concern International – USAID (CPI)
Fundación Rio
Alcaldía de Posoltega
Coorinadora San Juan de Limay
Centro e la Mujer Xochilt Acalt (Malpaisillo)
Centro de la Mujer San Francisco Libre
Comunidad Los Pasos
Voluntarios Cuerpo de Paz (Peace Corps)
Fundación Sol (Ocotal, Nicaragua)
Tecuilcan – Managua (Proyecto Nueva Vida)
Cantera
FUMDEC (Matagalpa, Nicaragua)
ADIC (Matagalpa, Nicaragua)
ADOVEC (Jinotego, Nicaragua) (With InterAmerican Foundation Funding)
Asociación de Madres La Paz Centro
Siempre Verde (Matagalpa, Nicaragua)
Hermanas del Buen Paston (Proyecto Nueva Vida)
PRONICA
AMLAE (San Juan de Limay)
Comité de Mujeres (Ocotal, Nicaragua)
Tienda Campesina (Achuapa)
Family Planning International (Guatamala)
CORDES (El Salvador)
Accíon Medíca Christiana (San Francisco Libre)

In addition to production in Nicaragua, Ron has worked with interested people and organizations in other countries to establish their own filter factories. People find PFP and the water filtration system via the internet, and contact Ron. Ron will then visit and help set up a filter factory. In 2000, factories were established in Mexico, Bangladesh, and Cambodia. In 2001, factories were established in Haiti, Guatemala, El Salvador, and Nepal. These factories operate on a smaller scale than the Managua factory, but they follow the model of the development of the Managua site, and could all grow to meet demand.

In addition, factories are in the development stage for 2002 in Pakistan, Uzbekistan, and Ghana.

3 Waterborne Disease

3.1 Waterborne Disease

In the Report of the WHO Commission on Health and Environment (undated), the WHO described three mechanisms of transmittal for waterborne diseases. The three modes of transmission are:

1. Waterborne diseases

   "These arise from the contamination of water by human or animal faeces or urine infected by pathogenic viruses or bacteria, which are directly transmitted when the water is drunk or used in the preparation of food."

2. Water-washed diseases

   "Scarcity and inaccessibility of water make washing and personal cleanliness difficult and infrequent. Where this is so some diarrhoeal diseases and contagious skin and eye infections are prevalent. All waterborne diseases can also be water-washed diseases…. Water-washed diseases diminish whenever an adequate supply of water is available and used."

3. Water-based diseases

   "Water provides the habitat for intermediate host organisms in which some parasites pass part of their life cycle."

In addition, the WHO detailed the public health impact worldwide of waterborne diseases (Table 3-1). A number of diseases have not yet had morbidity, mortality, and population at risk statistics developed, however, the statistics that have been enumerated show that a significant fraction of the world population is both at risk for, and contracts, waterborne diseases.

Table 3-1: Worldwide Public Health Impact of Waterborne Disease (WHO, undated)

Disease	Morbidity (per year)	Mortality (deaths / year)	Population at risk
Waterborne & water-washed			
Cholera			
Diarrheal disease	1,500 million episodes in children under 5	4 million in children under 5	over 2,000 million
Enteric fevers	500,000 cases	25,000	
Poliomyelitis	204,000	25,000	
Ascariasis (roundworm)	1,000,000	20,000	
Leptospirosis			
Trichuriasis			
Water-washed			
Trachoma	6 – 9 million blind		500 million
Leishmaniasis	400,000 new infections / year		350 million
Relapsing fever			
Typhus fever			
Water-based			
Schistosomiasis	200 million	200,000	500 – 600 million
Dracunculiasis	over 10 million		over 100 million

The microorganisms that cause these waterborne diseases are classified as bacteria, protozoa, viruses, and helminths (Levinson, 1996). These four organisms belong to different kingdoms and are eukaryotic (containing DNA with a nuclear membrane), prokaryotic (without a defined membrane), and noncellular (Table 3-2).

Table 3-2: Biologic Relationships of Pathogenic Microorganisms (Levinson, 1996)

Kingdom	Pathogenic Microorganism	Type of Cell
Animal	Helminths	Eukaryotic
Protist	Protozoa Fungi	Eukaryotic Eukaryotic
Prokaryote	Bacteria	Prokaryotic
	Viruses	Noncellular

Bacteria are single-celled prokaryotic (without nucleus) members of the eubacteria group (MEI, 1991). Although they are not eukaryotes (with a defined nucleus), they have similar cell chemistry to eukaryotes. Their size varies from 0.3 to 100 µm in length, depending on their shape (Table 3-3). *E. coli* is a rod shaped bacteria that is 0.5 µm in width and 2 µm in length. Most of the bacteria are larger than the 1µm pore size that Potters for Peace aims to maintain in their filter.

Table 3-3: Bacteria Types and Size (adapted from MEI, 1991)

Shape	Name	Size
Spherical	cocci, coccus	1 – 3 µm in diameter
Rod	bacilli, bacillus	0.3 – 1.5 µm in width 1.0 – 10 µm in length
Curved rod	vibrios	0.6 – 1.0 µm in width 2 – 6 µm in length
Spiral	spirilla	up to 50 µm
Filamentous		up to 100 µm and longer

Protozoa are single-celled eukaryotic (with a nucleus) organisms. They feed on bacteria and other microscopic organisms. *Giardia lamblia* and *cryptosporidium* are common disease-causing protozoa. Protozoa range in size from 8 – 100 µm.

Viruses are parasitic particles consisting of a strand of genetic material. They do not have the ability to synthesize new compounds, and instead invade the host cell and redirect the host genetic material to produce viral particles. Because they do not have the structure to reproduce themselves, viruses are the smallest of the disease-causing organisms, at 0.02 – 0.2 µm.

Helminths are worms that are part of the animal kingdom. Platyhelminthes (flatworms) and Aschelminthes (flukes, tapeworms) are present in water bodies throughout the world, and enter the human body to cause diseases such as trichinosis, hookworm, and roundworm infestation.

Infectious agents commonly found in drinking water include members of the bacteria, virus, protozoa, and helminth groups and cause diseases ranging from diarrhea to jaundice to acute respiratory illnesses (Table 3-4).

Table 3-4: Waterborne Disease-Causing Organisms (MEI, 1991)

Organism	Disease	Remarks
Bacteria		
Escherichia coli	Gastroenteritis	Diarrhea
Legionella pneumophila	Legionellosis	Acute respiratory illness
Leptospira	Leptospriosis	Jaundice, fever
Salmonella typhi	Typhoid fever	Fever, diarrhea
Salmonella	Salmonellosis	Food poisoning
Shigella	Shigelloisis	Bacillary dysentery
Vibrio cholerae	Cholera	Heavy diarrhea, dehydration
Yersinia enterolitica	Yersinosis	Diarrhea
Viruses		
Adenovirus	Respiratory disease	
Enteroviruses (67 types, including polio, echo, etc.)	Gastroenteritis, heart anomalies, meningitis	
Hepatitis A	Infectious hepatitis	Jaundice, fever
Norwalk agent	Gastroenteritis	Vomiting
Reovirus	Gastroenteritis	
Rotavirus	Gastroenteritis	
Protozoa		
Balantidium coli	Balantidiasis	Diarrhea, dysentery
Cryptosporidium	Cryptosporidiosis	Diarrhea
Entamoeba histolytica	Amebiasis	Diarrhea, bleeding
Giardia lamblia	Giardiasis	Diarrhea, nausea, indigestion
Helminths		
Ascaris lumbricoides	Ascariasis	Roundworm infestation
Enterobius vericularis	Enterobiasis	Pinworm
Fasciola hepatica	Fascioliasis	Sheep liver fluke
Hymenolepis nana	Hymenolepiasis	Dwarf tapeworm
Taenia saginata	Taeniasis	Beef tapeworm
T. solium	Taeniasis	Pork tapeworm
Trichuris trichiura	Trichuriasis	Whipworm

Thus, a number of different organisms of varying size and pathology contribute to waterborne disease throughout the world. Two mechanisms in the PFP filter contribute to reduction of these organisms. The first mechanism is filtration. The PFP filter will trap any particle or organism that is larger than the pore size of the filter. PFP aims to have a pore size of 1 µm (1 micron). This would trap a significant portion of bacteria, and all protozoa and helminths. However, viruses are smaller than 1 micron, and thus would not be trapped.

To date, no studies have been completed analyzing the pore size of the PFP filter. For Report 1 of this study (December 2001), analysis of the pore size of the PFP filter and retention rates of selected viruses and protozoa will be completed.

The second inactivation mechanism for organisms contributing to waterborne disease utilized in the PFP filter is colloidal silver.

4 Colloidal Silver as a Disinfectant

Silver is a soft, malleable metal, which is stable in water and oxygen but attacked by sulfur compounds in air to form a black sulfide layer (CRC, 1997). The atomic number of silver is 47, its atomic weight is 107.868, and it exists in its common valence states of Ag^{+}, Ag^{2+}, and the mineral form of argentite, $Ag^{2}S$. Typical ambient concentrations of silver are presented in Table 4-1. Silver is present throughout the environment in small concentration (milligram to nanogram), but is not essential for animal or plant life.

Table 4-1: Typical Ambient Concentrations of Silver (adapted from CRC, 1997)

Content	Concentration
Total Content in Soils	0.03 – 0.9 mg/kg
Soluble Content in Soils	0.01 – 0.05 mg/kg in 1 N NH_4AOC
Content in Sea Water	0.04 µg/kg
Content in Fresh Water	0.13 µg/kg
Content in Marine Animals	3 – 10 mg/kg
Content in Humans	Blood: < 2.7 µg/L Bone: 1.1 mg/kg Liver: <5 – 32 ng/g
Content in Animals	6 µg/kg
Content in Plants	0.01 – 0.5 mg/kg
Content in Common Foods	0.07 – 20 mg/kg
Essentiality	Plants: no Animals: no

The daily dietary intake by humans is estimated at 0.0014 to 0.08 mg (CRC, 1997). When the maximum CRC intake per day (0.08 mg) is calculated over a 70-year lifetime, a total of 2.0 grams of silver are ingested per person per lifetime.

$$0.08 \text{ mg / day} \bullet 365 \text{ days / year} \bullet 70 \text{ years} = 2.0 \text{ grams / lifetime}$$

Toxic intake for humans is 60 milligrams, while a lethal intake is 1.3 to 6.2 grams (CRC, 1997).

4.1 Silver Human Health Standards and Regulations

4.1.1 World Health Organization (WHO)

In their Guidelines for Drinking-Water Quality, 2nd Edition (1993), the WHO addressed human health effects of silver and guidelines values to prevent those effects.

WHO determined that:

1. The retention rate of silver in humans and animals is only 0 – 10 percent. The retained silver is mainly stored in the liver and skin. The half-life of silver in the liver is 50 days.
2. Silver is occasionally found naturally in ground and surface water at 5 µg/L.
3. Average human intake of silver is 7.1 µg/day.
4. The acute lethal dose of silver nitrate is a minimum of 10 grams.
5. Argyria is the only known human health effect of silver, and "is a condition in which silver is deposed on skin and hair."

Based on their research, the WHO recommended a guideline value for silver of 10 grams per lifetime. This is a NOAEL (no observed adverse exposure limit) standard. WHO concludes by stating "as the contribution of drinking-water to this NOAEL will normally be negligible, the establishment of a health-based guideline value is not deemed necessary." In 1996, the WHO reiterated this determination by designating silver as a "U" compound. "It is unnecessary to recommend a health-based guideline value for these compounds [U compounds] because they are not hazardous to human health at concentrations normally found in drinking-water."

However, the WHO addresses the fact that silver is often used as a disinfectant, and in such cases, "the daily intake of silver from drinking-water can constitute the major route of oral exposure." Thus, WHO has established an additional guideline value for when silver is "used to maintain the bacteriological quality of drinking-water." This guideline states "higher levels of silver, up to 0.1 mg/L (this concentration gives a total dose over 70 years of half the human NOAEL of 10 g) could be tolerated in such cases without risk to health."

Thus, the guideline value appropriate for use in analyzing the PFP filter is 0.1 mg/L (or 100 µg/L) in the finished, filtered water.

4.1.2 United States Environmental Protection Agency (USEPA)

The USEPA has also investigated silver to determine appropriate drinking water standards. The USEPA recommends a maximum intake of 5 µg/kg/day (1996). In the average 70 kilogram adult, this is equivalent to 350 µg/day. This recommendation was established to prevent argyria, "a medically benign but permanent bluish-gray discoloration of the skin. Argyria results from the deposition of silver in the dermis and also from silver-induced production of melanin." Argyria is "more pronounced in areas exposed to sunlight due to photoactivated reduction of the metal", and "although the deposition of silver is permanent, it is not associated with any adverse health effects."

In addition, “no evidence of cancer in humans has been reported despite frequent therapeutic use of the compound over the years.” Silver was used for centuries to treat syphilis, and as an astringent in topical preparations.

The 2001 National Secondary Drinking Water Regulations recommends a maximum silver concentration of 0.10 mg/L (or 100 µg/L), but specifically states that “EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards.” These secondary non-enforceable guidelines regulate “contaminants that may cause cosmetic effects or aesthetic effects in drinking water.” The USEPA does not address separate standards for use of silver as a disinfectant. It is of note that the USEPA secondary standard is the same as the WHO guideline value for use of silver as a disinfectant: 0.1 mg/L or 100 µg/L.

4.1.3 Argyria

Argyria, “a medically benign but permanent bluish-gray discoloration of the skin,” develops over time due to silver absorption into the skin (USEPA, 1996). Argyria begins in the eyes and the fingertips, and continues throughout the skin, especially in areas that are exposed to sunlight (Egli, personal conversation). The condition is irreversible, disfiguring, and non-cancer causing (Jacobs, 2001; USEPA, 1996). Current cases of argyria have resulted from: ingestion of silver coated candy to prevent smoking in Japan (Hanada, 1998), implanted acupuncture needles (Suzuki, 1997), an impacted earring (Sugden, 2001), treatment of venous leg ulcers using silver sulphadiazine (Russell, 1994), and ingestion of naturopathic colloidal silver (Egli, personal conversation).

Rosemary Jacobs, a woman who developed argyria as a child due to intranasal medication for allergies, is a speaker and advocate against the use of silver (Jacobs, 2001). She developed argyria over time as a young teenager, and her skin has been discolored throughout her life. Pictures of Ms. Jacobs convey the image of the effect of argyria on one’s life, even though it is medically benign.

4.1.4 Colloidal Silver and USFDA/USEPA Regulation

A colloidal solution is “a true solution that consists of colloidal macromolecules and solvent and that is thermodynamically stable and readily reconstituted after separation of the macromolecules from the solvent (Stenesh, 1996).” Furthermore, a colloid is “a macromolecule or a particle in which at least one dimension has a length of 10^{-9} to 10^{-6} meters.” Thus, colloidal silver is a stable solution of very small silver particles suspended in distilled water or proteins. Higher concentrations of colloidal silver (such as used by PFP) are suspended in proteins because they would not be stable in water (Quinto, personal conversation).

In 1999, the United States Food and Drug Administration (USFDA) issued a ruling that “all over-the-counter (OTC) drug products containing colloidal silver ingredients or silver salts for internal or external use are not generally recognized as safe and effective and are misbranded. FDA is issuing this final rule because many OTC drug products containing colloidal silver ingredients or silver salts are being marketed for numerous serious disease conditions and FDA is not aware of any substantial scientific evidence that supports the use of OTC colloidal silver ingredients or silver salts for these disease conditions (Federal Register, August 17, 1999)."

The burgeoning naturopathic market for colloidal silver in the United States prompted this ruling. In a cease-and-desist letter issued to Mr. Randy Winters, the USFDA quoted Mr. Winters' web site as stating, "colloidal silver has been proven to be useful against over 650 diseases, including cancer, without any known harmful side effects. It has been found to cause rapid regeneration of damaged cells and tissues, subdue inflammation and promote faster healing (FDA, 2000)." A simple web search for "colloidal silver" leads to numerous sites advertising unsubstantiated healing properties, and another set of sites selling home-based colloidal silver generation machines.

On August 8, 2001, I spoke with Ms. Roma Egli, the colloidal silver contact person at the USFDA, about the PFP filter and the use of colloidal silver for disinfection. Ms. Egli said that the USFDA does not deal with disinfection agents, and that the USEPA would regulate the use of colloidal silver in this manner. As long as PFP does not state that the filters are treating animals or humans for disease, and does not state that the colloidal silver is an antibiotic, the product is not regulated under the USFDA. She also mentioned that colloidal silver is used for water disinfection on transportation systems such as airplanes, trains, and boats. When asked, Ms. Egli did state that she has seen argyria cases in people only using naturopathic colloidal silver. No case she has seen is as severe as Rosemary Jacobs', but she has seen permanently blue fingertips. Overall, Ms. Egli expressed the viewpoint that the USFDA is concerned about labeling of colloidal silver as a medical drug when there is no research to support such claims. They are not concerned with colloidal silver as a disinfectant, and in fact Ms. Egli recommended that I talk with the Silver Institute (a promoter of colloidal silver as an antibiotic) about purchasing a generator to make colloidal silver in Nicaragua rather than importing it from Mexico. Because the generators are only capable of producing colloidal silver in the ppm range, as opposed to the 3.2 percent solution that PFP uses, this idea was determined to be not appropriate for PFP.

I then spoke with Wade Travathan, of the USEPA, about colloidal silver as a disinfectant. The EPA Office of the Pesticide Program regulates disinfectants because microorganisms in the United States are legally classified as pests. Thus, any product that kills microorganisms is classified under federal law as a pesticide. Mr. Travathan said that there are current, active products that are registered with EPA that use colloidal silver as a disinfectant. To become registered as a pesticide, you submit data that details toxicity and efficacy. You can refer to data that has already been submitted by another company, by offering that company appropriate compensation. The submission forms are available on the web site and submission is free of charge. However, there is a maintenance fee of US$1,000 dollars per year on your permit. The Office of the Pesticide Program can be reached at www.epa.gov/pesticides.

Thus, with the appropriate permitting from the USEPA Office of the Pesticide Program, and data supporting that the finished water concentration of silver is less than the USEPA secondary standard of 100 µg/L, a colloidal silver impregnated filter is a legal product to distribute and use in the United States and meets all USA regulations.

4.2 Silver in Ceramics

Potters for Peace is not the only organization to use silver as a disinfectant in ceramic filtration units. Basu (1982) in India soaked ceramic candle filters with a pore size of 6 – 31 microns, and a filtration rate of 3 – 4 liters per hour, in silver salts. Filtered water with this system was bacteria-free. Basu chose silver over gold as the bacteriocide, and also tested candle filters with finer pores that would capture the bacteria. The filtration rate was so slow with these finer pores, however, that the filters were "not of much practical value." Thus a larger pore size, combined with a disinfectant, is of more practical value because the flow rate is high enough to provide enough water for a family.

4.3 Mechanisms of Action of Silver

Russell (1994) details the historic uses of silver, beginning with Aristotle advising Alexander the Great to boil water and store it in silver or copper vessels to prevent waterborne disease on his campaigns. In 1869, Ravelin reported that silver exerted its antimicrobial effect at very low concentrations, an effect with was later termed "oligodynamic" or "active with few" (Russell, 1994). In 1881, Crede advocated silver to prevent eye infections in newborns, and silver drops were used to prevent gonorrhea of the eye in newborns until very recently. In 1920, the microbiological action of silver was determined to be due to the Ag^+ ions formed by tarnishing, surface-oxidation, or electrical activation.

Today, silver is more commonly used as a drinking water and swimming pool disinfectant in Europe than in the United States (Russell, 1994). Studies have shown that silver can be used when chlorine is present for additional disinfection. Argyria, first reported in 1647, is less common today but is still reported.

Three main mechanisms are responsible for bacterial inactivation with silver (Russell, 1994):

1. Silver reacts with thiol (sulphydryl, SH) groups in the bacterial cell
    a. In structural groups
    b. In functional (enzymic) proteins
2. Silver produces structural changes in bacterial cell membranes
3. Silver interacts with nucleic acids

These three mechanisms are described in further detail in the following sections. Although it is unknown at this time which of these mechanisms is predominant in the PFP filter, laboratory data clearly shows that PFP filters impregnated with colloidal silver remove 99 – 100 percent of bacteria (CIRA-UNAN, various dates). Further information on the mechanism of action of colloidal silver in the filter and data on laboratory tests on the filter are presented in Report 2 (December 2001).

Heinig's research on silver deposited on an inert surface is of special note in relation to the PFP filter. Heinig (1993) showed silver on a large inert surface area exhibited a strong catalytic reaction with oxygen, which resulted in strong bactericidal activity. The factors controlling the rate of the catalytic reaction were: the size and dispersion of the silver on the surface area of the bed, and the volume of oxygen in solution. Heinig found that bacteria and viruses were killed on contact without the need for the release of metals into the water.

4.3.1 Silver as an Enzyme Inhibitor

"Living cells are characterized by a complex and beautifully organized pattern of chemical reactions mediated and directed by enzyme systems (Webb, 1963)." Webb continues by describing the theory of inhibiting enzymes as a means to understanding the "energetics of the cell."

> Directly distorting the pathways of enzymically directed reactions by the introduction of a chemical substance is one approach amongst others to alter metabolic activity. Other ways to alter metabolic activity including changing the temperature or the pH, by irradiation of high pressure, are nonspecific and seldom does one have any idea as to exactly what is occurring in the complex protoplasmic matrix. If one had to choose the most interesting and important characteristic of enzyme inhibitors, what it is that makes them one of the most powerful tools in so many fields of biological investigation, it would be their relative specificity. The more we know about the exact nature of the perturbation produced and the more selective this action can be made, the more likely it is that clear interrelationships will emerge and the goal of understanding the energetics of the cell be achieved.

A number of metals are known to inactivate the SH (sulfur-hydrogen, or sulfhydryl, or thiol) bond in enzymes. Silver is widely used in biochemistry applications to determine if an enzyme has a SH group as part of its functional structure.

Webb's summary of data collected on the action of silver on the SH bond shows extremely varied inactivation depending on specific enzyme and concentration (Table 4-2). These different reactivities could be attributed to an electric field surrounding the SH group, steric factors depending on where the SH group is in the protein structure, occurrence of disulfide linkages, complexes of the SH group with surrounding groups, and whether there is a single or double SH group. Other SH inhibitors studied include mercury, arsenite, cadmium, iodine, ferricyanide, and permanganate.

Although there exists a large variation, silver clearly inactivates certain enzymes in sources that are responsible for waterborne disease (Table 4-2). Waterborne disease sources are boldfaced in Table 4-2.

Table 4-2: Comparison of Enzyme Inhibition by Silver (adapted from Webb, 1966)

Enzyme	Source	Concentration of Ag^+, mM	Reference
Adenosinase	***Vibrio cholerae***	0.07	Agarwala, 1954
Alanine dehydrogenase	*Bacillus cereus*	0.1	O'Connor, 1960
Aldehyde dehydrogenase	*Acetobecer suboxydans*	0.015	King and Cheldelin, 1956
Aldolase	Rabbit muscle	0.02	Herbert et al, 1940
α-Amylase	*Bacillus subtilis*	0.1	Di Carlo and Redfern, 1947
β-Amylase	Sweet potato	0.01	Englard et al, 1951
Aspartase	*Propionibacterium peterssonii*	1	Ellfolk, 1953
Aspartase	***Escherichia coli***	1	Ichihara et al, 1955
ATP:P_i exchange enzyme	Rat liver	0.05	Chigo and Plaut, 1959
Carbonic anhydrase	Spinach leaves	0.1	Chiba et al, 1954a
Catechol oxygenase	Pseudomonas fluorescens	0.01	Hayaishi et al, 1957
Cholinesterase	Human erythrocytes	1	Mounter and Whittaker, 1953
Creatine kinase	Rabbit erythrocytes	0.1	Solvonuk et al, 1956
2'-Deoxyribosyl-4-aminopyrimidone-2,5-diP aminohydrolase	Monkey liver	0.01	Scarano et al, 1962
Dihydroxyacid dehydratase	Spinach leaves	0.2	Kanamori and Wixom, 1963
Elastase	Flavobacterium	1	Mandl and Cohen, 1960
FMN phosphatase	Rat liver	5	McCormick and Russell, 1962
β-Galactosidase	***Escherichia coli***	0.165	Knopfmacher and Salle, 1941
D-Glutamate oxidase	Aerobacter sp.	5	Mizushima and Izaki, 1958
Hydrogenase	***Escherichia coli***	1	Joklik, 1950 b
Leucine aminopeptidase	Rat kidney	10	Green et al, 1955
NADH:cytochrome c oxidoreductase	Pig liver	3	Garfinkel, 1957
NADH:H2O2 oxidoreductase	*Streptococcus faecalis*	0.001	Dolin, 1957
3-Phosphoglyceral-dehyde dehydrogenase	Rabbit muscle	0.01	Park et al, 1961
Proteinase	*Trifoium repens*	20	Brady, 1961
Protein disulfide reductase	Peas	0.009	Hatch and Turner, 1960
Pyrosphosphatase	Human erythrocytes	0.2	Nagnna and Menon, 1948
Pyruvate decarboxylase	Yeast	0.0025	Stoppani et al, 1952
Urocanase	*Pseudomonas aeruginosa*	1	Ota et al, 1956

Berger (1976) compared electrically generated silver (colloidal silver) with silver sulfadiazine and found that 16 organisms were inhibited at 1.25 µg/mL colloidal silver, and killed at 10.5 µg/mL colloidal silver (Table 4-3). With silver sulfadiazine, inhibition rates were much higher. Colloidal silver ions acted by altering the mesosomal function of the cell. The mesosome is a part of the cell wall that is responsible for respiration. Mammalian cells showed no inhibition of function due to the silver.

Table 4-3: Concentration Needed for Inhibition and Inactivation of Bacteria

	Concentration needed for Inhibition (µg/mL)	Concentration needed for Inactivation (µg/mL)
E. coli	0.50	2.02
E. coli (dental)	1.03	8.25
Providencia stuartii	0.13	0.73
Proteus mirabilis	0.08	2.51
Pseudomonas aeruginosa	0.31	2.51
Serratia	0.08	0.51
Staphylococcus albus	0.12	0.85
Staphylococcus aureus	0.03	0.26
Staphylococcus aureus	0.25	8.25
Streptococcus group D	0.63	10.05
Streptococcus mitis	0.31	10.05
Streptococcus monila	1.25	10.05
Streptococcus mutans	0.63	10.05
Streptococcus pyogenes	0.24	0.48
Streptococcus pyogenes	0.24	0.48
Streptococcus salivarius	1.03	8.25

A number of other studies in the literature detail the effects of silver on different bacteria at varying concentrations.

4.3.2 Silver Interaction with Cell Walls

Russell (1994) details that silver binds to the cell membrane of bacteria. Sensitive cells then increase in size and cytoplasmic contents, and cell membrane and outer cell layers all present abnormalities. These abnormalities result in cell lysis and death. Hugo (1971) also discusses the role of silver in causing cell lysis, as the silver replaces compounds in the cell membrane that are required for cell membrane stability.

4.3.3 Silver Interaction with Nucleic Acids

Russell (1994) details the reaction between Ag^+ and the GC (guanine-cytosine) and AT (adenine-thymine) DNA base pairs). With UV-exposed DNA, the Ag^+ - DNA complex causes thymine dimerization and prevents DNA replication.

4.4 Silver in Medicine

Ever since Crede (1881) introduced the use of silver nitrate for the prevention of gonorrhea opthalmicum, silver has been a useful disinfectant in medicine. Although it fell out of favor in the 1930's due to the introduction of antibiotics and studies on argyria, silver is still studied, and used, in medicine today.

Becker (2000) tested silver for the regeneration of bone after trauma using a silver nylon anode consisting of silver crystals averaging 50 nM in diameter. Over 100 patients have been treated with no effects of argyria. The average rates of granulation tissue growth were noted as around 1 cm^2/day, a rate ten times higher than the non-silver-treated open bone graft granulation rate of 0.1 cm^2/day. With silver iontophoretic treatment all soft tissues as well as the vascular supply of the bone become contributors of granulation. Standard in vitro culture of these cells show characteristics of stem cells, indicating dedifferentiation of mature human cells or expansion of preexisting stem cells in the tissues. Becker (2000) states "the responsible agent for these cellular effects is believed to be the electrically generated silver ion."

In addition, silver sulfadiazine is used in acute burn wounds as an antibacterial agent on the skin (Tsipouras, 1997). Silver-coated iodine-colored bandages are specially made for burn patients. In addition, copper / silver ionization is used in the drinking water systems of more than 30 hospitals in the United States to control *Legionella* (Lin, 1997). *Legionella* is problematic for immuno-comprised patients, such as those with HIV.

Thus, although silver is not used as a wide-scale antibiotic anymore, the microbial inactivation properties of silver are still used throughout medicine on a small-scale, but very present, level.
No matter the exact mechanism in each individual situation, silver and colloidal silver clearly exhibit an antimicrobial effect that has been used for centuries in medicine and to purify water.

5 Previous Field Studies on the PFP Filter

Three main studies had been conducted on the PFP filter prior to the initiation of the enclosed report. These studies were: an epidemiological study completed by AFA Guatemala, ICAITI and the Harvard School of Public Health in 1995, a study with focus groups of women using the current PFP filter in Nicaragua in 2000, and studies of families currently using the PFP filter in Nicaragua conducted by a social worker from 1999 – 2001.

5.1 Guatemala Study

AFA Guatemala began implementing the PFP water filter in rural areas of Guatemala because of the 80 percent poverty rate and the subsequent effects of undernourishment, malnourishment, preventable common illnesses and infant mortality (1995). A third of the children under five were thought to have diarrhea. Because chlorination and boiling were not found to be practical or acceptable, AFA Guatemala began to work with ICAITI to implement water filtration. The objective of this study was to determine if an education program in conjunction with ceramic filters helps alleviate the problem of infant mortality. The rate of diarrhea in under-5 year-old children was used as a metric for infant mortality.

After deciding to use the ICAITI filter, families in three communities were chosen for the study: Costa Sur (on the coast), a poor section of Guatemala City, and communities in the high plateau region. Families were selected to have similar socioeconomic status, incidence of diarrhea in children, number of children under five, microbiological contamination in source water, and hygiene habits. Families were grouped into four groups based on what they received:

1. Education
2. Filters
3. Education and Filters
4. Control (received neither education or filters)

The total number of people in the study is detailed in Table 5-1, with the total number of children under five in each group detailed in Table 5-2.

Table 5-1: Families by Region in the AFA Guatemala Study

Groups	Total	Costa Sur	Guatemala City	High Plateau
Education	161	70	59	32
Filters	176	70	70	36
Filters & Education	167	70	63	34
Control	176	70	68	38
Total	680	280	260	140

Table 5-2: Children under-5 by Region in the AFA Guatemala Study

Groups	Costa Sur	Guatemala City	High Plateau	Total
Education	115	91	59	265
Filters	115	112	62	289
Filters & Education	118	111	68	297
Control	101	107	61	269
Total	449	421	250	1120

For the education piece of the program, AFA Guatemala worked with small groups of women using six modules that covered three aspects of human health: physical, psychological, and holistic medicine. The physical section included human physiologic, hygiene, and nutrition. The psychological section included family planning, childhood development, and communication in relationships. The six modules covered: hygiene, oral rehydration therapy, the danger to the body of bad water and dehydration, basic nutrition, traditional family values, and nutrition during pregnancy. The total education course was 60 hours long.

Throughout the two-year long study, bacterial samples and family visits were conducted every two weeks. Results indicated few technical problems with filter, and 91 percent of filtered water had no bacterial contamination.

At the end of the study, incidence of diarrhea based on bimonthly surveys for 24 months from December 1993 – November 1994 showed clearly that families with education and filters had the lowest percent of diarrhea in children under five (Table 5-3). In addition, education and filter use on their own reduced the rate of diarrhea, but not as significantly as education and filter use in conjunction.

Table 5-3: Percent Diarrhea in Children under-5 in the AFA Guatemala Study

Group	Total	Costa Sur	Guatemala City	High Plains
Education	4.21	4.71	4.78	2.29
Filters	2.5	2.46	3.7	0.38
Education / Filters	1.88	1.68	3.03	0.3
Control	5.34	6.57	5.91	2.34

Fecal coliform sampling in the three communities shows that before filtration, risk from disease-causing organisms varied from low to extreme across the three communities (Table 5-4).

Table 5-4: Fecal Coliform Results in AFA Guatemala Study

	Costa Sur	Guatemala City	High Plateau
First Sampling	270	45	5.2
Second Sampling	261	0.67	19
Third Sampling	74	104	2.7

1 – 10	Low risk
11 – 50	Medium to high risk
50 and higher	Extreme risk

The researchers concluded that the filter was readily accepted by the community, significantly diminished the diarrheal disease of children, and did not have cultural barriers. The combination of filters and education was most effective for reducing under-5 diarrhea, and education was most effective when it was continuous and scheduled at a good time for the community. They recommended implementation of both of these low-cost measures on a nationwide scale throughout Guatemala.

5.2 Tulane Study

In 2000, students from Tulane University visited three communities in Nicaragua using the Potters for Peace filter and held focus group meetings with women who had received the filter. The three communities visited were Ocotal, Matagalpa, and Malacotova. The percent usage of the filter by women who attended the focus groups varied from 20 – 70 percent (Table 5-5). The low rate in Malacotova was attributed to bronze spigots that leaked, the lack of follow-up by the cooperating NGO, and the fact that MINSA regularly distributes chlorine tablets in the community.

Table 5-5: Filter Usage Rates in Tulane Study

Community	Percent Usage
Ocotal	70
Matagalpa	70
Malacotova	20

Women were asked what they liked about the filter, and one woman responded by saying:

> The difference to us is that it is fast, it is easy to manage, and there are not complications in using the two pieces, the filters given to us by other organization are more complicated, thus the majority don't use them.

In addition, women found it easy to use, easy for their children to use, and they liked the fact it was a closed system and it kept the water cool.

When asked why they no longer used the filter the most common responses were:

1. Not enough water flows through the filter.
2. The filter or the spigot is broken.
3. The filter or the spigot leaked.
4. Men leave for the fields in the morning and take all the water.

Quotes from the women on why they no longer used the filter include:

> "The filter doesn't filter."
> "It broke when we were cleaning it."
> "The filter had cement inside that prevented it from filtering."
> "It is pretty but delicate."
> "When you clean it you have to take it out and replace it very carefully, it is small but heavy."

The Tulane students concluded that the three main factors which inhibit use of the filter are:

1. Too low of a filtration rate.
2. Malfunctioning.
3. Fragileness.

They recommended a "spare parts" storage facility in each location that could be used when parts were broken, and highlighted the need for continued health monitoring of the families.

5.3 Social Studies of the Filter

In 1999 – 2001 Mariela Mena Valerio, a social worker in Nicaragua, conducted social studies of communities utilizing the PFP filter in Nicaragua. Ms. Valerio was hired by PFP to provide information on social factors that influenced use of the filter, the filter's impact on user populations, and problems that were occurring in the field with the filter. The survey evolved as the study continued, so the same questions were not asked in each community. The percent usage of the filter in each community ranged from 10 – 94 percent (Figure 5.1) and Ms. Valerio determined that the usage was correlated with:

1. Education
2. Training
3. Health capacity

She also concluded that communities need to develop projects to create a conscience about why clean water is important before filters will be accepted and used in a community. A promotional period should be designed to implement the filter. Then, training about filter use and continued follow-up is "indispensable" to filter success.

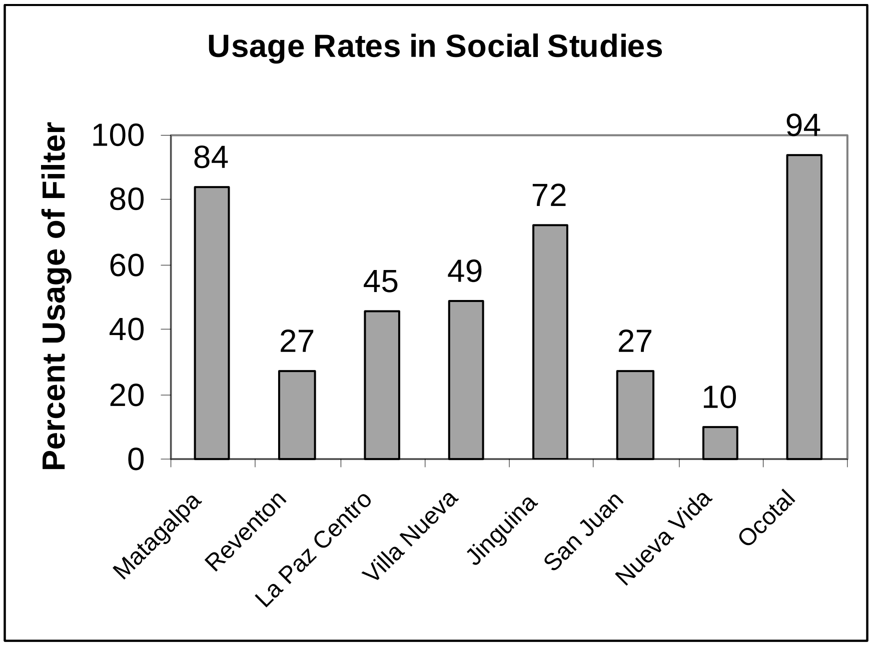

Figure 5.1: Percent Usage by Community in Social Studies

Other conclusions from her work include:

- Many NGOs had families apply the colloidal silver to their own filters. This had the benefit that the families knew why their filter worked, but had the drawback that a number of families never applied the colloidal silver.
- In Matagalpa, the NGO partner felt an important reason people used the filter is that the Ministry of Health and USAID had installed a system that was more complex to use. Because the PFP filter was easier and more practical, people used it more.
- The NGO partner in Matagalpa also felt people did not know how to clean the filter appropriately. Ms. Valerio also found this in her studies. She recommended education for the families about cleaning the filter with a toothbrush, and also noted in Jinotega that 60 percent of the families cleaned their filter with water directly from the contaminated source.
- The most common problems seen in the studies were low filtration rates, and broken filters and spigots.
- Ms. Valerio recommended filling the filter with water multiple times per day to obtain a greater amount of water per day.
- Filters need to have economic value to the family if they are to be used.

The results of these three studies show that the filter can be effective at reducing diarrheal disease in children under 5, yet there are some problems in the current implementation of the program that could be solved by better initial education and continued follow-up with the filter in each community.

6 Field Sampling Methodology

The goals of the field sampling were to:

1. Determine if families were using the filter and if they were doing so correctly.
2. Determine the factors that affect usage of the filter.
3. Determine the effectiveness of the filters in the field.

To investigate these goals, a twofold approach was developed. First, a survey was designed for families that asked questions about water supply, filter usage, and family health. Secondly, a field sampling methodology was developed that sampled for water quality variables, including microbiological sampling, of water before and after filtration. The findings of the survey were compared with the water quality results to determine if the filters were being used correctly and effectively in the field. Lastly, these results were used to compare the PFP filter with two other household water filtration systems also used in rural areas of developing countries.

6.1 Household Survey

The survey administered to families during the sampling procedure consisted of three sections: one on water supply, one on filter usage, and one on family health. The goal of the survey was to determine factors that correlated with filter use and to gain of understanding of the water situation in each home.

The first section addressed access to water supply. The questions asked were:

1. Where do you go for your water?
2. How many times per day do you gather water?
3. Who gathers the water?
4. How long is the wait at this source?
5. Is there always water at this source?
   a. When is there no water is this source?
   b. Where do you go then?
6. Do you think the water at this source is clean?
7. Who constructed this source?
8. Do you ever buy water?

The second section addressed usage of the PFP filter. The questions asked were:

1. How old is the filter?
2. How many times per day do you use the filter?
3. How much time does it take for the water to filter?
4. When do you add more water to the filter?
5. How many people use the filter every day?
   a. How many adults?
   b. How many children?

6. When do you drink unfiltered water?
7. With what do you clean the filter (sponge, towel, water)?
8. How often do you clean the filter?
9. Have you had any problems with the filter?
10. What do you use the water in the filter for?
11. Do you always use the filter?
12. What do you drink when you are not at home?
13. What do you like about the filter?

After the first day of sampling, the additional question "With what water do you clean the filter (well, filtered, river?" was added to the survey.

The third section addressed family health. The questions asked were:

1. When do you wash your hands?
   a. After going to the bathroom?
   b. Before eating?
   c. Before cooking?
2. What type of bathroom do you have?
3. Where is the bathroom?
4. In the last month, how many days has each of your children had diarrhea?

The survey was administered in Spanish by Potters for Peace staff member Ivania Jerez. An adult family member, with knowledge of filter use in the household, was chosen to complete the survey. Responses were recorded on data sheets, and reviewed and translated nightly.

6.2 Water Quality Data

Water quality data was collected in each home both before and after filtration. To ensure comparable data, filters were completely emptied upon arriving at a home to sample. The filter was then filled with the water normally used by that family in the filter. Water quality sampling was then completed on the water used to fill the filter. We then returned 2 – 4 hours later to collect and sample water from the receptacle.

Two criteria were used to select the water quality parameters to be tested in Nicaragua: parameters that might influence filter effectiveness, and parameters that effect human health. A total of eight chemical water quality parameters were initially selected, and based on field observation, flow was added as an important parameter after the first day of sampling. In addition, three measurements of bacteria – total coliform, *E. coli*, and hydrogen-sulfide producing bacteria – were selected for sampling.

Table 6-1: Water Quality Parameters Measured in Field Sampling

Parameter	Reason for Sampling
DO (mg/L)	Might be a catalyst for bacteriological inactivation with silver (Heinig, 1993).
Turbidity (NTU)	Possibly related to filtration rate.
Temperature (C)	Determine effect of plastic and ceramic receptacles on finished water.
pH	Indicator of water chemistry.
Salinity (ppt)	Human taste effect.
Conductivity (µS/cm)	Indicator of water chemistry.
TDS (ppm)	Indicator of water chemistry.
Silver (ppb)	Human health effect – argyria.
Flow Rate (L/hr)	Determine if there is enough drinking water produced per day for an average family.
Microbiological Sampling:	
Total Coliform	Indicator of presence of bacteria that can cause waterborne disease.
E. coli	Organism causing waterborne disease.
H_2S-producing bacteria	Indicator of presence of bacteria that can cause waterborne disease.

Dissolved oxygen was measured with a LaMotte Modified Winkler test kit. The author has conducted studies comparing LaMotte dissolved oxygen kits with calibrated laboratory meters in the past, and found that the standard error when comparing the two methods is less than five percent (Lantagne, 2000).

Turbidity was measured with a Hach Pocket Turbidimeter. The meter was calibrated once per week with 1 and 20 NTU solutions purchased from Hach. The meter was also checked daily with standard solutions to ensure no deviation. The second week of the field sampling there was some difficulty calibrating the meter due to accumulation of humidity in the sampling port, and the turbidimeter was placed in front of a fan overnight to dry it out. The meter then calibrated correctly, although readings in the field varied $^+/-$ 0.5 NTUs. Thus, the error bar on each sample is $^+/-$ 0.5 NTUs.

pH, conductivity and total dissolved solids were measured with a Hanna portable HI9812 multimeter. A two-point pH calibration (4 and 7), and a one-point conductivity calibration (1.412 mS) were completed weekly. In addition, the meter was checked daily with standard solutions to ensure no deviation. No problems with calibration or deviations from the standards were seen throughout the three-week field trip.

Salinity was measured with a Sper Scientific salt refractometer with automatic temperature compensation that was calibrated weekly.

Silver was sampled using two mechanisms. The first was a Hach Rapid Silver test kit, with a range of 0 – 50 ppb. For the second method, samples were collected in laboratory containers, preserved with nitric acid, kept cold on ice or in the refrigerator, and transported back to the United States for laboratory analysis. The original intention of this duplicate sampling was to evaluate the accuracy of the Rapid Silver test kit as a simple test kit for future use in Nicaragua by Potters for Peace. However, the Rapid Silver test kit employs a filtration mechanism in its procedure. This filtration mechanism does not work at water turbidity above approximately 4.0 NTU. Because much of the water in Nicaragua was above 4.0 NTU, only a subset of the homes was sampled using the Rapid Silver test kit. Due to the turbidity, it was determined that the test kit is not appropriate for use in Nicaragua.

The laboratory samples were kept cold throughout their time in Nicaragua, and on the flight back to the United States. They were delivered to Toxicon Laboratories (a certified Massachusetts state laboratory for silver analysis) and analyzed well before the six-month holding time allowed for preserved samples. Samples were analyzed using an Inductively Coupled Plasma Atomic Emissions Spectometry Method 6010B. Lab and field duplicates were analyzed and met quality assurance standards.

Flow rate was added to the parameters list after the first day of sampling when it was noted that the flow rate in some filters was extremely slow. Flow rate was calculated in one of two mechanisms: (1) If the flow rate was minimal, the flow was calculated by summing the volume of the sample containers collected until the filter was empty and then dividing by the time the filter had been filtering. (2) If the flow rate was high, the rate was calculated by the time it took for the filter to empty completely. This method provided a rough estimate of filtration rate only, with an error range of $^{+}/-$ 50 mL per time collected.

Total coliform and *E. coli* were analyzed using Hach presence/absence with MUG broth. Plastic sampling bottles were sterilized for 10 minutes in boiling water and then stored in clean ziplock bags. Water samples were collected using sterile Whirl-Pak bags with dechlorinating agent and stored on ice no more than six hours before processing. 100 mL of each sample was transferred into sampling bottles and the presence/absence with MUG broth was added using asceptic techniques. Samples were then incubated in a cooler with a heating pad for 48 hours, and analyzed every 12 hours for the color change indicating presence of total coliform and for UV fluorescence indicating presence of *E. coli.* After sampling, bottles were emptied, scrubbed with isopropyl alcohol, and boiled.

Hydrogen sulfide (H_2S) producing bacteria was analyzed using Hach PathoScreen broth, following the same procedures as detailed above.

Three types of duplicate sampling were conducted. The first was simple duplicate samples of the finished water. The second method was to collect a sample of the filtered water that was present in the filter when we arrived at the home. Then the filter was emptied, new water was run, and a second finished water sample was collected. This can be termed a "filter duplicate." The third method was collection of samples for analysis at CIRA-UNAN. Raw and finished water samples were collected from seven homes and enumerated for total coliform, fecal coliform, *E. coli,* and tecal streptococcus in the lab. These results were then compared with the results obtained from the presence / absence testing.

The WHO guideline values and the USEPA standards for total coliform and *E. coli* are 0 colonies / 100 mL of sample, or a negative presence/absence test (1993, 2001). The total coliform presence / absence test is an approved USEPA method for analyzing bacteria in drinking water. Total coliform bacteria include the genera *Escherichia, Enterobactor,* and *Klebsiella.* They are characteristically facultative anaerobic, gram-negative, non-spore-forming, rod-shaped bacteria that can ferment lactose to produce gas (Maier, 2000). Traditionally, total coliform has been the standard to judge water quality. The H_2S-

producing test includes bacteria in the following families: *Salmonella*, *Citrobacter*, *Proteus*, *Edwardsiella*, some *Klebsiella*, and a few other organisms (Manja, 1982). The H_2S test is considered a more appropriate test for tropical areas because in some tropical areas total coliform can be present naturally. Thus, total coliform has a less defined relationship to human waste and human health effects. Both total coliform and H_2S-producing bacteria are indicator tests. Disease-causing organisms are present in drinking water at very low concentrations. Total coliform and H_2S-producing bacteria are present in human waste at much higher concentration. Thus, the presence of these more common, more easily measured organisms indicates the presence of disease-causing organisms. *E. coli* directly measures a bacteria that causes human health effects.

7 Field Visits

7.1 Ocotal

On October 4th and 5th, 2001, field visits were conducted near Ocotal in the department of Nueva Segovia. Located near the Honduras border, this area was hit hard during Hurricane Mitch, and reconstruction of bridges continues even now. Fundación Sol, a non-governmental organization located in Ocotal, works with the local citizens on issues of health and access to medicine.

In August 2000, Fundación Sol purchased 200 filters and distributed them in groups of 10 to 50 throughout small villages around Ocotal. Villages were selected for filters based on their known low quality of water. Families were chosen to receive a filter based on their proximity to a water source. A seminar was conducted for families before distribution that detailed safe health practices and information on how to use the filter. In addition, the Director of Fundación Sol, Edith Matute, has led personal training, skits on local television, and training sessions with community leaders.

If they could afford it, families paid a subsidized price of 50 cordobas (approximately US$4) for the filters. A grant supported the initial purchase and distribution of the filters, but did not include money for extended training, maintenance, or home visits, although Edith has conducted some. She does more continuous follow-up in nearby communities because she does not have a car to access the more distant communities. She does feel the filters work, for every six months she asks people if they have had diarrhea and not many still have diarrhea. She is interested in expanding the program, but needs funding to do so.

7.1.1 El Batidero de Macuilizo

On October 4th, six homes in the village of El Batidero de Macuilizo, approximately a one-hour drive from Ocotal, were visited. Filters were installed in this community 14 months ago, and approximately 6 months ago, a North American Peace Corps volunteer reapplied colloidal silver to all 50 filters in this community. Of the six homes, only two were using the filter appropriately (Table 7-1). All six of these homes were using the ceramic version of the receptacle.

Table 7-1: Usage in El Batidero de Macuilizo

Home	Filter Usage
1	Filter parts all present and assembled, but dry and not used.
2	Using the filter as a container for dried food and the receptacle with water for drinking.
3	Using the receptacle to store and obtain water from, but no filter present.
4	Would not let us see the filter. In another room, not being used.
5	Filter assembled with water in the filter filtering.
6	Filter assembled with water in the filter filtering.

7.1.2 Ciudad Antigua

On October 5th, six houses in Ciudad Antigua, a small village of approximately 3,000 people about 45 minutes from Ocotal, were visited. After Mitch, water in the wells used for drinking water in this community turned pink. A new river formed during Mitch is now the primary source of drinking water for the town and is extremely turbid. Of the six houses visited, four were using the filter correctly, and two were using only the receptacle without the filter for water storage. In this community, all receptacles were plastic.

7.2 Jinotega Field Visits

ADOVEC is a 14-employee NGO working throughout the Jinotega area on projects relating to environment (latrines, filters, and well installation) and food security (family gardens, breastfeeding, and agriculture). ADOVECs funding comes from the InterAmerican Foundation and an organization called Esperanza in Arizona.

ADOVEC initially purchased approximately 550 filters and has distributed 100 filters each in three communities. The remaining 250 filters are still in the office, and ADOVEC plans to distribute these to other communities as time permits. They choose the three communities for filter distribution based on experience with the communities, knowing that there were more problems with water, higher incidence of diarrhea, and a higher population of children in these communities.

Individual families were chosen to receive the filter based on three criteria:

- The mother had to have children under five years old.
- The family had to be poor.
- The families have to do some work in the community.

In each of the three communities is a community leader who supervises the program. Community leaders were chosen based on six years of experience and are also community leaders for other projects.

ADOVEC recommends community leaders visit the houses with filters once per month, although this is not supervised by ADOVEC.

The Executive Director of ADOVEC, Victorino, knew Ron Rivera personally because of Ron's previous visits to Jinotega, and that was why he purchased the Potters for Peace filter. He did not investigate any other filter. He feels the filters have improved health because children have less cases of diarrhea. He speaks directly to the children in interviews with the family, because they know more about their diarrhea than the mothers. A problem he sees with the filters is transportation – some were broken when they arrived. He is working with Ron to establish a factory in Jinotega, and then the filter program will expand greatly. Victorino says the filter is "one of the best options we have here," for it is "cheapest and easiest for the families," and the water is "clear and cool."

7.2.1 Mancotal

Mancotal is a small community approximately one hour from Jinotega. Families use a variety of different water sources, including wells, surface water, and storage tanks of piped groundwater. The community leader knew the type of source each house used for their water supply, and was able to direct us to sample at houses with different sources. All were ceramic receptacles, some very small, except for House 6, which had a plastic receptacle.

In Mancotal, all six houses were using the filter correctly when we arrived in the homes.

7.2.2 Jingüina

Jingüina is a small community also approximately one hour from Jinotega. The community has a piped water supply installed by Ayuda Obrada Swisse and Care International that all families we visited were connected to. Seven homes were visited in this community, and four of the seven were using the filter. Of the three other homes, two had broken filters (as of 15 days ago, and 3 months ago), and one entire filter and receptacle had fallen off the counter and broken completely. The entire community used ceramic receptacles.

7.3 San Francisco Libre Field Visits

The filter program in San Francsico Libre is supported by the NGO Accíon Medíca Christiana (AMC). AMC works with seven communities within the San Francisco Libre area – two traditional campesino communities and five post-Mitch constructed communities with homes close together connected by grided streets. The mission of AMC is to serve and empower the poor, as well as theological aspects. Their projects include sanitary education, community organization, disaster prevention, mental health projects, sanitary construction of wells and latrines, training of other organizations, monetary support to other organizations, support in terms of medicine, fuel and money to MINSA doctors, and the development of a pharmacy in San Francisco Libre. Three people work for the organization. The director is Janice Téllez, and the person in charge of the filter project is Luis.

The seven communities AMC works in were initially chosen using the following criteria:

- Communities affected by Hurricane Mitch.
- Communities without houses, schools, and water.
- Communities not supported by other NGOs.
- Communities where education is needed.

Janice has noticed problems with fights, alcoholism and violence in the families in the five post-Mitch constructed communities, as the Nicaraguan people are not used to living so close to one another. Also, the latrines and water systems are still not quite complete.

Initially when working with the family, AMC made a gift of its projects, for example giving seeds to people for family gardens and food security. Now they ask for something back, in the case of the filters AMC and the community leaders agreed that the filters should cost 20 cordobas. For latrine construction, the families assist as construction labor. In each community are community leaders that AMC works with on many projects. These community leaders are either paid promoters or volunteer educators for the filter, and were the ones to choose the families to receive the filter. Although AMC did not always agree with the choices for the filters, they left the decision to the communities.

Janice estimates that 90 percent of the people who purchased the filter use it for the following reasons: they bought it, they think their water supply is not good water because it is not chlorinated, and because people are trained in the use of the filter. Janice estimates that Luiz spends one day per week on filter follow-up in different communities with the promoters and educators. Also the health education that AMC sponsors is complementary to the use of the filter.

A total of approximately 700 filters have been purchased by AMC, with 283 held in reserve in the office waiting for additional communities. Janice learned of the filters when PFP did a presentation / demonstration to the central office of AMC. Although she would like more filters, there are no set funds for filters or for the follow-up education and this is difficult.

Janice is a doctor, and feels that many changes in health, sanitary health, and food contribute to the reduction of diarrhea. Currently she sees mostly respiratory diseases and parasites. She has seen changes in health in terms of diarrhea and gastrointestinal, but can not say that is due to just the filter. Of note is that part of the reason she thinks the filter works is that the bacteriological testing conducted for this study convinced her.

7.3.1 Los Teisos

On October 18th, two homes in the post-Mitch community of Los Teisos were visited. Approximately 20 – 30 families live in the community, with 24 filters. A paid promoter, the teacher, works within the community to educate and train about the filter. Both families visited were using the filter, with plastic receptacles.

7.3.2 Los Piches

On October 18th, 2001, three homes were visited in another post-Mitch community that pipes water from three kilometers away into a storage container capable of holding 20,000 gallons. Families could choose to be connected to the system directly with pipes to their home or to go to one of the manual spigots in the community. The system was installed by Mujer y Communidad, a Nicaraguan women's organization. All three homes were using the filter, with plastic receptacles.

7.3.3 Villa Esperanza

On October 19th, three homes in the post-Mitch community of Villa Esperanza were visited. Janice and both other staff members of AMC were present on the trip. Janice and the staff members were warmly greeted – Janice often with hugs and smiles and kind words. A rope-pump well installed by ENACAL provided the water for the community. All three homes were using the filter, and all receptacles were plastic.

7.4 Summary Statistics for Community Visits

A total of 33 homes were visited in seven communities in three geographical locations of Nicaragua. Of these 33 homes, 24 were using the filter when we made an unannounced visit to their home. The breakdown of usage per community shows a range of 33 – 100 percent usage (Figure 7.1). The four communities with 100 percent usage rates are the four communities where families with filters are visited for follow-up visits regularly. In the three San Francisco Libre communities, an AMC staff member works with a community leader in each community to visit the families. In Mancotal, the community leader clearly visited the families with filters regularly, for he knew which home used which water source and was able to direct us in our sampling. In Jingüina, although ADOVEC recommends the community leaders visit the homes once per month, it was clear that the leader had not been in the homes in three months because he was not aware that filters had been broken that long. And in the two Ocotal communities, Edith does not have the resources to visit the families, and thus the usage rate is low. This data supports the conclusion found by Valerio (1999 – 2001) that continued follow-up is indispensable to the program.

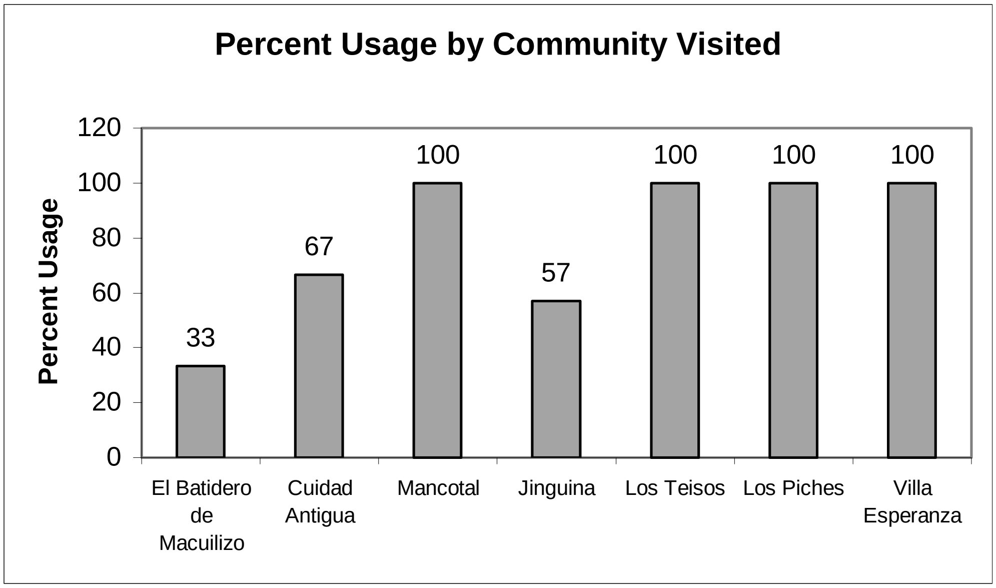

Figure 7.1: Percent Usage by Community Visited

Of the 33 houses visited, nine were not using the filter. The most common reason (6 homes) was that the filter or the filter and receptacle were broken (Table 7-2).

Table 7-2: Reasons for Not Using the Filter

Community	Home	Reason for Not Using
El Batidero de Macuilizo	1	Unknown – dry filter and receptacle
El Batidero de Macuilizo	2	Unknown – filter storing beans
El Batidero de Macuilizo	3	Filter broken
El Batidero de Macuilizo	4	Would not show us
Ciudad Antigua	4	Filter broken
Ciudad Antigua	5	Filter broken
Jingüina	1	Filter broken
Jingüina	3	Filter broken
Jingüina	4	Filter and receptacle broken

Based on the breakage rate seen, it is recommended that NGOs purchase extra filters to distribute to families after breakage. In addition, homes in Mancotal secured their filter by wrapping a piece of wire around the receptacle and tying it to the wall. This simple security feature could prevent filter breakage.

Other commonly seen problems were breakage around the lip of the filter and, in one home, dripping from the spigot. In this home the mother had devised a plug using a stick of wood covered by plastic inserted into the spigot. Although this plug prevented dripping, it also provided a contamination route for the finished water.

8 Survey Results, Conclusions, and Recommendations

The complete sampling protocol, including administration of the survey and water quality analysis, was completed at 24 homes in seven different communities in Nicaragua.

8.1 Survey Results

The survey consisted of three sections: water supply, filter usage, and family health. The results from the survey are presented by section.

8.1.1 Water Supply Section

Twenty-three families responded to the question of "Who collects the water for the household?" Of the seven families who responded that all members of the family collect water, six had an indoor piped system. Thus, in cases where families walk to gather their water, the women and children are primarily responsible for the collection (Table 8-1). No person walked longer than five minutes to reach their water supply. Families collected water 1 – 3 times per day, with an average of 1.8 times. Most families collected water from the source in large plastic containers that were then stored under the sink until use. This collection system adds another step for possible microbial contamination if the collection containers are not kept clean.

Table 8-1: Water Collectors in the Family

Who Collects	Responses (of 23 families)
Mother and/or children	14
Father	2
All members of family	7

Only four of the 24 families ever had to wait for water at the source. All four of these families lived in the post-Mitch constructed villages near San Francisco Libre. These families sometimes waited up to 1 – 2 hours for the groundwater to recharge around their rope-pump well. In addition, only two of the 24 families did not have water at their source throughout the year. These two families live in Mancotal, and use a cistern containing piped groundwater as their water source. In the summer, the cistern sometimes runs dry, and the families walk to a ravine to collect water.

When asked whether people felt the water in their source was clean, the majority (59%) said yes, although they then filter their water through the PFP filter (Table 8-2).

Table 8-2: Water Source Perception of the Families

Do you think your source water is clean?	Responses (of 22 families)
Yes	13
No	6
Don't know	2
Yes, except when they are processing coffee	1

Of note is that responses were correlated strongly with community, and less with type of source. Although everyone using river water thought their source was dirty, and almost everyone using piped water thought it was clean, some people found wells clean and some thought they were dirty. There was strong agreement, however, within a community that either their water source was clean or contaminated (Table 8-3).

Table 8-3: Water Source Perception by Community

Community	Responses		
	Yes	No	Other
El Batidero de Macuilizo	1		
Cuidad Antigua		3	
Mancotal	4		Don't know (1) Yes, except in the time of coffee (1)
Jingüina	4		
Los Teisos	1		Don't know (1)
Los Piches		3	
Villa Esperanza	3		

Selected quotes describing why people find their water source to be clean include:

- "because wells are clean"
- "because MINSA tests"
- "because it is deep"
- "it is a piped water supply"

Selected quotes describing why people find their water source to be contaminate (dirty) include:

- "piped systems are dirty"
- "wells are dirty"
- "because I sometimes see small animals in it"

As can be seen from the above quotes, many exhibit a lack of detailed knowledge of why a water supply would be contaminated or clean. Of note is that no correlation existed between perception of clean or dirty water and whether or not the source was contaminated with *E. coli*.

Three of the 24 families surveyed purchase water. In Ciudad Antigua, home 3 was the home of a doctor, who uses the filter for drinking water of the adults in the home and purchases water for the young child in the home. In Los Piches, 2 of the 3 families spend 25 cordobas per month on water. The remainder of the families said they would not or did not have the money to buy water.

Water sources were constructed by a variety of different government agencies, NGOs, and international organizations in the communities visited (Table 8-4).

Table 8-4: Organizations Constructing Water Supply

Community	Agency	Type of Water Supply
Mancotal	Swiss Aid Agency	Groundwater Storage Tank
	Nicaraguan Government	Well
	Community	Well
Jingüina	Ayuda Obrada Swisse and Care International	Piped water supply sytem
Los Teisos	CONSUDE / ENACAL	Rope-pump well
Los Piches	Mujer y Communidad	Piped water system
Villa Esperanza	ENACAL / community	Rope-pump well

In summary, the majority of the families visited have access to a nearby water source throughout the year. Only rarely do families purchase water, and a number of aid agencies are working in the rural communities in Nicaragua to ensure access to an improved water source.

8.1.2 Filter Usage Section

Filters were installed in the seven communities visited between 6 and 18 months ago, with an average filter age of 11.8 months. The average size of the family using the filter was 5.7, including 2.7 children. Of those 2.7 children, 0.8 were on average under the age of 5.

Families predominantly use the filter for drinking only (50%), but some also use the filter for cooking and/or making juice (Table 8-5)

Table 8-5: Use of the Filtered Water

Use	Number of Families
Drinking only	12
Drinking and cooking	6
Drinking and making juice	4
Drinking, cooking, and juice	2

When asked how long it takes for the filter to filter, families responded with times ranging from 1 – 48 hours, with an average of four hours. Flow rates, as determined in the water quality analysis, ranged from 0.13 to 3.5 Liters / hour, with an average of 0.98 Liters/hour. Using the average amount of water consumed per person per day and the average family size, the minimum amount of filtered water necessary per day can be calculated. The WHO bases exposure calculations from drinking water at a consumption of 2 Liters / person / day. If each family member drinks 2 Liters / day, and the average family size is 5.7, the filter needs to produce a minimum of 11.4 Liters / day. Assuming 24-hour usage, the minimum flow rate to produce 11.4 Liters / day is 0.475 Liters / hour. Fourteen of the 24 filters analyzed did not meet this basic criterion.

One of the reasons the filtration rate is slow is that three of the 22 families who responded to the question only fill the filter when the filter is completely empty of water. Because the filtration rate is faster when head pressure is maintained in the filter, it is recommended that families be educated on how to increase the filtration rate by filling the filter continuously. This recommendation agrees with the recommendation for continuous filtering made by Valerio (1999 – 2001).

The major reason the filtration rate is slow, however, depends on how the families clean the filter. Rates of filter cleaning range from once every day to once a month, with an average of once every seven days (Table 8-6).

Table 8-6: Rate of Cleaning the Filter

How Often Clean	Number of Families
Daily	5
Biweekly	8
Weekly	6
Bimonthly	1
Monthly	2

However, families mean different things when they say they clean the filter. Most families clean the filter with a brush, but without any disinfection agent, like detergent, soap, or bleach (Table 8-7). In addition, the majority of families (78%) clean the filter with water from the source, which has not been filtered, and thus families unintentionally contaminate the receptacle as they clean it. Because there is no residual from the colloidal silver, contamination of the receptacle leads to contamination of the filtered water.

Table 8-7: Method Used to Clean the Filter

Method	Number of Families
Brush	17
Water	2
Towel	1
Brush Soap	2
Filtered Water	4
Dirty Water	14

In addition, most families, as evidenced by the low filtration rate, do not scrub their filter when they clean it. Katadyn (undated) prevents growth on their commercially distributed ceramic filters with "bacteriostatic silver which is dispersed and fixed throughout the ceramic material by Katadyn's proprietary manufacturing process." Furthermore, Katadyn states that the "life span of the filter element depends on the degree of contamination of the water to be filtered. The filter element can be regenerated by simple brushing of the dirty ceramic surface; this process can be repeated up to 300 times with the same filter element." Katadyn supplies a brush with each filter, and although "brushing removes a thin layer of ceramic," it "can normally be repeated hundreds of times before filter element replacement becomes necessary due to wear." With this simple maintenance, "most owners of Katadyn filters will not need replacement filter elements or other spare parts for many years."

Thus, a commercially available filter utilizing the same technology as the PFP filter recommends scrubbing the filter to regenerate the flow rate. To test out whether scrubbing the PFP filter would regenerate the flow rate, the filter from home Mancotal-6 was collected and scrubbed in the Potters for Peace office. A toothbrush and water was used to scrub the filter, and a fine layer of clay was removed during the process. Flow rate was tested with Managua city water both before and after scrubbing. Scrubbing with a toothbrush increase the filtration rate from 0.28 Liters / hour to 2.0 Liters / hour (Table 8-8).

Table 8-8: Flow Regeneration due to Scrubbing in Filter Mancotal-6

Mancotal-6 Filter	Flow Rate
Before scrubbing	0.28 L / hr
After scrubbing	2.0 L / hr

Thus, simple scrubbing of the filter with a brush will regenerate a flow rate sufficient to provide water for drinking and cooking for an average family in Nicaragua. Currently, families are not taught that this is the appropriate mechanism to clean the filter, and are probably wary of scrubbing the filter hard enough to see ceramic on the brush. A new education decal, designed to be placed on the plastic receptacle, shows a woman cleaning the filter with a rough scrub-brush. With this decal and appropriate education from the local NGO, flow rates can be maintained to provide sufficient water for the family, and one of the main complaints (low flow rate) seen in the previous studies about the filter can be addressed.

Thus, families can be taught to scrub the filter when they notice a decrease in the flow rate of the filter. In areas with high turbidity, where the layer of fine sediment will accumulate more quickly on the filter, families will need to scrub more often. One question that arises when considering periodic scrubbing of the filter is how will that affect the performance of the colloidal silver? When colloidal silver is applies, much of the silver sorbs quickly directly into the filter. Thus, it seems that the silver is present in more than the immediate surface of the filter. However, repeated scrubbings could have an effect on the colloidal silver, and it is recommended that a new filter be tested for microbial reduction and then scrubbed very hard, to approximately monthly scrubbings for one year. Then, the filter should be retested to determine if there is a reduction in the percentage of microbial removal.

When asked when they drink unfiltered water, the most common responses were "never" and when they are "not at home" (Table 8-9). In addition, people drink unfiltered water when the filter is empty, when they are at work, or in the morning after the husband leaves for work with a full water bottle leaves behind an empty filter. Only one-third of the families drink only filtered water. Continued education on the importance of drinking filtered water at all times, and mechanisms (such as periodic scrubbing) to increase the flow rate to ensure that there is always filtered water in the receptacle are critical to ensuring reduction of waterborne disease.

Table 8-9: Times When Families Drink Unfiltered Water

When Drink Unfiltered Water	Number of Families
Never	8
When filter is empty	4
When not in the house	8
When at work	3
When husband takes all water to work	1

In order for the filter to provide safe water and prevent waterborne disease, the flow rate of the filter must be maintained at greater than 0.5 Liters / hour. When the flow rate is lower than this, the filter does not provide enough water for the family to drink. Currently, families are primarily using the filter only for drinking water, with some families also using the filtered water for cooking or making juice. With changes in the cleaning protocol, and continuous filling of the filter to maintain head pressure, the flow rate of the filter can be maintained at a level that provides enough water for drinking and also cooking and juices.

In addition, education for the families about the need to drink only filtered water is necessary. This education must occur with education on filter cleaning. Then, the filter can maintain a flow rate that allows for families to bring filtered water with them when they leave the home. Lastly, the majority of families are currently cleaning their receptacle with unfiltered raw source water. This process can contaminate both the receptacle and the finished water. Education on cleaning the filter with filtered water is needed to prevent this contamination route.

8.1.3 Family Health Section

In the health section of the survey, questions about hand-washing, latrine use, and childhood diarrhea were asked.

All families responded "yes" when asked if they washed their hands before eating, before cooking, and after going to the bathroom. It is possible that families replied dishonestly to this question, for the quick, positive responses could have been because they knew they were supposed to, not that they did. A more appropriate way to ask this question would have been to say, "When do you and your children wash your hands?" Then, the respondents would have provided their own list, instead of just saying yes to our questions. Thus, hand-washing data is not considered to be accurate enough to use for analysis in this study.

Seventeen of the 24 families surveyed had a private latrine (Table 8-10). Of the remaining families, one had an indoor bathroom, one had a shared latrine, and five families did not have a latrine. The average distance to the latrine from the home was 7.6 meters. This average was calculated without including the one latrine that was located 200 meters from the home. This far-away latrine was not often used. Four of five of the families with no latrine lived in Mancotal. The fifth family lived in Villa Esperanza.

Table 8-10: Latrine Ownership in the Families

Type of facility	Number of families
Private latrine	17
Indoor bathroom	1
Shared latrine	1
No latrine	5

In the 24 families surveyed, there were a total of 62 children. Nineteen of these 62 children were under the age of five. A total of four children had had diarrhea in the last month according to their parents – three under the age of five, and one age five. Thus the percent of children under-5 with diarrhea in the last month was 16, and the percent of children with diarrhea in the last month was 6 (Table 8-11).

Table 8-11: Childhood Diarrhea in Last Month in Families Surveyed

	Total Number	Number with Diarrhea in last month	Percentage with Diarrhea in last month
Children under-5	19	3	16 %
All children (0 – 16)	62	4	6 %

Although this is a small sample size and only a single survey was administered, the percentage of children under-5 with diarrhea was significantly higher in this study than the rate found in the AFA Guatemala study. Due to the small sample size, however, statistically comparison is not possible.

8.2 Survey Conclusions and Recommendations

Based on the results of the survey conducted with 24 families in seven communities, conversations with local NGO partners, review of previous studies, and observation of the drinking water situation in these seven communities, the following conclusions and recommendations are presented.

Conclusions:

1. Monthly visits to families using the filter by the local NGO partner or a community leader was strongly correlated with continued use of the filter by the families.

2. The most common problem seen was breakage of the filter, the receptacle, and the lip of the filter. In addition, leakage from the spigot was noted.

3. Currently, there exists a lack of education about safe water sources, and correct filter cleaning and maintenance in the families using the filter.

    a. Families have only a perception of whether their source water is clean or not.
    b. Only four families used filtered water to clean their filter with.
    c. Two of 22 families only refilled the filter when empty.
    d. Filters were not being scrubbed to improve the flow rate.

4. In 14 of 24 homes visited the flow rate of the filter was inadequate to provide enough drinking water for the family.

Recommendations

1. Information about the following topics needs to be presented to the local NGOs before filters are purchased. This information could be conveyed by personal conversation, or by the development and distribution of a brochure or manual describing factors contributing to filter success.

    a. Filter success rate is directly correlated to NGO follow-up, and staff or community leader time needs to be dedicated to this role.

    b. Education about filter use and maintenance needs to be presented to the families, including but not limited to the following topics.

        i. Cleaning with filtered water
        ii. Scrubbing to regenerate flow rate
        iii. Securing filters to the wall to prevent breakage
        iv. Emptying the filter before lifting it to prevent damage to the lip
        v. Filling the filter continuously to maintain head pressure
        vi. Water and sanitation education, for when families understand why safe water is important, they understand why using the filter is important

c. Filters are ceramic, and as such break. Purchasing extra filter at the beginning will allow for replacement of broken filters.

2. A cleaning kit needs to be developed and sold with the filters.

   a. Cleaning of the filters is critical to maintaining flow rate and correct cleaning of the receptacles is critical so that the finished water is not contaminated. Currently families in rural areas do not have the supplies necessary to complete this cleaning in their homes. A small cleaning kit could be developed and sold as an accessory to accompany the filter. The cleaning kit should include the following items.

      i. Scrub brush for scrubbing the filter
      ii. Cloth and disinfectant (detergent, bleach, or "Potters for Peace" cleaning solution) to clean and disinfect the receptacle
      iii. Directions for cleaning the filter (using pictures and written directions)

The PFP filter is simple in design, easy for families to use, and performs exceptionally well in laboratory tests (see Report 1, December 2001). Adoption of these recommendations will improve the usage of the filter in rural family homes.

9 Water Quality Monitoring Results, Conclusions, and Recommendations

Raw and filtered water samples were analyzed for a water quality parameters, silver concentration, and microbiological contamination in 24 homes in seven communities throughout Nicaragua. The results of water quality parameter testing show that DO is increased as it flows through the filter, turbidity is on average decreased, pH is increased, and conductivity is not affected (Table 9-1). Of note is that finished water sampling for these parameters was only completed in 12 of the 24 homes. This is due to the fact that the filtration rate was so slow that upon return four hours later there was only enough water to complete the microbiological and silver sampling. Thus, conductivity and temperature averages are not included because the missing data is not represented. Dissolved oxygen, turbidity, and pH averages are included because trends were consistent across the data set.

Table 9-1: Water Quality Parameter Results Summary

Parameter	Before Filtration			After Filtration		
	Average	Minimum	Maximum	Average	Minimum	Maximum
Dissolved oxygen (mg/L)	5.7	1.7	7.6	7.0	6.0	7.8
Turbidity (NTU)	10	0.0	62	3.2	0.0	23
pH	7.3	6.5	7.8	8.1	7.5	8.5
Conductivity (mS/cm)	280	40	620		60	620
Temperature (C)	24	20	31		20	30

Dissolved oxygen (DO) is an important parameter to measure because one of the mechanisms for inactivating bacteria using colloidal silver needs oxygen in the reaction. Oxygen was present in all before and after filtration samples taken. Agitation of the water during filling of the filter, and as the water flows through the filter ensures presence of oxygen in the water. Only one sample, from a large cement standing-water receptacle in the yard, was below 3 mg/L of dissolved oxygen in the before filtration water. Agitation due to filtration increased the DO by an average of 1.3 mg/L in the sampling.

On average, turbidity was reduced through the filter, but not completely eliminated. The average percent reduction of turbidity through the filter was 83 percent, with a range of 30 – 100 percent. In addition, two filters added turbidity: from 0 in the source water to 2 NTUs in the finished water and from 0 in the source water to 6 NTUs in the finished water. Neither of these filters that added turbidity removed bacteria in the microbiological sampling. Addition of turbidity indicates that the receptacle is not cleaned, and accumulation of turbid water occurs. In home 6 in El Batidero de Macuilizo, we upended the filter to obtain more water for sampling. We found that the water below the level of the spigot was very dirty – for turbidity in the finished water settles and accumulates here if the filter is not regularly cleaned.

Communities in Ocotal had the highest turbidity readings, for the river formed by Mitch was at 56.3 and 61.9 NTUs. The recommended standard for drinking water is no more than 5 NTUs (USEPA, 2001; WHO, 1993). All but two finished water samples were below the 5 NTU standards. Both of these above standard samples came from highly turbid water in Ocotal. Thus, the filter does reduce turbidity to below the WHO and USEPA standards the majority of the time. Extremely turbid source water and infrequent cleaning of the receptacle cause turbidity to be higher than the standards in some cases.

pH was consistent throughout the data set. All source water samples ranged from slightly acidic to slightly basic (6.5 to 7.8), and all finished water samples increased by an average 0.8 pH points to a slightly basic range of 7.5 to 8.5. This increase is attributed to the material in the ceramic and has been described in other studies (Baide, 2001). pH measurements using a filter without colloidal silver also show this same increase in pH. Thus, the colloidal silver has no effect on the pH.

Conductivity ranged from 30 – 150 mS/cm in water from river and rope-pump well sources. In piped water supplies, conductivity ranges from 170 – 450 mS/cm due to slight leaching of metal from the pipes into the water. These conductivity ranges are not problematic, and simply indicate there are some ions present in the water, especially when the water is piped through metal. In addition, salinity was measured at each home, and no home had a value of other that 0 ppt of salt in the water. Thus, none of the conductivity is due to saltwater intrusion or waterlogging of the water supply.

Temperature varied depending on the ambient temperature of the region where the sampling was conducted. An important result is that temperature was lower in finished water by 2 – 3 degrees C in ceramic receptacles. Thus, people enjoy the taste of the water with the ceramic receptacles because the ceramic cools the water. This cooling effect has been detailed in other studies as well (Baide, 2001). The plastic receptacles did not increase or decrease the filtered water temperature.

9.1 Silver Results

Silver samples were collected at each home visited, preserved in nitric acid, kept cold, transported back to the United States, and analyzed at the Massachusetts-certified Toxicon Laboratories. The WHO guideline value for silver concentration in drinking water disinfected with silver and the USEPA secondary drinking water standard are both 100 µg/L (0.100 mg/L). No filtered water sample exceeded, or approached, the WHO and USEPA standards (Table 9-1). Only two samples (CA-3 and BM-6) were above the detection limit of 5 µg/L.

Table 9-2: Silver Laboratory Results

Home	Silver (µg/L or ppb)
El Batidero de Macuilizo – 5	Non-detect (less than 5 µg/L)
El Batidero de Macuilizo – 6	6
Cuidad Antigua – 1	Non-detect (less than 5 µg/L)
Cuidad Antigua – 2	Non-detect (less than 5 µg/L)
Cuidad Antigua – 3	15
Cuidad Antigua – 6	Non-detect (less than 5 µg/L)
Mancotal – 1	Non-detect (less than 5 µg/L)
Mancotal – 2	Non-detect (less than 5 µg/L)
Mancotal – 3	Non-detect (less than 5 µg/L)
Mancotal – 4	Non-detect (less than 5 µg/L)
Mancotal – 5	Non-detect (less than 5 µg/L)
Mancotal – 6	Non-detect (less than 5 µg/L)
Jingüina – 2	Non-detect (less than 5 µg/L)
Jingüina – 5 (source water)	Non-detect (less than 5 µg/L)
Jingüina – 5	Non-detect (less than 5 µg/L)
Jingüina – 6	Non-detect (less than 5 µg/L)
Jingüina – 7	Non-detect (less than 5 µg/L)
Los Teisos – 1	Non-detect (less than 5 µg/L)
Los Teisos – 2	Non-detect (less than 5 µg/L)
Los Teisos – 2 (duplicate)	Non-detect (less than 5 µg/L)
Los Piches – 1	Non-detect (less than 5 µg/L)
Los Piches – 2	Non-detect (less than 5 µg/L)
Los Piches – 3	Non-detect (less than 5 µg/L)
Villa Esperanza – 1	Non-detect (less than 5 µg/L)
Villa Esperanza – 2	Non-detect (less than 5 µg/L)
Villa Esperanza – 3	Non-detect (less than 5 µg/L)

Both CA-3 and BM-6 had filters that were 14 months old, although the colloidal silver in BM-6 and BM-5 had been reapplied six months prior to sampling by a Peace Corps volunteer. It is possible that because of the recent reapplication of silver, there was silver leaching in the filter or silver contamination of the receptacle. No other home with six-month old filters showed leaching of silver from the filter into the finished water, however. The homes in Los Teisos, Los Piches, and Villa Esperanza all had filters that were six months old.

CA-3 was the home of a doctor who drove into Ocotal to obtain Ocotal water to run through the filter. No other home used a large city water supply, and it is possible that there is some silver concentration in Ocotal city water from pipes or solder or other exposure to metal.

Although it is not conclusive why these two homes showed a silver concentration in the filtered water, the concentration is much lower than the standards set by USEPA and WHO. This data clearly shows that silver concentrations in the filtered water do not exceed USEPA and WHO standards, and water filtered with PFP purifiers does not place users at risk for argyria.

Full results of silver testing using new filters with new application of colloidal silver will be presented in Report 1 (December 2001). No sample from these studies, however, exceeded 61 µg/L, even at higher concentrations of silver than PFP normally uses and during the first run of the filter. PFP recommends not drinking the water used the first run of the filter because of the slightly metallic taste. Silver concentrations determined for laboratory studies dropped off significantly after the first run of the filter.

9.2 Microbial Results

Unfortunately, the microbial results obtained during this field investigation were not as clear as the results obtained from the silver sampling. In addition, unlike the extensive laboratory analyses completed at CIRA-UNAN showing consistent reduction of bacteriological indicator species by 99 – 100 percent (various dates), the field investigations did not show consistent reduction of bacteriological indicators through filtration. Previous laboratory studies will be detailed and analyzed in Report 1 (December 2001). Of note is that, before running the filter in the lab, the technicians wash the receptacle with detergent and then rinse the receptacle with boiled distilled water. Thus, all lab samples in the past were conducted with clean receptacles. This report contains the microbiological samples collected in the field and analyzed using presence / absence methodology. In addition, duplicate samples were enumerated at CIRA-UNAN.

Samples for total coliform and *E.coli* were collected both before and after filtration at 24 homes. Samples for H_2S-producing bacteria were collected at 22 homes, because 2 homes did not have a high enough filtration rate to allow for the collection of the 100 mL needed for analysis after filtration. Total coliform and H_2S-producing bacteria were present in all 24 raw water samples. *E. coli* was present in 15 of the 24 raw water supplies. Only one of a possible 24 filters removed total coliform, six of a possible 22 filters removed H_2S-producing bacteria, and eight of a possible 15 filters removed *E. coli* contamination (Table 9-3).

Table 9-3: Presence / Absence Microbial Results

	Total Coliform		H_2S-producing		*E. coli*	
	Before	After	Before	After	Before	After
Positive	24	23	24	16	15	8
Negative	0	1	0	6	9	16

The total coliform results indicate that the filter is not capable of removing total coliform to a level that will test negative on a presence / absence test. This result is not alarming, because total coliform is not the best indicator of organisms causing human health effects in tropical countries. It is, however, an important WHO and USEPA indicator. The one filter that removed total coliform was in Los Piches, using the Muyer y Communidad water supply system.

Six of the 24 filters tested negative for H_2S-producing bacteria in the finished water. These filters were at the doctor's home in Ciudad Antigua, in both homes in Los Teisos, in two of the three homes in Los Pichos, and in one of the three homes in Villa Esperanza. It is important to note that all finished water samples that removed H_2S-producing bacteria were in plastic receptacles. No finished water in a ceramic receptacle tested negative for H_2S-producing bacteria. Of the four filters that were washed with filtered water, two of the four removed H_2S-producing bacteria, one of the four was contaminated for all three microbiological indicators in the finished water, and one of the four was not tested for H_2S-producing bacteria due low filtration rate. In addition, all families with filters that tested negative for H_2S-producing bacteria in the finished water owned a private latrine.

E. coli results showed that *E. coli* was present in 15 of the 24 before filtration water samples tested. Sources without *E. coli* included the river in Ciudad Antigua, one private well in Mancotal, and in some homes using the water systems in Los Teisos, Los Piches, and Villa Esperanza. Of the 15 homes that had *E. coli* in the source water, eight tested negative for *E. coli* in the finished water. Thus, 53 percent of the source water contaminated with *E. coli* was not contaminated after filtration. The seven samples that tested positive for *E. coli* in the finished water came from homes that, on observation, were not as clean as other homes. This indicates that household cleanliness is a metric of filter success. In addition, five of the eight homes that removed *E. coli* had a private latrine.

All but one of the systems that removed H_2S-producing bacteria either removed *E. coli* or *E. coli* was not present in the source water to begin with. This indicates that removal of H_2S-producing bacteria and removal of *E. coli* correlate with one another. Another important correlation is that no home with a filter that removed *E. coli* or H_2S-producing bacteria had a child with diarrhea in the past month. Thus, childhood diarrhea in the past month only occurred in filters with contaminated filtered water.

An important note is that in all communities, the majority of families collect their water from the source in plastic containers and store these containers under their sink. Thus, there is an additional possible route contamination: in the source itself, in the collection containers stored under the sink, or in an unclean filter receptacle. The growth of significant amounts of bacteria in collection containers could affect filter performance.

In Villa Esperanza, duplicate testing was completed by CIRA-UNAN. Total coliform results agreed – all of CIRA-UNANs samples showed contamination, and all of the presence / absence samples were positive (Table 9-4). The *E. coli* results also agreed, except in one sample which had an enumeration result of 15 colonies per 100 mL and a negative presence / absence test. This is due to the fact that the presence / absence may be negative when only a small amount of bacteria is present.

Table 9-4: Enumeration and Presence / Absense Comparison

	CIRA – UNAN Enumeration				Presence / Absence		
	Total Coliform	Fecal Coliform	*E. coli*	Fecal Streptococcus	Total Coliform	H2S-producing	*E. coli*
Source Water	124	70	0	0			
Home 1 – before					+	+	-
Home 1 - after	190	160	15	95	+	+	-
Home 2 – before					+	+	-
Home 2 – after	2100	48	0	21	+	-	-
Home 3 – before					+	+	+
Home 3 - after	4900	4320	1920	0	+	+	+

Of particular interest is that there is always more total coliform after filtration than before. In addition, there is a significant amount more of total coliform, fecal coliform, and *E. coli* in the filtered water at home 3. Clearly there is some contamination occurring between the well and the finished water. In home 3, all before filtration presence / absence tests were positive, indicating that the contamination occurred after collection at the well, but before filling the filter with water. This is especially evident because there was no *E. coli* in the well, but there was *E. coli* present in the before filtration water. This contamination could have occurred in the collection and storage bucket. Increased values of total coliform in home 1 and 2 could have occurred in the collection bucket before filtration, and then due to an unclean receptacle in the filter.

Additional duplicate sampling in the community of Jingüina showed similar results – increased total coliform due to contamination, and agreement with presence / absence sampling.

9.3 Water Quality Conclusions and Recommendations

Based on the water quality analysis completed in the field with 24 families in seven communities throughout Nicaragua, the following conclusions and recommendation are presented.

Conclusions:

1. The concentration of silver in water filtered with the PFP filter does not exceed, or even approach, the WHO and USEPA standards. Thus, ingestion of water filtered using the PFP filter does not pose a human health risk of argyria due to silver contamination.

2. Microbiological data showed that:

    a. 6 percent of the filters removed total coliform
    b. 25 percent of the filters removed H_2S-producing bacteria
    c. 53 percent of the filters removed *E. coli*
    d. Enumeration of samples from seven homes showed increased amounts of total coliform in all finished water, and increased amounts of *E. coli* in some of the filters. This is attributed to contamination from storage and in unclean receptacles.
    e. No family with a filter that removed microbial contamination had a child with diarrhea in the last month.

3. Latrine use and household cleanliness are correlated with microbial removal.

4. Although ceramic receptacles are traditional, employ artisans, and improve the taste of the water by reducing the temperature, they are difficult to clean. Microbiological results showed that no filter with a ceramic receptacle removed hydrogen sulfide-producing bacteria.

Recommendations:

1. No action is needed to address silver concentration in the filtered water.

2. Education about contamination of water due to unclean storage containers is necessary. Also, PFP should work with NGOs to recommend to families that only recently collected water should be used in the PFP filter.

3. Maintenance of a sterile receptacle is critical to reducing microbiological contamination.

a. A cleaning kit was recommended in Section 8-3 to address issues of filtration rate. This cleaning kit is also vital to maintaining a sterile receptacle for microbial removal purposes. Families need to be trained to clean their filter regularly with a disinfectant and filtered water to prevent contamination.

4. Possible modifications to the receptacle to maintain sterility of the filtered water could include:

   a. Addition of chlorine as a residual through a constructed input area.
   b. Addition of colloidal silver as a residual through a constructed input area.
   c. Colloidal silver painted receptacle.
   d. Colloidal silver impregnated disk in the bottom of the receptacle.

5. NGOs purchasing the filters should be advised that plastic receptacles have been shown to be more effective in microbial reduction that ceramic receptacles.

Lastly, additional water quality and microbial research results will be presented in Report 1 (December 2001). Data in Report 1 with include:

1. Previous microbiological data from CIRA-UNAN and other programs.

2. Microbiological and silver concentration results from targeted studies with filters with:

   a. different flow rates;
   b. different concentration of colloidal silver; and
   c. different application methods for colloidal silver.

3. Results from laboratory testing of three filters (both used and new) for removal of:

   a. VOCs
   b. Pesticides
   c. Viruses

10 Comparison with Other Point-of-Use Water Treatment Methods

Lastly, the PFP filtration system is compared with two other commonly used point-of-use systems: the Gift of Water, Incorporated two-bucket purifier, and the Center for Disease Control Safe Water System.

Gift of Water, Incorporated (GWI) is a non-governmental organization based in Satellite Beach, Florida. GWI assembles, installs, and maintains point-of-use water purification systems in villages in rural Haiti (Lantagne, 2001). The system consists of two 20-liter plastic buckets, placed one on top of the other and connected by a check valve. Above the check valve in the top bucket is a string-wound filter to reduce suspended solids. Below the check valve in the bottom bucket is a granulated activated carbon (GAC) filter. To use the filter, 5 mL of 5.25 % sodium hypochlorite is added to source water in the top bucket and allowed to sit for 30 minutes. Then the top bucket is connected to the bottom bucket and water flows through the string-wound filter, the check valve, and the GAC filter. Five drops of chlorine bleach is added to the bottom bucket to form the residual.

Funding for the GWI program comes from groups (often churches) in the United States who sponsor a village in Haiti. GWI then works with the Haitian community to establish a volunteer water committee, to select homes to receive the purifier, and to hire local technicians who visit the homes 1 – 3 times per week to ensure correct and continued usage and maintenance of the purifier. The percentage of families using the purifier correctly varies from 20 – 100 percent, depending on the following three factors:

1. Dedicated and well-selected technicians.
2. Distribution of purifiers within a small area.
3. Education in the community about the need for safe water and sanitation.

One purifier costs US$15 to construct, ship to Haiti, and assemble. To account for training, transportation, testing, and implementation GWI charges sponsor groups in the United States US$50 per year to install and maintain each filter.

The Center for Disease Control (CDC) in Atlanta, Georgia developed the Safe Water System (SWS) program for developing countries (CDC, 2001). The CDC provides a manual and technical support to communities who then establish a sodium hypochlorite generation plant, and also a plant to generate and distribute plastic water containers. The community then markets the program to families who purchase a plastic water container with a small opening to prevent contamination, and bleach from the local generation facility. Families are taught to add a specific amount (varies depending on chemisty of the source water) of bleach to the container, and then drink the water.

The CDC distributes a manual for development of a safe water system program (CDC, 2001a). The manual recommends beginning with scoping the project, and obtaining funding. Then, organizations or communities establish the plants, and market and distribute the products. Finally, evaluation, implementation, and behavior change modification are recommended. One issue that is not addressed in the CDC program is problems associated with chlorine taste and possible chlorination by-products, including trihalomethanes.

Oates (2001) developed an evaluation matrix for rural point-of-use water treatment using criteria from Lehr (1980) and Shultz (1984). These twelve criteria were assigned a numerical value of 0 (not meeting criterion), 1 (partially meeting criterion), and 2 (meets criterion) for each of the CDC, GWI, and PFP systems. A total of 24 points was possible.

All three filters investigated received the same total score (19), although systems lost points for different reasons (Table 10-1). Both the CDC and GWI systems use chlorine. Much research has been conducted on chlorine's effectiveness on pathogens (1), while colloidal silver has not been researched as extensively. Thus, the PFP filter is assigned 1 for this criterion, while the CDC and GWI systems are assigned a 2. All three systems perform regardless of water fluctuations (2), and operate in the appropriate pH and temperature range (3), so all systems were assigned values of 2 for these criteria. The GWI purifier uses GAC to remove the chlorine taste from the water, while the CDC system does not, so the CDC system is assigned a value of 1 because the chlorine taste makes the water unpalatable (4) to some. The GWI purifier is a complicated system that requires significant follow-up, so is assigned a value of 1 because it is not easy to handle (5). Chemical concentrations (6) are minor in the PFP and GWI systems, but are more major in the CDC system, so the CDC system is assigned a value of 1 for this criterion. The PFP system does not have a residual (7), so it is assigned a value of 0. The CDC and GWI systems are more expensive (8) than the PFP system, so they are assigned values of 1 for this criterion. All three systems work to adapt their filter to local conditions (10), so all three receive a value of 2. Specialized equipment (10) is produced locally in the PFP filter, imported and established as micro-enterprises in the CDC system, and completely imported in the GWI purifier. Thus the PFP filter is assigned a value of 2, the CDC system a value of 1, and the GWI system a value of 0. It is traditional to keep water in ceramic pots in Nicaragua, so the PFP system is culturally appropriate (11). The GWI and CDC systems can be made appropriate with education, so they are assigned a value of 1. The GWI purifier is approved by the Haitian Ministry of Health, and the CDC system is approved by multilateral agencies, so both are assigned a value of 2 for this criterion (12), while the PFP system is assigned a value of 0 because it has not yet been approved by a governmental organization, although it is used by many NGOs.

Table 10-1: Comparison of Three Household Water Filtration Systems

	CDC Safe Water System	GWI Purifier	PFP Filter
1. Effective on many types and large numbers of pathogens	2	2	1
2. Performs regardless of water fluctuations	2	2	2
3. Operates in appropriate pH and temperature range	2	2	2
4. Does not make the water toxic or unpalatable	1	2	2
5. Easy and safe to handle	2	1	2
6. Chemical concentrations are minor	1	2	2
7. Provides residual protection against possible recontamination	2	2	0
9. Affordable to all	1	1	2
9. Adapted to local conditions and variations	2	2	2
10. Specialized equipment produced locally	1	0	2
11. Accepted by traditions, customs, and cultural standards	1	1	2
12. Complies with national sanitation and pollution policies	2	2	0
TOTAL	19	19	19

Thus, all three systems compare equally based on these criteria, although they lose points for different individual criterion. Improvements to the PFP filter that should be investigated are: research on the effectiveness of colloidal silver on a variety of pathogens, establishment of a residual in the finished water, and approval by the Nicaraguan government. Research on inactivation of pathogens will occur in Report 1 of this study (December 2001).

To conclude, the PFP filter is an appropriate technology that works exceptionally well in the lab (Report 1), but needs some improvements in education and implementation to work as well in the field.

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Note: Dates in this section are listed in day-month-year format.

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11 Appendix A: Field Data by Home Visited

11.1 Octotal: El Batidero de Macuilizo

The sampling protocol was completed at two homes in El Batidero de Macuilizo. Both homes obtained water from the same rope-pump well that a total of five families use. Home five had indoor pipes flowing from the well. At home six, the 11-year-old daughter collects water from the well in the morning and afternoon. It was approximately a four-minute easy walk from home six to the well. There was no issue of the well ever running dry, and they did not know who installed the well.

11.1.1 El Batidero de Macuilizo Home 5

Home five was very clean, and in the backyard were a flower garden, turkeys, and chickens. We were offered warm milk, fruit, and flowers during our return visit to collect the finished water samples.

Table 11-1: El Batidero de Macuilizo Home 5 Survey Data

Question	Response
Who collects water for the household?	N/A – indoor supply
How many times per day do you collect water?	N/A – indoor supply
Do you ever have to wait at the water source?	N/A – indoor supply
Is there always water at this source?	Yes
Do you think the water at this source is clean?	Yes
Do you ever buy water?	No
Receptacle type	Ceramic
How old is the filter?	14 months
How many people use the filter regularly?	Four 2 adults, 2 children
When do you add water to the filter?	
How long does it take for the filter to filter?	1 hour
When do you drink unfiltered water?	Never
How do you clean the filter?	With a brush
How often do you clean the filter?	Each month
What water do you use to clean the filter?	
What do you use the filtered water for?	Drinking
What do you like about the filter?	The taste of the water
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Private
What are the ages of the children who drink filtered water?	12, 6
Have any of these children had diarrhea in the last month?	No

Table 11-2: El Batidero de Macuilizo Home 5 Water Quality Data

Parameter	Before Filtration	After Filtration
DO (mg/L)	6.6	7.2
Turbidity (NTU)	33.1	23.2
Temperature (C)	26	23
pH	7.2	8.2
Salinity (ppt)	0.0	0.0
Conductivity (µS/cm)	120	150
TDS (ppm)	60	70
Silver (ppb)	CNC[1]	CNC[1]
Flow Rate (L/hr)		0.6

1. Turbidity too high to allow completion of the Silver test.

Results of the bacteriological sampling show positive results after 24 hours for both coliform and hydrogen sulfide producing bacteria both before and after filtration (Table 3). After 48 hours, however, E.coli was positive before filtration, but not after. This indicates that the filter effectively reduced *E. coli* to a non-detect level.

Table 11-3: El Batidero de Macuilizo Home 5 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform	–	+	+	+	+	+	+	+
E. coli							+	–
H_2S	–	–	+	+	+	+	+	+

11.1.2 El Batidero de Macuilizo Home 6

Table 11-4: El Batidero de Macuilizo Home 6 Survey Data

Question	Response
Who collects water for the household?	Daughter
How many times per day do you collect water?	2 times
Do you ever have to wait at the water source?	No
Is there always water at this source?	Yes
Do you think the water at this source is clean?	
Do you ever buy water?	No
Receptacle type	Ceramic
How old is the filter?	14 months
How many people use the filter regularly?	Four 2 adults, 2 children
When do you add water to the filter?	
How long does it take for the filter to filter?	½ hour
When do you drink unfiltered water?	Never
How do you clean the filter?	With a brush
How often do you clean the filter?	Every 3 days
What water do you use to clean the filter?	
What do you use the filtered water for?	Drinking, juice, coffee
What do you like about the filter?	The taste of the water
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Shared latrine
What are the ages of the children who drink filtered water?	11, 22 months
Have any of these children had diarrhea in the last month?	Had diarrhea 5 days ago for 2 – 3 days because stayed in another house

Table 11-5: El Batidero de Macuilizo Home 6 Water Quality Data

Parameter	Before Filtration	After Filtration (CNC[2])
DO (mg/L)	5.2	
Turbidity (NTU)	20.7	
Temperature (C)	23	
pH	6.5	
Salinity (ppt)	0.0	
Conductivity (µS/cm)	80	
TDS (ppm)	40	
Silver (ppb)	CNC[1]	
Flow Rate (L/hr)		0.45

1. Turbidity too high to allow completion of the Silver test.
2. Upon return to home there was not enough water in the filter to complete anything but the microbiological and silver lab tests.

Bacteriological results show all samples positive for total coliform, *E. coli*, and hydrogen sulfide producing bacteria after 48 hours (Table 11-6). This is different from Home 5, and is probably due to the fact that this home in general was not as clean. Also, despite the fact that the senora said she cleaned the filter every three days, the receptacle was not clean. When we tried to obtain more water from the filter by upending the receptacle (because the spout is approximately 2 inches above the bottom and allows a pooling of water) we found very turbid, dirty water in the bottom. This is because the finished water settles and that pooled water in the bottom was never removed. The weight of the ceramic receptacle makes it difficult to be cleaned.

Table 11-6: El Batidero de Macuilizo Home 6 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform	–	–	+	+	+	+	+	+
E. coli							+	+
H_2S	–	–	+	+	+	+	+	+

11.2 Ocotal: Ciudad Antigua

Three of the homes sampled in Ciudad Antigua (1, 2, and 6) collect water from the river and keep it in large containers in their home until the water is used in the filter or for other purposes. The fourth home sampled was owned by a doctor (3), and they bring water from the Ocotal piped water supply to their home to filter.

11.2.1 Ciudad Antigua Home 1

Table 11-7: Ciudad Antigua Home 1 Survey Data

Question	Response
Who collects water for the household?	Mother, children.
How many times per day do you collect water?	2 times
Do you ever have to wait at the water source?	No
Is there always water at this source?	Yes
Do you think the water at this source is clean?	No
Do you ever buy water?	No
Receptacle type	Plastic
How old is the filter?	14 months
How many people use the filter regularly?	Five 2 adults, 3 children
When do you add water to the filter?	When filter is half-empty
How long does it take for the filter to filter?	12 hours
When do you drink unfiltered water?	When at work
How do you clean the filter?	With a brush
How often do you clean the filter?	Every day
What water do you use to clean the filter?	
What do you use the filtered water for?	Drinking
What do you like about the filter?	The taste of the water
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Private latrine, 10 meters from home
What are the ages of the children who drink filtered water?	15, 12, 6
Have any of these children had diarrhea in the last month?	No

Table 11-8: Ciudad Antigua Home 1 Water Quality Data

Parameter	Before Filtration	After Filtration
DO (mg/L)	6.4	7.4
Turbidity (NTU)	61.9	2.0
Temperature (C)	25	26
pH	7.7	8.2
Salinity (ppt)	0.0	0.0
Conductivity (µS/cm)	60	60
TDS (ppm)	30	30
Silver (ppb)	CNC[1]	0.0
Flow Rate (L/hr)		0.2 L / hour

1. Turbidity too high to allow completion of the Silver test.

Results of the bacteriological sampling show positive results after 24 hours for both coliform and hydrogen sulfide producing bacteria both before and after filtration (Table 11-9). Of interest is that the river water is not positive for E.coli after 48 hours.

Table 11-9: Ciudad Antigua Home 1 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform	+	+	+	+	+	+	+	+
E. coli	–	–	–	–	–	–	–	–
H_2S	+	–	+	+	+	+	+	+

11.2.2 Ciudad Antigua Home 2

Table 11-10: Ciudad Antigua Home 2 Survey Data

Question	Response
Who collects water for the household?	Father
How many times per day do you collect water?	1 / day
Do you ever have to wait at the water source?	No
Is there always water at this source?	Yes
Do you think the water at this source is clean?	No
Do you ever buy water?	No
Receptacle type	Plastic
How old is the filter?	14 months
How many people use the filter regularly?	Four 2 adults, 2 children
When do you add water to the filter?	As needed
How long does it take for the filter to filter?	12 hours
When do you drink unfiltered water?	When filter is empty
How do you clean the filter?	With water only
How often do you clean the filter?	Every day
What water do you use to clean the filter?	River water
What do you use the filtered water for?	Drinking
What do you like about the filter?	The taste of the water
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Private latrine, 8 meters from home
What are the ages of the children who drink filtered water?	4, 3
Have any of these children had diarrhea in the last month?	No

At home 2, water stored in a large container under the counter that had previously been collected from the river was used in the filter. As in home 1, the turbidity was very high and the flow rate was 0.18 liters per hour. Upon our return 2.5 hours after our initial sampling, there was only enough water to complete the lab silver, bacterial, and turbidity tests, so the rests of the tests were not performed.

Table 11-11: Ciudad Antigua Home 2 Water Quality Data

Parameter	Before Filtration	After Filtration (CNC[2])
DO (mg/L)	6.8	
Turbidity (NTU)	56.3	11.1
Temperature (C)	23	
pH	7.8	
Salinity (ppt)	0.0	
Conductivity (µS/cm)	60	
TDS (ppm)	30	
Silver (ppb)	CNC[1]	
Flow Rate (L/hr)		0.18 L / hr

1. Turbidity too high to allow completion of the Silver test.
2. Upon return to home there was not enough water in the filter to complete anything but the microbiological and silver lab tests.

Results of the bacteriological sampling show positive results after 12 hours for both coliform and hydrogen sulfide producing bacteria both before and after filtration (Table 11-12). In addition, like in home 1, the river does not show positive *E. coli*.

Table 11-12: Ciudad Antigua Home 2 Water Quality Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform	+	+	+	+	+	+	+	+
E. coli	–	–	–	–	–	–	–	–
H_2S	+	+	+	+	+	+	+	+

11.2.3 Ciudad Antigua Home 3

Home 3 belonged to a doctor, was very clean, and had three different types of receptacles in the room with the filter. Water used here did not come from the river, but instead from Ocotal city water. They drive to collect water when it is needed. They think the water is more or less clean, but purchase water for their one year old child.

Table 11-13: Ciudad Antigua Home 3 Survey Data

Question	Response
Who collects water for the household?	Family
How many times per day do you collect water?	When needed from Ocotal
Do you ever have to wait at the water source?	No
Is there always water at this source?	Yes
Do you think the water at this source is clean?	More of less
Do you ever buy water?	For child
Receptacle type	Plastic
How old is the filter?	14 months
How many people use the filter regularly?	Three 3 adults
When do you add water to the filter?	When it is half-empty
How long does it take for the filter to filter?	It is rapid
When do you drink unfiltered water?	Never
How do you clean the filter?	Brush
How often do you clean the filter?	
What water do you use to clean the filter?	
What do you use the filtered water for?	Drinking
What do you like about the filter?	The taste of the water
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Private latrine, 8 meters from home
What are the ages of the children who drink filtered water?	None
Have any of these children had diarrhea in the last month?	

Table 11-14: Ciudad Antigua Home 3 Water Quality Data

Parameter	Before Filtration	After Filtration
DO (mg/L)	5.6	7.5
Turbidity (NTU)	0.9	0.0
Temperature (C)	22	23
pH	6.75	7.5
Salinity (ppt)	0.0	0.0
Conductivity (µS/cm)	550	450
TDS (ppm)	270	220
Silver (ppb)	0	5
Flow Rate (L/hr)		1.4

Results of the bacteriological sampling show positive results for total coliform after 12 hours both before and after filtration (Table 11-15). However, this location showed positive hydrogen sulfide producing bacteria and *E. coli* only before filtration. Thus, a clean home using Ocotal city water removes both H_2S and *E. coli*. Of note is that Ocotal city water is positive for all three microbiological tests, indicating that when Edith cleaned the receptacles with the city water, she was contaminating the new receptacles.

Table 11-15: Ciudad Antigua Home 3 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform	+	+	+	+	+	+	+	+
E. coli	–	–	–	–	+	–	+	–
H_2S	–	–	+	–	+	–	+	–

1. No sample in either day in Ocotal had enough water upon return to allow for duplicate testing.

11.2.4 Ciudad Antigua Home 6

Home 6 had a cement receptacle of piped water from the river near their home. They do not, however, use this water in the filter. They collect water directly from the river to put in the filter.

Table 11-16: Ciudad Antigua Home 6 Survey Data

Question	Response
Who collects water for the household?	Children
How many times per day do you collect water?	3 times per day
Do you ever have to wait at the water source?	No
Is there always water at this source?	Yes
Do you think the water at this source is clean?	No
Do you ever buy water?	No
Receptacle type	Plastic
How old is the filter?	10 months
How many people use the filter regularly?	Seven 3 adults, 4 children
When do you add water to the filter?	When half-empty
How long does it take for the filter to filter?	1 to 2 days
When do you drink unfiltered water?	When filter is empty drink river water
How do you clean the filter?	With brush
How often do you clean the filter?	Every month
What water do you use to clean the filter?	
What do you use the filtered water for?	Drinking, Cooking
What do you like about the filter?	The taste of the water
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Indoor bathroom
What are the ages of the children who drink filtered water?	9, 8, 5, 1.5 years
Have any of these children had diarrhea in the last month?	Youngest has various parasites and diarrhea for 3 to 4 days each in last month.

Table 11-17: Ciudad Antigua Home 6 Water Quality Data

Parameter	Before Filtration	After Filtration (CNC[1])
DO (mg/L)	1.7	
Turbidity (NTU)	1.5	
Temperature (C)	25	
pH	7.2	
Salinity (ppt)	0.0	
Conductivity (µS/cm)	260	
TDS (ppm)	130	
Silver (ppb)	0	
Flow Rate (L/hr)		0.35

1. Upon return to home there was not enough water in the filter to complete anything but the bacteriological and silver lab tests.

Results of the bacteriological sampling show positive results after 36 hours for all bacteriological tests (Table 11-18).

Table 11-18: Ciudad Antigua Home 6 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform	+	+	+	+	+	+	+	+
E. coli	–	–	–	+	+	+	+	+
H_2S	+	+	+	+	+	+	+	+

11.3 Jinotega: Mancotal

Six homes were visited and sampled in Mancotal. Two homes obtained water from a system that pipes water from a groundwater source to a storage tank installed by a Swiss aid agency (Home 1 and 2). Another home (Home 3) obtains water from the river or rainwater, and the three remaining homes obtain water from wells (Home 4, 5, 6).

11.3.1 Mancotal Home 1

This was the home of the community leader who visits homes with the filter once per month, and knew what water source each home in the community used in their filter. Upon our return, we were offered rice, beans, and tortillas to eat.

Table 11-19: Mancotal Home 1 Survey Data

Question	Response
Who collects water for the household?	Daughter, age 8
How many times per day do you collect water?	1 time per day
Do you ever have to wait at the water source?	No
Is there always water at this source?	Yes, except sometimes in the summer. They then walk to a ravine to gather water.
Do you think the water at this source is clean?	Yes
Do you ever buy water?	No
Receptacle type	Ceramic
How old is the filter?	14 months
How many people use the filter regularly?	Five 3 adults, 2 children
When do you add water to the filter?	When half-empty
How long does it take for the filter to filter?	Through the night
When do you drink unfiltered water?	When the husband leaves for work, he takes water with him. This leaves no water in the filter for the children, and they drink the water at school.
How do you clean the filter?	With brush and soap
How often do you clean the filter?	Two times per week
What water do you use to clean the filter?	Water from the storage tank
What do you use the filtered water for?	Drinking, juice
What do you like about the filter?	The taste and freshness of the water
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Private latrine, 6 meters from home
What are the ages of the children who drink filtered water?	8, 4 years
Have any of these children had diarrhea in the last month?	No

Table 11-20: Mancotal Home 1 Water Quality Data

Parameter	Before Filtration	After Filtration (CNC[2])
DO (mg/L)	7.6	
Turbidity (NTU)	5.0	
Temperature (C)	21	
pH	7.6	
Salinity (ppt)	0	
Conductivity (µS/cm)	50	
TDS (ppm)	20	
Silver (ppb)	CNC[1]	
Flow Rate (L/hr)		500 mL in 3:50 130 mL / hour

1. Turbidity too high to allow completion of the Silver test.
2. Upon return to home there was not enough water in the filter to complete anything but the bacteriological and silver lab tests.

Water stored in the storage tank tested positive for all three microbiological indicators. This filter removed *E. coli* from the water.

Table 11-21: Mancotal Home 1 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform			+	+			+	+
E. coli			–	–			+	–
H_2S			–	–			+	+

11.3.2 Mancotal Home 2

Table 11-22: Mancotal Home 2 Survey Data

Question	Response
Who collects water for the household?	Mother
How many times per day do you collect water?	1 time per day
Do you ever have to wait at the water source?	No
Is there always water at this source?	Yes, except sometimes in the summer. They then walk to a ravine to gather water.
Do you think the water at this source is clean?	Do not know
Do you ever buy water?	No
Receptacle type	Ceramic
How old is the filter?	14 months
How many people use the filter regularly?	Five 2 adults, 3 children
When do you add water to the filter?	When half-empty
How long does it take for the filter to filter?	1 to 2 hours
When do you drink unfiltered water?	When we do not remember to fill and empty the filter, when husband is at work
How do you clean the filter?	
How often do you clean the filter?	Every day
What water do you use to clean the filter?	Water from the storage facility
What do you use the filtered water for?	Drinking, juice
What do you like about the filter?	The taste and freshness of the water
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Do not have a latrine
What are the ages of the children who drink filtered water?	7, 4, 1 year(s)
Have any of these children had diarrhea in the last month?	No

Table 11-23: Mancotal Home 2 Water Quality Data

Parameter	Before Filtration	After Filtration (CNC[1])
DO (mg/L)	7.0	
Turbidity (NTU)	4.0	0.7
Temperature (C)	20	
pH	7.5	
Salinity (ppt)	0	
Conductivity (μS/cm)	40	
TDS (ppm)	20	
Silver (ppb)	0	
Flow Rate (L/hr)		550 mL in 4 hours

1. Upon return to home there was not enough water in the filter to complete anything but the bacteriological and silver lab tests.

As with the last filter, the water from the storage tank tests positive for all three microbiological indicators, and the filter removes *E. coli*.

Table 11-24: Mancotal Home 2 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform			+	+			+	+
E. coli			–	–			+	–
H_2S			+	+			+	+

11.3.3 Mancotal Home 3

This home collects water from either the river or a rainwater catchment system. Because it was the rainy season when we visited, the family was using rainwater in their filter.

Table 11-25: Mancotal Home 3 Survey Data

Question	Response
Who collects water for the household?	Daughter, 15 years old
How many times per day do you collect water?	2 times per day
Do you ever have to wait at the water source?	No
Is there always water at this source?	Yes
Do you think the water at this source is clean?	The river is contaminated in the time of the coffee.
Do you ever buy water?	No
Receptacle type	Ceramic
How old is the filter?	14 months
How many people use the filter regularly?	22 6 adults, 16 children (children from nearby homes use the filter)
When do you add water to the filter?	When half-empty
How long does it take for the filter to filter?	Morning to afternoon
When do you drink unfiltered water?	When there is no water in the filter
How do you clean the filter?	With a brush
How often do you clean the filter?	Every three days
What water do you use to clean the filter?	River water
What do you use the filtered water for?	Drinking
What do you like about the filter?	The taste and cleanness of the water.
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Private latrine, 6 meters from home
What are the ages of the children who drink filtered water?	1 to 15 years old
Have any of these children had diarrhea in the last month?	No

Table 11-26: Mancotal Home 3 Water Quality Data

Parameter	Before Filtration	After Filtration (CNC[1])
DO (mg/L)	6.5	
Turbidity (NTU)	16.0	
Temperature (C)	21.5	
pH	7.2	
Salinity (ppt)	0	
Conductivity (µS/cm)	70	
TDS (ppm)	30	
Silver (ppb)	CNC[1]	
Flow Rate (L/hr)		475 mL in 3.5 hours 130 mL / hour

1. Turbidity to high to allow completion of silver test.
2. Upon return to home there was not enough water in the filter to complete anything but the bacteriological and silver lab tests.

The rainwater used in this filter tested positive for all three microbiological indicators, as did the finished water. The (+) designation of the *E. coli* indicates that the fluorescence of the sample was not as bright as other positive samples. The rainwater probably tests positive for microbiological indicators because of contamination in the storage container.

Table 11-27: Mancotal Home 3 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform			+	+			+	+
E. coli			+	–			+	(+)
H_2S			+	+			+	+

11.3.4 Mancotal Home 4

This home used a well installed by the Nicaraguan Government as their water supply.

Table 11-28: Mancotal Home 4 Survey Data

Question	Response
Who collects water for the household?	Daughter, 17 years old
How many times per day do you collect water?	1 time per day
Do you ever have to wait at the water source?	No
Is there always water at this source?	Yes
Do you think the water at this source is clean?	Yes
Do you ever buy water?	No
Receptacle type	Ceramic
How old is the filter?	14 months
How many people use the filter regularly?	Seven 3 adults, 4 children
When do you add water to the filter?	When half-empty
How long does it take for the filter to filter?	
When do you drink unfiltered water?	Never
How do you clean the filter?	Soft towel
How often do you clean the filter?	
What water do you use to clean the filter?	Well water
What do you use the filtered water for?	Drinking
What do you like about the filter?	The cleanliness and flavor of the water
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Do not have a latrine
What are the ages of the children who drink filtered water?	18, 15, 12, 6
Have any of these children had diarrhea in the last month?	No

Table 11-29: Mancotal Home 4 Water Quality Data

Parameter	Before Filtration	After Filtration (CNC[2])
DO (mg/L)	3.3	
Turbidity (NTU)	3.0	0.0
Temperature (C)	21	
pH	7.8	
Salinity (ppt)	0	
Conductivity (μS/cm)	280	
TDS (ppm)	140	
Silver (ppb)	CNC[1]	
Flow Rate (L/hr)		450 mL in 2.5 hours 180 mL / hour

1. Turbidity to high to allow completion of silver test.
2. Upon return to home there was not enough water in the filter to complete anything but the bacteriological and silver lab tests.

Like the other water in this community, the source water tested positive for all three microbiological indicators. Also similar to the other homes in this community, the filter removed *E. coli,* but not the other indicators of microbial contamination.

Table 11-30: Mancotal Home 4 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform			+	+			+	+
E. coli			–	–			+	–
H_2S			+	+			+	+

11.3.5 : Mancotal Home 5

The gather their water at a well 50 meters away that people in the community constructed.

Table 11-31: Mancotal Home 5 Survey Data

Question	Response
Who collects water for the household?	Mother
How many times per day do you collect water?	2 times per day
Do you ever have to wait at the water source?	No
Is there always water at this source?	Yes
Do you think the water at this source is clean?	Yes, because wells are clean
Do you ever buy water?	No
Receptacle type	Ceramic
How old is the filter?	14 months
How many people use the filter regularly?	Five 3 adults, 2 children
When do you add water to the filter?	When empty
How long does it take for the filter to filter?	From morning until afternoon
When do you drink unfiltered water?	When not in the home
How do you clean the filter?	With a brush
How often do you clean the filter?	Every two days
What water do you use to clean the filter?	Well water
What do you use the filtered water for?	Drinking
What do you like about the filter?	The cleanliness and flavor of the water.
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Do not have a latrine
What are the ages of the children who drink filtered water?	7, 5
Have any of these children had diarrhea in the last month?	No

Table 11-32: Mancotal Home 5 Water Quality Data

Parameter	Before Filtration	After Filtration (CNC[2])
DO (mg/L)	5.8	
Turbidity (NTU)	9.4	
Temperature (C)	21	
pH	7.5	
Salinity (ppt)	0	
Conductivity (µS/cm)	80	
TDS (ppm)	40	
Silver (ppb)	CNC[1]	
Flow Rate (L/hr)		450 mL in 2 hours 225 mL / hour

1. Turbidity to high to allow completion of silver test.
2. Upon return to home there was not enough water in the filter to complete anything but the bacteriological and silver lab tests.

This well, unlike other sources in this community, tested negative for *E. coli* contamination.

Table 11-33: Mancotal Home 5 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform			+	+			+	+
E. coli			–	–			–	–
H_2S			+	+			+	+

11.3.6 : Mancotal Home 6

A person in the home constructed the well. This filter had no lip and was inside a plastic container such that the filter slipped halfway into the receptacle. The well is 60 meters away.

Table 11-34: Mancotal Home 6 Survey Data

Question	Response
Who collects water for the household?	People who are 25 and 11 years old
How many times per day do you collect water?	1 time per day
Do you ever have to wait at the water source?	No
Is there always water at this source?	Yes
Do you think the water at this source is clean?	Yes
Do you ever buy water?	No
Receptacle type	Plastic
How old is the filter?	14 months
How many people use the filter regularly?	Five 2 adults, 3 children
When do you add water to the filter?	When half-empty
How long does it take for the filter to filter?	From morning until night
When do you drink unfiltered water?	When there is no water in the filter
How do you clean the filter?	With a brush
How often do you clean the filter?	Once per week
What water do you use to clean the filter?	Well water
What do you use the filtered water for?	Drinking, juice, milk for the children
What do you like about the filter?	The water is hygienic, fresh, cold and tastes good
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Do not have a latrine
What are the ages of the children who drink filtered water?	11, 6, 3
Have any of these children had diarrhea in the last month?	No

Table 11-35: Mancotal Home 6 Water Quality Data

Parameter	Before Filtration	After Filtration (CNC[2])
DO (mg/L)	4.4	
Turbidity (NTU)	12.5	
Temperature (C)	21	
pH	7.6	
Salinity (ppt)	0	
Conductivity (µS/cm)	530	
TDS (ppm)	260	
Silver (ppb)	CNC[1]	
Flow Rate (L/hr)		800 mL in 2 hours 400 mL / hour

1. Turbidity to high to allow completion of silver test.
2. Upon return to home there was not enough water in the filter to complete anything but the bacteriological and silver lab tests.

Table 11-36: Mancotal Home 6 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform			+	+			+	+
E. coli			+	–			+	–
H_2S			+	+			+	+

11.4 Mancotal: Jingüina

Jingüina is a small community also approximately one hour from Jinotega. The community has a piped water supply installed by Ayuda Obrada Swisse and Care International that all families visited were connected to. Seven homes were visited in this community, and four of the seven were using the filter. Of the three other homes, two had broken filters (as of 15 days ago, and 3 months ago), and one entire filter and receptacle had fallen off the counter and broken completely. The entire community used ceramic receptacles.

11.4.1 : Jingüina Home 2

Table 11-37: Jingüina Home 2 Survey Data

Question	Response
Who collects water for the household?	Father
How many times per day do you collect water?	N/A piped water supply
Do you ever have to wait at the water source?	N/A piped water supply
Is there always water at this source?	N/A piped water supply
Do you think the water at this source is clean?	Yes
Do you ever buy water?	No
Receptacle type	Ceramic
How old is the filter?	18 months
How many people use the filter regularly?	Four 2 adults, 2 children
When do you add water to the filter?	When half-empty
How long does it take for the filter to filter?	1 to 2 hours
When do you drink unfiltered water?	None
How do you clean the filter?	Brush
How often do you clean the filter?	Every 8 days
What water do you use to clean the filter?	Piped water
What do you use the filtered water for?	Drinking, juice, cooking
What do you like about the filter?	The water is clean, cold, and rich
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Private latrine, 7 meters away
What are the ages of the children who drink filtered water?	4
Have any of these children had diarrhea in the last month?	No

Table 11-38: Jingüina Home 2 Water Quality Data

Parameter	Before Filtration	After Filtration
DO (mg/L)	7.1	7.0
Turbidity (NTU)	7.3	0.0
Temperature (C)	20	20
pH	7.5	7.6
Salinity (ppt)	0	0
Conductivity (µS/cm)	100	170
TDS (ppm)	50	80
Silver (ppb)	CNC[1]	0
Flow Rate (L/hr)		800 mL in 2 hours 400 mL/hour

1. Turbidity to high to allow completion of silver test.

All microbiological indicators were positive after 24 hours. A duplicate sample was collected at this site and analyzed at CIRA-UNAN.

Table 11-39: Jingüina Home 2 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform			+	+			+	+
E. coli			+	+			+	+
H_2S			+	+			+	+

11.4.2 Jingüina Home 5

Table 11-40: Jingüina Home 5 Survey Data

Question	Response
Who collects water for the household?	All members of household
How many times per day do you collect water?	When needed
Do you ever have to wait at the water source?	No
Is there always water at this source?	Yes
Do you think the water at this source is clean?	Yes
Do you ever buy water?	No
Receptacle type	Ceramic
How old is the filter?	18 months
How many people use the filter regularly?	Five 4 adults, 1 child
When do you add water to the filter?	When half-empty
How long does it take for the filter to filter?	
When do you drink unfiltered water?	When not in home, drink whatever is available
How do you clean the filter?	Brush
How often do you clean the filter?	Every three days
What water do you use to clean the filter?	Filtered water
What do you use the filtered water for?	Drinking, cooking
What do you like about the filter?	The cleanliness and coolness of the water
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Private latrine, 8 meters from home
What are the ages of the children who drink filtered water?	6
Have any of these children had diarrhea in the last month?	No

1. Could not complete H_2S testing because filtered water needed for laboratory duplicate testing.

Table 11-41: Jingüina Home 5 Water Quality Data

Parameter	Before Filtration	After Filtration (CNC[2])
DO (mg/L)	5.8	
Turbidity (NTU)	2.5	
Temperature (C)	21	
pH	6.5	
Salinity (ppt)	0.0	
Conductivity (µS/cm)	130	
TDS (ppm)	60	
Silver (ppb)	CNC[1]	
Flow Rate (L/hr)		350 mL in 1.5 hours 230 mL / hour

1. Turbidity to high to allow completion of silver test.
2. Upon return to home there was not enough water in the filter to complete anything but the bacteriological and silver lab tests.

Only the total coliform and *E. coli* tests were completed here because there was not enough finished water upon return for the H_2S test. A duplicate sample was collected at this site and analyzed by CIRA-UNAN.

Table 11-42: Jingüina Home 5 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform			+	+			+	+
E. coli			–	–			(+)	(+)
H_2S			CNC[1]	CNC[1]			CNC[1]	CNC[1]

11.4.3 Jingüina Home 6

Table 11-43: Jingüina Home 6 Survey Data

Question	Response
Who collects water for the household?	All members of household
How many times per day do you collect water?	N/A
Do you ever have to wait at the water source?	No
Is there always water at this source?	Yes
Do you think the water at this source is clean?	Yes, it's a piped water supply
Do you ever buy water?	No
Receptacle type	Ceramic
How old is the filter?	18 months
How many people use the filter regularly?	10 5 adults, 5 children
When do you add water to the filter?	When half-empty
How long does it take for the filter to filter?	2 hours
When do you drink unfiltered water?	When not at home, drink whatever is available
How do you clean the filter?	With a brush
How often do you clean the filter?	Every four days
What water do you use to clean the filter?	Piped water
What do you use the filtered water for?	Drinking
What do you like about the filter?	How good the water is
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Private latrine, 8 meters
What are the ages of the children who drink filtered water?	13, 6, 5, 4, 3
Have any of these children had diarrhea in the last month?	Yes, three year old has frequent diarrhea

Table 11-44: Jingüina Home 6 Water Quality Data

Parameter	Before Filtration	After Filtration (CNC[2])
DO (mg/L)	4.6	
Turbidity (NTU)	3.5	
Temperature (C)	21	
pH	6.5	
Salinity (ppt)	0	
Conductivity (μS/cm)	130	
TDS (ppm)	60	
Silver (ppb)	CNC[1]	
Flow Rate (L/hr)		350 mL in 1:15 280 mL / hour

1. Turbidity to high to allow completion of silver test.
2. Upon return to home there was not enough water in the filter to complete anything but the bacteriological and silver lab tests.

Total coliform was positive, but *E. coli* remained negative at this site. A duplicate sample was collected at this site and analyzed by CIRA-UNAN.

Table 11-45: Jingüina Home 6 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform			+	+			+	+
E. coli			–	–			–	–
H_2S			CNC[1]	CNC[1]			CNC[1]	CNC[1]

1. Could not complete H_2S testing because filtered water needed for laboratory duplicate testing.

11.4.4 Jingüina Home 7

Table 11-46: Jingüina Home 7 Survey Data

Question	Response
Who collects water for the household?	All members of household
How many times per day do you collect water?	Whenever necessary
Do you ever have to wait at the water source?	No
Is there always water at this source?	Yes
Do you think the water at this source is clean?	Yes, except after rain
Do you ever buy water?	No
Receptacle type	Ceramic
How old is the filter?	18 months
How many people use the filter regularly?	Four 2 adults, 2 children
When do you add water to the filter?	When half-empty
How long does it take for the filter to filter?	1 hour
When do you drink unfiltered water?	Never
How do you clean the filter?	With a brush
How often do you clean the filter?	Once per week
What water do you use to clean the filter?	Piped water
What do you use the filtered water for?	Drinking, cooking
What do you like about the filter?	Because it is clean water
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Private latrine, 8 meters
What are the ages of the children who drink filtered water?	8, 6
Have any of these children had diarrhea in the last month?	No

Table 11-47: Jingüina Home 7 Water Quality Data

Parameter	Before Filtration	After Filtration (CNC[1])
DO (mg/L)	6.7	
Turbidity (NTU)	3.1	
Temperature (C)	21	
pH	6.6	
Salinity (ppt)	0	
Conductivity (µS/cm)	130	
TDS (ppm)	60	
Silver (ppb)	0.0	
Flow Rate (L/hr)		350 mL in 1.25 hours 280 mL / hour

1. Upon return to home there was not enough water in the filter to complete anything but the bacteriological and silver lab tests.

This filter removed *E. coli* from the water supply. A duplicate sample was completed at this site and analyzed by CIRA-UNAN.

Table 11-48: Jingüina Home 7 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform			+	+			+	+
E. coli			+	–			+	–
H_2S			CNC[1]	CNC[1]			CNC[1]	CNC[1]

1. Could not complete H_2S testing because filtered water needed for laboratory duplicate testing.

11.5 San Francisco Libre: Los Teisos

A rope-pump well installed by the Swiss organization COSUDE and the Nicaraguan government organization ENACAL is in the center of the community. Both homes sampled in Los Teisos use this well.

11.5.1 Los Teisos Home 1

The well is 100 meters away from this home.

Table 11-49: Los Teisos Home 1 Survey Data

Question	Response
Who collects water for the household?	Granddaughter, 20 years old
How many times per day do you collect water?	2 times per day
Do you ever have to wait at the water source?	Sometimes 1 hour
Is there always water at this source?	Yes
Do you think the water at this source is clean?	Do not know
Do you ever buy water?	No
Receptacle type	Plastic
How old is the filter?	6 months
How many people use the filter regularly?	Five 2 adults, 3 children
When do you add water to the filter?	When half-empty
How long does it take for the filter to filter?	1 to 2 hours
When do you drink unfiltered water?	When not in the home, drink whatever is available
How do you clean the filter?	Organic brush
How often do you clean the filter?	Every day
What water do you use to clean the filter?	Well water
What do you use the filtered water for?	Drinking, cooking
What do you like about the filter?	Cleanliness and flavor of the water
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Private latrine, 7 meters from house
What are the ages of the children who drink filtered water?	7, 4, 4
Have any of these children had diarrhea in the last month?	No

Table 11-50: Los Teisos Home 1 Water Quality Data

Parameter	Before Filtration	After Filtration
DO (mg/L)	5.4	7.0
Turbidity (NTU)	2.0	1.0
Temperature (C)	29	29
pH	7.4	8.3
Salinity (ppt)	0	0
Conductivity (μS/cm)	620	590
TDS (ppm)	300	390
Silver (ppb)	0	0
Flow Rate (L/hr)		1.5

The flow rate was high enough in this community to allow for duplicate sampling upon return. As can be seen, the duplicate is the same results as the original – *E. coli* is removed, and H_2S is reduced.

Table 11-51: Los Teisos Home 1 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform	+	–	+	+	+	+	+	+
E. coli	–	–	+	–	+	–	+	–
H_2S	–	–	+	–	+	(+)	+	(+)
Duplicate – P/A		–		+		+		+
Duplicate – *E. coli*		–		–		–		–
Duplicate – H_2S		–		–		(+)		(+)

11.5.2 Los Teisos Home 2

Well is 70 meters from home.

Table 11-52: Los Teisos Home 2 Survey Data

Question	Response
Who collects water for the household?	Mother or daughter
How many times per day do you collect water?	2 times per day
Do you ever have to wait at the water source?	Sometimes one to two hours
Is there always water at this source?	Yes
Do you think the water at this source is clean?	Yes, because it is deep
Do you ever buy water?	No
Receptacle type	Plastic
How old is the filter?	6 months
How many people use the filter regularly?	Seven 5 adults, 2 children
When do you add water to the filter?	When half-empty
How long does it take for the filter to filter?	1 to 2 hours
When do you drink unfiltered water?	When not at home, drink whatever is available
How do you clean the filter?	With a brush
How often do you clean the filter?	Two times per week
What water do you use to clean the filter?	Filtered water
What do you use the filtered water for?	Drinking
What do you like about the filter?	Water is rich
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Private latrine, 4 meters from home
What are the ages of the children who drink filtered water?	8 years, 10 months
Have any of these children had diarrhea in the last month?	No

Table 11-53: Los Teisos Home 2 Water Quality Data

Parameter	Before Filtration	After Filtration
DO (mg/L)	6.0	6.8
Turbidity (NTU)	4.0	1.0
Temperature (C)	29	29
pH	7.4	8.3
Salinity (ppt)	0	0
Conductivity (µS/cm)	610	600
TDS (ppm)	300	300
Silver (ppb)	CNC[1]	0
Flow Rate (L/hr)		1.75

1. Turbidity to high to allow completion of silver test.

Although this family uses the same source as the family in Home 1, this sample was not contaminated with *E. coli* prior to filtration. This indicates that the *E. coli* contamination is possible from the containers used to store water in the households. This filter also reduced H_2S bacteria – like the filter in Home 1.

Table 11-54: Los Teisos Home 2 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform	+	–	+	+	+	+	+	+
E. coli	–	–	–	–	–	–	–	–
H_2S	–	–	+	–	+	–	+	(–)

11.6 San Francisco Libre: Los Piches

On October 18th, 2001, three homes were visited in another post-Mitch community that pipes water into a storage container capable of holding 20,000 gallons from 3 kilometers away. Families could either choose to be connected to the system using a tuberia or to go to one of the manual wells in the community. The system was installed by Mujer y Communidad, a Nicaraguan women's organization.

11.6.1 Los Piches Home 1

In this home were two filters (for the two families living in home). This family has a piped water supply into the home.

Table 11-55: Los Piches Home 1 Survey Data

Question	Response
Who collects water for the household?	Whoever needs water
How many times per day do you collect water?	Whenever needed
Do you ever have to wait at the water source?	No
Is there always water at this source?	Yes
Do you think the water at this source is clean?	No, piped system is dirty
Do you ever buy water?	No
Receptacle type	Plastic
How old is the filter?	6 months
How many people use the filter regularly?	Eight 6 adults, 2 children
When do you add water to the filter?	When half-empty
How long does it take for the filter to filter?	2 hours
When do you drink unfiltered water?	Never
How do you clean the filter?	Brush, soap
How often do you clean the filter?	1 time per week
What water do you use to clean the filter?	Well water
What do you use the filtered water for?	Drinking, cooking, juice
What do you like about the filter?	Water is clean and flavor is different
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Private Latrine, 7 meters from home
What are the ages of the children who drink filtered water?	7, 2
Have any of these children had diarrhea in the last month?	No

Table 11-56: Los Piches Home 1 Water Quality Data

Parameter	Before Filtration	After Filtration
DO (mg/L)	3.8	6.8
Turbidity (NTU)	0.8	0.0
Temperature (C)	27	29
pH	7.5	8.1
Salinity (ppt)	0	0
Conductivity (µS/cm)	490	490
TDS (ppm)	240	240
Silver (ppb)	0.0	0.0
Flow Rate (L/hr)		1.75

The piped water into this household was contaminated with all three microbiological indicators. This filter removed H_2S, but not *E. coli.*

Table 11-57: Los Piches Home 1 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform	+	–	+	+	+	+	+	+
E. coli	–	–	+	+	+	+	+	+
H_2S	+	–	+	–	+	–	+	–

11.6.2 Los Piches Home 2

This home uses the tap approximately 100 meters away, for it does not have piped water to the house.

Table 11-58: Los Piches Home 2 Survey Data

Question	Response
Who collects water for the household?	Mother
How many times per day do you collect water?	2 times per day
Do you ever have to wait at the water source?	No
Is there always water at this source?	Yes
Do you think the water at this source is clean?	No, wells are dirty
Do you ever buy water?	Yes, 25 cordobas per month
Receptacle type	Plastic
How old is the filter?	6 months
How many people use the filter regularly?	7 3 adults, 4 children
When do you add water to the filter?	When half-empty
How long does it take for the filter to filter?	3 hours
When do you drink unfiltered water?	When not in the home, drink whatever is available
How do you clean the filter?	With a brush
How often do you clean the filter?	Every 15 days
What water do you use to clean the filter?	Filtered water
What do you use the filtered water for?	Drinking, sometimes cooking
What do you like about the filter?	Water is crystal and healthy
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Private, 200 meters from home – so not use too much
What are the ages of the children who drink filtered water?	13, 11, 8, 5
Have any of these children had diarrhea in the last month?	In 5 year old, 2 days ago

Table 11-59: Los Piches Home 2 Water Quality Data

Parameter	Before Filtration	After Filtration
DO (mg/L)	6.3	7.0
Turbidity (NTU)	0.6	0.0
Temperature (C)	29	30
pH	7.2	8.2
Salinity (ppt)	0	0
Conductivity (µS/cm)	500	500
TDS (ppm)	250	250
Silver (ppb)	0.0	0.0
Flow Rate (L/hr)		1.75

The water from the tap was contaminated with total coliform and H_2S-producing bacteria, but not *E. coli*. However, after filtration all three microbiological indicators were positive.

Table 11-60: Los Piches Home 2 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform	–	–	+	+	+	+	+	+
E. coli	–	–	–	+	–	+	–	+
H_2S	–	–	+	+	+	+	+	+

11.6.3 : Los Piches Home 3

This family uses a manual tap 80 meters away from their home.

Table 11-61: Los Piches Home 3 Survey Data

Question	Response
Who collects water for the household?	Mother and daughters
How many times per day do you collect water?	2 times per day
Do you ever have to wait at the water source?	Sometimes
Is there always water at this source?	Almost always
Do you think the water at this source is clean?	No, because she sometimes sees small animals in it
Do you ever buy water?	Yes, 25 cordobas every month
Receptacle type	Plastic
How old is the filter?	6 months
How many people use the filter regularly?	8 6 adults, 2 children
When do you add water to the filter?	When half-empty
How long does it take for the filter to filter?	2 hours
When do you drink unfiltered water?	Never
How do you clean the filter?	With water
How often do you clean the filter?	Every 3 days
What water do you use to clean the filter?	
What do you use the filtered water for?	Drinking, cooking
What do you like about the filter?	Water is fresh and flavorful
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Private latrine, 8 meters from home
What are the ages of the children who drink filtered water?	6, 1
Have any of these children had diarrhea in the last month?	No

Table 11-62: Los Piches Home 3 Water Quality Data

Parameter	Before Filtration	After Filtration
DO (mg/L)	6.8	7.0
Turbidity (NTU)	0.5	0.8
Temperature (C)	29	29
pH	7.5	8.3
Salinity (ppt)	0	0
Conductivity (µS/cm)	490	500
TDS (ppm)	240	240
Silver (ppb)	0.0	0.0
Flow Rate (L/hr)		1.75

Like in Home 2, this tap showed contamination with total coliform and H_2S-producing bacteria, but not with *E. coli*. Unlike Homes 1 and 2 though, this filter removed all of the bacteria indicators.

Table 11-63: Los Piches Home 3 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform	+	–	+	–	+	–	+	–
E. coli	–	–	–	–	–	–	–	–
H_2S	–	–	+	–	+	–	+	–

11.7 San Francisco Libre: Villa Esperanza

Home in Villa Esperanza use a rope-pump well in the center of the community for water supply. All three homes visited used this same water source.

11.7.1 Villa Esperanza Home 1

The well is 100 meters from the home.

Table 11-64: Villa Esperanza Home 1 Survey Data

Question	Response
Who collects water for the household?	All members of household
How many times per day do you collect water?	2 times per day
Do you ever have to wait at the water source?	No
Is there always water at this source?	Yes
Do you think the water at this source is clean?	Yes, because MINSA tests
Do you ever buy water?	No
Receptacle type	Plastic
How old is the filter?	6 months
How many people use the filter regularly?	6 2 adults, 4 children
When do you add water to the filter?	When half-empty
How long does it take for the filter to filter?	2 hours
When do you drink unfiltered water?	When not in home, drink whatever water is available
How do you clean the filter?	With a brush
How often do you clean the filter?	Every 8 days
What water do you use to clean the filter?	Well water
What do you use the filtered water for?	Drinking
What do you like about the filter?	Because the water is not contaminated and the children do not get sick
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Private latrine, 8 meters
What are the ages of the children who drink filtered water?	15, 14, 12, 9
Have any of these children had diarrhea in the last month?	No

Table 11-65: Villa Esperanza Home 2 Water Quality Data

Parameter	Before Filtration	After Filtration
DO (mg/L)	6.4	6.8
Turbidity (NTU)	0.0	6.0
Temperature (C)	30.5	30
Ph	7.2	8.1
Salinity (ppt)	0.0	0.0
Conductivity (µS/cm)	410	390
TDS (ppm)	200	190
Silver (ppb)	0.0	0.0
Flow Rate (L/hr)		3.5

The rope pump well water was positive for total coliform and H_2S-producing bacteria, but not *E. coli*. Duplicate sampling with water originally in the filter was conducted here and results of the duplicate sampling matched the duplicate sampling – indicating that the microbiological results are repeatable in the same filter. In addition, duplicate sampling was conducted here by CIRA-UNAN.

Table 11-66: Villa Esperanza Home 1 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform	+	+	+	+			+	+
E. coli	–	–	–	–			–	–
H_2S	+	+	+	+			+	+
Original filtered water – Total Coliform		+		+				+
Original filtered water – *E. coli*		–		–				–
Original filtered water – H_2S		+		+				+

11.7.2 Villa Esperanza Home 2

The well is 200 meters away from the home.
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Table 11-67: Villa Esperanza Home 2 Survey Data

Question	Response
Who collects water for the household?	Mother
How many times per day do you collect water?	3 times per day
Do you ever have to wait at the water source?	Every once in a while
Is there always water at this source?	Yes
Do you think the water at this source is clean?	Yes
Do you ever buy water?	No
Receptacle type	Plastic
How old is the filter?	6 months
How many people use the filter regularly?	6 2 adults, 4 children
When do you add water to the filter?	When half-empty
How long does it take for the filter to filter?	1 to 2 hours
When do you drink unfiltered water?	Never, except husband drinks whatever there is at work
How do you clean the filter?	With a brush
How often do you clean the filter?	Once per week
What water do you use to clean the filter?	Filtered water
What do you use the filtered water for?	Drinking
What do you like about the filter?	Because the water is rich and good for health
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Private latrine, 8 meters from home
What are the ages of the children who drink filtered water?	9, 5, 3, 2
Have any of these children had diarrhea in the last month?	No

Table 11-68: Villa Esperanza Home 2 Water Quality Data

Parameter	Before Filtration	After Filtration
DO (mg/L)	5.6	7.8
Turbidity (NTU)	0.0	0.0
Temperature (C)	30	30
pH	7.3	8.2
Salinity (ppt)	0.0	0.0
Conductivity (µS/cm)	420	400
TDS (ppm)	210	200
Silver (ppb)	0.0	0.0
Flow Rate (L/hr)		3.5

The results from the rope pump well water are the same as in home 1: positive total coliform and H_2S-producing bacteria and negative *E. coli*. However, this filter filtered out H_2S-producing bacteria, both in the original water in the filter when we arrived, and the filtered water after we ran the filter. In addition, duplicate sampling was conducted here by CIRA-UNAN.

Table 11-69: Villa Esperanza Home 2 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform	+	+	+	+			+	+
E. coli	–	–	–	–			–	–
H_2S	+	–	+	–			+	–
Original filtered water – P/A		+		+				+
Original filtered water – *E. coli*		–		–				–
Original filtered water – H_2S		–		–				–

11.7.3 Villa Esperanza Home 3

Table 11-70: Villa Esperanza Home 3 Survey Data

Question	Response
Who collects water for the household?	Mother
How many times per day do you collect water?	1 time per day
Do you ever have to wait at the water source?	No
Is there always water at this source?	Yes
Do you think the water at this source is clean?	Yes
Do you ever buy water?	No
Receptacle type	Plastic
How old is the filter?	6 months
How many people use the filter regularly?	9 4 adults, 5 children
When do you add water to the filter?	When empty
How long does it take for the filter to filter?	2 hours
When do you drink unfiltered water?	When not in the home, drink whatever is available
How do you clean the filter?	
How often do you clean the filter?	Every day
What water do you use to clean the filter?	Well water
What do you use the filtered water for?	Drinking
What do you like about the filter?	The taste of the water
Do you wash your hands before cooking, before eating, and after using the bathroom?	Yes, yes, yes
What type of latrine do you have and how far away is it?	Do not have a latrine
What are the ages of the children who drink filtered water?	14, 13, 11, 5, 3
Have any of these children had diarrhea in the last month?	No

Table 11-71: Villa Esperanza Home 3 Water Quality Data

Parameter	Before Filtration	After Filtration
DO (mg/L)	5.6	6.
Turbidity (NTU)	0.0	2.0
Temperature (C)	30.5	29.5
pH	7.4	8.5
Salinity (ppt)	0.0	0.0
Conductivity (μS/cm)	420	420
TDS (ppm)	210	210
Silver (ppb)	0.0	0.0
Flow Rate (L/hr)		1

Here, all three microbiological indicators tested positive for both before and after filtration. In addition, duplicate sampling was conducted here by CIRA-UNAN.

Table 11-72: Villa Esperanza Home 3 Microbiological Data

Time	12 hours		24 hours		36 hours		48 hours	
	Before	After	Before	After	Before	After	Before	After
Total Coliform	+	+	+	+	+	+	+	+
E. coli	–	–	–	–			+	+
H_2S	–	+	+	+	+	+	+	+

^ Investigation of the Potters For Peace Colloidal Silver Impregnated Ceramic Filter, Daniele S. Lantagne, December 21, 2001, accessed October 29, 2009. ^ A Simple Way to Make Bad Water Safe, Jen Banbury, UNICEF USA, October 15, 2008, accessed October 28, 2009.Â ^ Theoretical and Experimental Investigation of Water Flow through Porous Ceramic Clay Composite Water Filter, A. K. Plappally, I. Yakub, L. C. Brown, W. O. Soboyejo and A. B. O. Soboyejo. FDMP: Fluid Dynamics & Materials Processing, Vol. 5, No. 4, pp. 373-398, 2009, accessed Nov 01, 2010. Abstract This study investigated the hydraulic properties of the Potters For Peace filter in greater detail than previous studies by Sten Eriksen and Daniele Lantagne. Hydraulic properties such as the hydraulic conductivity and tortuosity are important because they help determine the contact time of pathogens in the water with silver to provide inactivation. Two laboratory tests were conducted using both experimental and numerical methods for attaining the results.Â Keywords Engineers Without Borders, Potters For Peace, FiltrÃ³n, Appropriate technology, ceramic filter, colloidal silver, developing countries, drinking water, point-of-use treatment. Author kaiPosted on June 18, 2011July 14, 2012Categories StudiesTags document. Leave a Reply Cancel reply.