Water System Improvement Project

Los Toros, Dominican Republic

Assessment Report – Phase 1

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1.0 Introduction

1.1 Community

Los Toros is a community located in the Southern region of Dominican Republic with a population of approximately 6000 people. Marquette University was approached by the Los Toros Foundation (of Grafton, Wisconsin) to assist with their evaluation of the water conditions in the community. The local economy is driven in large part by agriculture, with major crops consisting of tobacco, sugar cane, bananas, tomatoes, and a wide variety of other smaller crops. In addition to agriculture, the community supports various initiatives geared towards early health and educational development for their children to be able to attend college in the capitol city, Santo Domingo. The Los Toros Foundation has been working with the community for over 15 years on establishing local committees, each focusing on a specific discipline such as: Health, Water, Agriculture, High School Education, Mothers Group, and Youth Group.

1.2 Water Project

Water in Los Toros is provided by a government-funded aqueduct system that serves 4 different communities: Guanabana, Tabara Arriba, Los Toros, and Sahanoa. The estimated age of the aqueduct is between 23-25 years. The system was built by INAPA, the national government authority on water projects. The aqueduct water is utilized for drinking, cooking, bathing, faucets, and toilets. Approximately 50 families use an additional treatment step prior to consumption in the form of string-carbon filters donated by a not-for-profit group based out of Florida. For members of the community that have the financial means, 5-gallon bottles of purified water is sold at local stores or *colmados* for RD$25 (Dominican pesos), and this water is used primarily for drinking. According to the Water Committee, the percentage of households who buy bottled water ranges from 15 to 25% of the village. The purpose of Marquette EWB's first trip to Los Toros is to:

- Continue the evaluation of the string-carbon bucket filters currently being used.
- Test the quality of the water used by the community and better understand typical water treatment and sanitary practices with the community.
- Establish a baseline understanding of water system function and physical condition of the distribution system.
- Perform a baseline health assessment of the community.

2.0 Marquette University Filter Testing

2.1 Filter Testing Introduction

Testing was conducted at the Marquette University Water Quality Center during the weeks leading to the assessment trip to Los Toros. The first round of testing took place on Thursday April 5th, 2007 with the following attendees:

Mike Dollhopf (Marquette University Water Quality Center)
David Bennett (Brown & Caldwell)

Neal Styka (EWB Marquette)
Philip Ritger (EWB Marquette)

The second round of testing took place on Thursday, May 17th, 2007 with the following attendees:

Mike Dollhopf (Marquette University Water Quality Center)
Neal Styka (EWB Marquette)
Philip Ritger (EWB Marquette)

The purpose of the testing was to determine the effectiveness of string-carbon filters currently being used by a number of families in Los Toros to filter and, in conjunction with point-of-use chlorine treatment, disinfect the aqueduct water in order to make it suitable for drinking.

The water filters consist of two buckets joined by a PVC casing which holds the carbon filter and string element (see Figure 2.1 at right). Water is placed in the upper bucket and 25 drops of chlorine are added to the full bucket in order to disinfect the water. After the water has passed through the filters, it is collected in the lower bucket and a plastic valve allows the user to fill other containers with the water once it is treated. The string element is intended to remove particulates before passing through the carbon filter, which is intended to remove some of the residual chlorine and harmful organic compounds in the water.

Figure 1-01: String-Carbon Filter

2.2 Procedure

The aim of the experimental procedure was to produce coliform levels similar to those seen in Los Toros as well as to replicate the treatment procedure typically practiced in the homes with filters. Therefore, the following procedure was followed for round 1 of the testing:

1. Aerated tap water samples were induced with a concentrated culture to produce approximately 500-1000 colony-forming units per milliliter (CFU/mL) concentration in the water prior to treatment. The contaminated water was then tested for presence/absence of coliforms using the Colilert® reagent method from IDEXX Laboratories, Inc. This consisted of collecting a 100 mL sample of the contaminated water in a sterilized beaker and adding one packet of Colilert reagent to the water. The beaker then was placed in an incubator at 35° C for 24 hours.
2. Half of the contaminated water (~2.5 gal) was sent through the filter element without chlorination. After approximately 1 hour, a 100 mL sample was collected from the lower bucket using a sterilized beaker. One packet of Colilert was then

added to the beaker, the beaker was mixed gently, and placed in an incubator at 35° C for 24 hours.

3. After the contaminated water was sent through the filter, the other half of the water (~2.5 gal) was poured into the upper bucket. After pouring the water into the bucket, the recommended chlorine dosage for drinking water as indicated on the package (5 drops per gallon or 13 drops total) was added and the bucket was lightly agitated to facilitate mixing of the chlorine with the water. After approximately 1 hour, a 100 mL sample was collected from the upper bucket using a sterilized beaker. One packet of Colilert was then added to the beaker, the beaker was mixed gently, and placed in an incubator at 35° C for 24 hours.
4. In addition to the chlorinated only water, a 100 mL sample was collected from the lower bucket (chlorinated and filtered water) in a sterilized beaker at the same time. One packet of Colilert was then added to the beaker, the beaker was mixed gently, and placed in an incubator at 35° C for 24 hours.
5. Steps 2-4 were repeated for another 5-gallon contaminated water sample.

The procedure was repeated for round 2 of the testing, except for the following modifications:

- Prior to performing the test, the filter was shock chlorinated, flushed and allowed to dry for 2 weeks in order to kill any residual bacteria in the string filter element that may have been affecting the results of round 1 of the testing.
- The contaminated water was chlorinated in a separate container for 1 hour in order to allow the disinfection process to occur prior to filtration and prohibit contaminated water to pass through the filter into the lower bucket.

2.3 Results and Discussion

The results of the coliform presence/absence testing are tabulated below:

Table 2.1: Round 1 Testing Results

	Treatment Description	Sample Number	Coliform Presence	Fecal Coliform Presence
	Contaminated Water (No Treatment)	1	Yes	Yes
Run A	Filtered Only	2	Yes	Yes
	Chlorinated Only	4	No	No
	Filtered & Chlorinated	5	Yes	Yes
Run B	Filtered Only	3	Yes	Yes
	Chlorinated Only	6	No	No
	Filtered & Chlorinated	7	Yes	Yes

Table 2.2: Round 2 Testing Results

	Treatment Description	Sample Number	Coliform Presence	Fecal Coliform Presence
	Aerated Tap Water (No Treatment)	1	No	No
Run A	Filtered Only	2	Yes	Yes
	Chlorinated Only	4	No	No

	Filtered & Chlorinated	5	No	No
Run B	Filtered Only	3	Yes	Yes
	Chlorinated Only	6	No	No
	Filtered & Chlorinated	7	No	No

For round 1 of the testing, there are a few suspected causes as to why the filtered and chlorinated water tested positive: 1) A significant amount of contaminated water passed through the filter before coming into contact with the chlorine, 2) The filter element already had significant levels of bacteria present and the chlorinated water simply flushed these bacteria to the lower bucket, and 3) A combination of the two scenarios. The results from round 2, in which the treatment method was slightly modified, suggest that if chlorination is performed prior to filtration, the effectiveness of bacteria removal is increased. Both cases indicate that the biggest factor in ensuring that the bacteria are properly killed off is chlorinating at the proper dosage rates (5 drops per gallon of water).

Physical filtration by means of the string filter may still be a beneficial step in the process in that it can help to remove larger matter and particulates that may be in the water. However, over time the filter may actually cause more harm than benefits if bacteria begin to be retained in the filter and thrive in the moist, hot environment. For this reason, changing filter elements at the manufacturer's recommended interval (8-12 months) is an important maintenance requirement that should not be ignored.

2.4 Conclusions

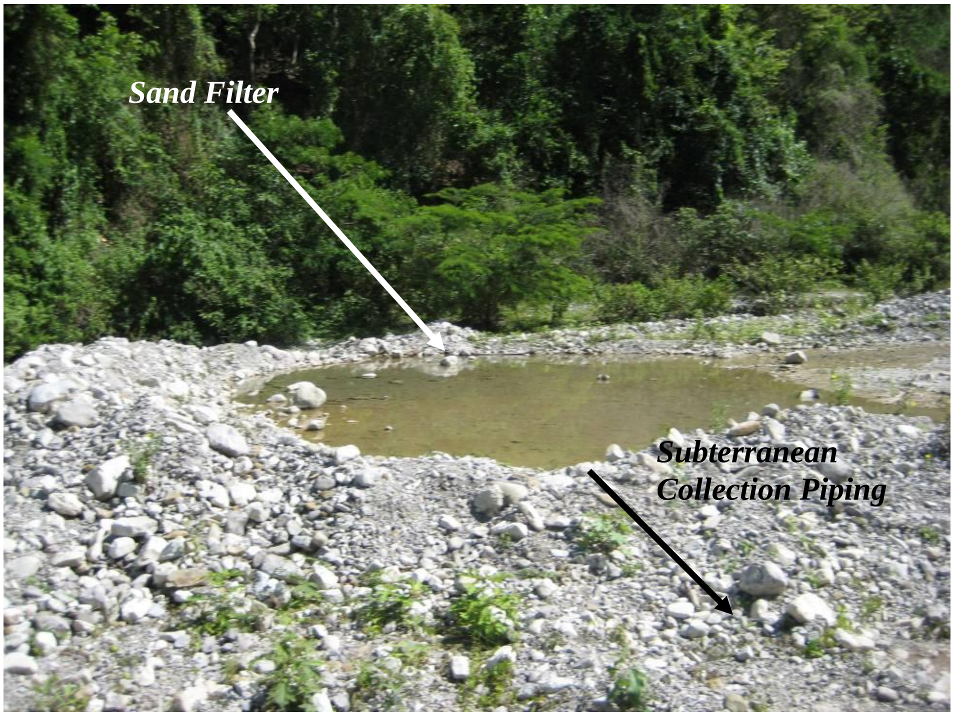
The testing of the string-carbon filters in a controlled environment at Marquette University revealed some important considerations in regards to usage and maintenance. The first consideration is the importance of disinfection in order to kill off the coliforms and bacteria present in the water sources in Los Toros. The recommended amount displayed on the instructions of locally available Clorox Bags is 5-15 drops per gallon, depending on whether the water is used for straight consumption or for washing produce. Although the chlorine will help to kill off some of the harmful organisms present in the water, a possible obstacle to widespread acceptance is objectionable taste and odor when consuming the chlorinated water. The price of the bags of Clorox (4 oz) is RD$5, which translates to roughly US$0.15. Therefore, the amount of water that can be disinfected using one 4 oz packet of Clorox ranges from 180 – 380 gallons. Some estimates put annual household income at around $2400 for the Dominican Republic[1]; therefore if a family were to use 100 gallons of disinfected water per day, this would translate to US$14.50 - $30.00, meaning a modest percentage of income (a little more than 1 percent) would go a long way towards better water quality.

3.0 Physical System Description

3.1 Aqueduct Function

The aqueduct is approximately 5 km long from the source of the water (the dry sand filter and the smaller stream in the mountains) to Los Toros. The dry sand filter and stream are collected in a large caption tank and enter the aqueduct. The dry sand filter consists of a rock and sand dam which traps the rainwater running down the mountain. This trapped water then provides pressure to force the water through a 4-6" layer of rocks and sand to trap sediments (see photo below).

Figure 3-01: River Bed Sand Filter



In the caption tank, there are three separate sections. The first is the actual collection tank, where water moves swiftly (see photo)

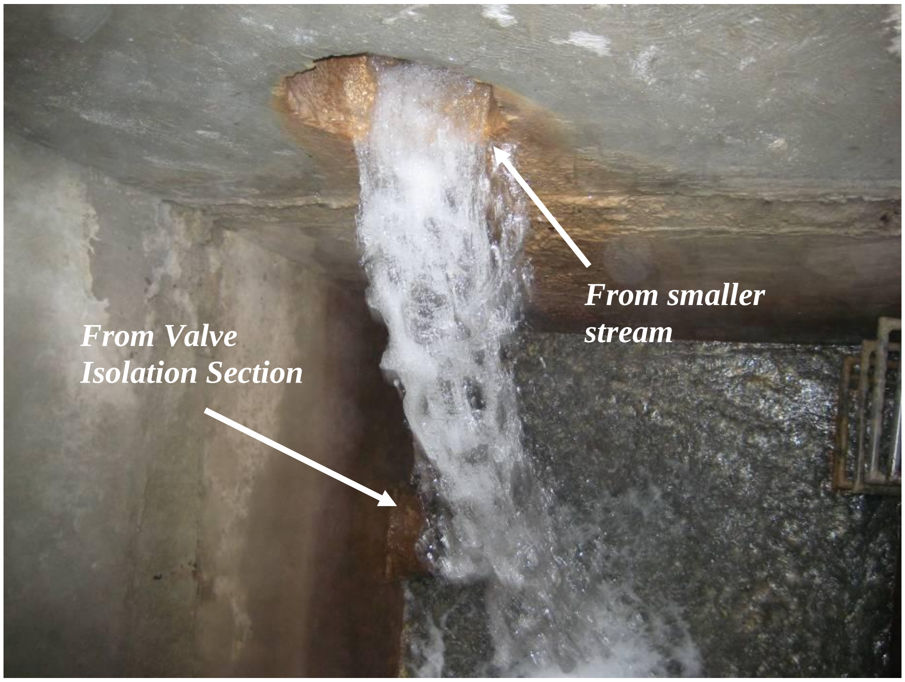


Figure 3-02: Collection Tank

The second section, which is closer to the dry river sand filter bed, contains the pipe from sand filter to the first collection tank. There is also a bypass pipe which conveys water directly from the sand filter to the main aqueduct line. Both pipes are 16" and have manual gate valves to actuate the individual lines. Kinko keeps the valves closed during normal operating conditions in order to maintain moisture in the sand filter. According to Kinko, letting the sand filter go dry will damage it in the future. Therefore, whenever it rains, Kinko travels up the dry river bed and opens the valve manually to allow sufficient flow to the community.

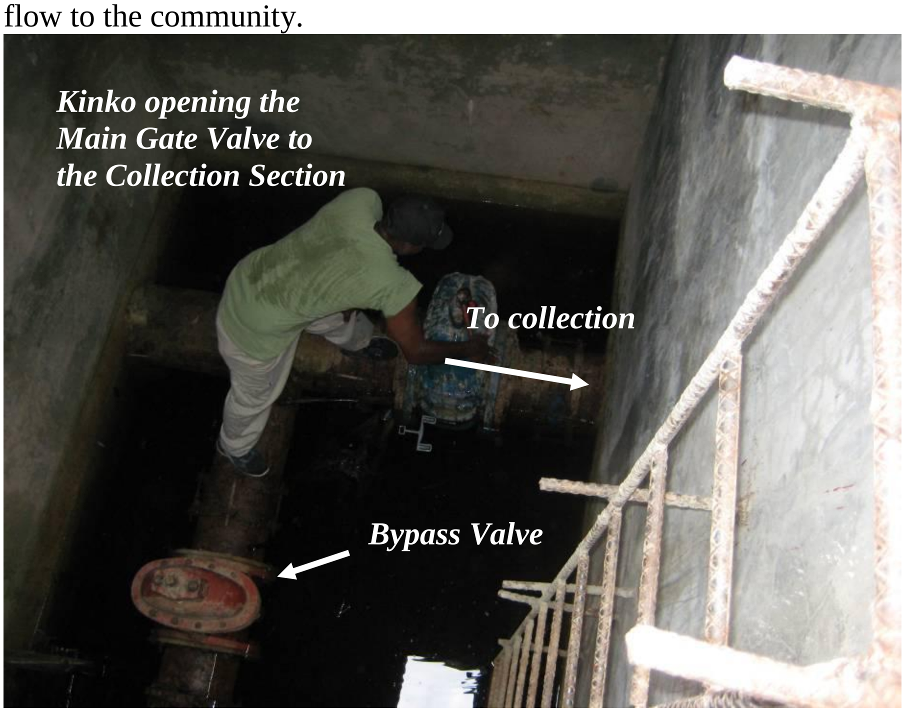


Figure 3-03: Valve Access Tank

According to the Kinko, the water that enters this exits through a central pipe at the bottom of the tank, below a thin layer of rocks and sand (~4"). This layer of rocks is not a designed component, but rather stray matter that has settled in the tank floor. The third section is a backup if the main collection tank does not work. From here, the water is conveyed down the mountain, along the dry river bed. The next major junction is at the secondary storage tank. At this junction, the water is split, with one main line going to Los Toros and Guanabana, and the rest of the water going to the secondary storage tank which serves Tabara Arriba and Sahanoa.

There was a large valve that was leaking upon our inspection. According to Kinko, the valve is sometimes broken deliberately by the local farmers for irrigating the fields. Part of the reason this problem exists is that the inspection door for this valve is in disrepair and there is no lock for the door. The fence leading up to the secondary storage tank is also in disrepair and can easily be bypassed. During the aqueduct inspection, the remaining lines to Tabara Arriba and Sahanoa were not inspected.

The secondary tank is in good physical condition, with no visible signs of leakage from the concrete structure.

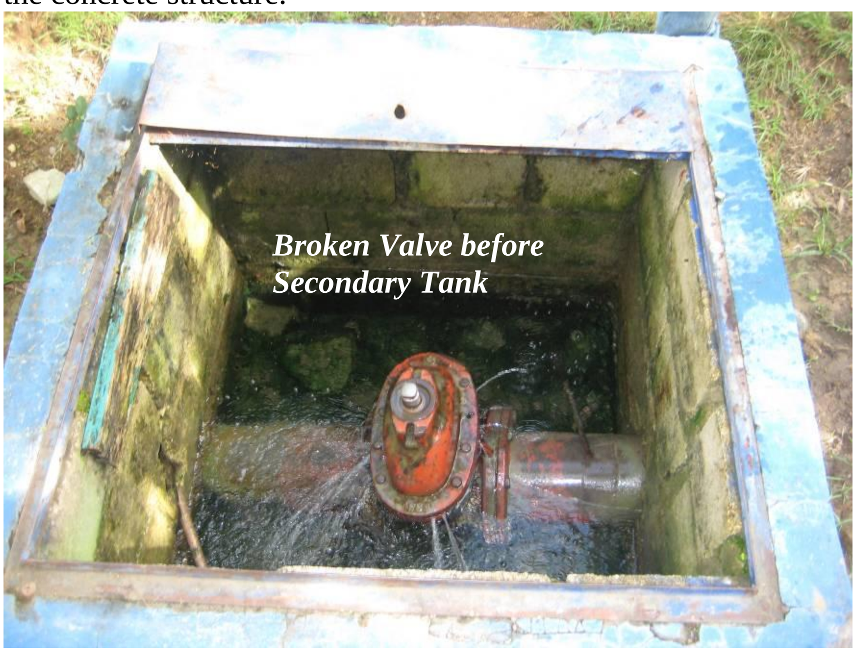


Figure 3-04: Broken Aqueduct Valve

Figure 3-05: Sahanoa-Tabbara Storage Tank

According to Kinko, all of the piping from the Caption tank to the secondary tank is Ductile Iron. The piping from this tank to the towns of Tabara Arriba and Sahanoa appear to be PVC (see photo below). Using a diameter tape, this pipe measures 8”.


Figure 3-06: Sahanoa-Tabbara Storage Tank Outlet Valve

The water for usage in Los Toros is conveyed via the other branch of this aqueduct junction. There is a caseta (maintenance shack) in which you can access the aqueduct leading to Los Toros (see photo below).

Figure 3-07: Chlorine Caseta #1 (out of service)

The next major junction is at the chlorination tank to Los Toros. This tank solely serves Los Toros. The chlorination tank has not been in service for approximately 10 years. There is a 6” inlet with a manual valve to the tank. The aqueduct water mixes with a chlorine solution and flows from the tank via two 6” outlet pipes. The 2 outlet pipes were installed for redundancy, and they join together shortly after the chlorination tank via a Y-intersection. In theory, as explained by Kinko, a solid chlorine compound is added to the tank via a small box. The box introduces water to the compound and chlorine solution is added to the main tank via a small pipe by a drip mechanism. Depending on water flow through the system, he would add between 1-2 pounds of chlorine to the tank. Maintenance consisted of monthly cleaning of sediment with brushes, and flushing to the local fields. The chlorination tank is currently being bypassed. The estimated size of the chlorination tank is 25,000 gallons.

Figure 3-08: Chlorine Contact Tank (out of service)

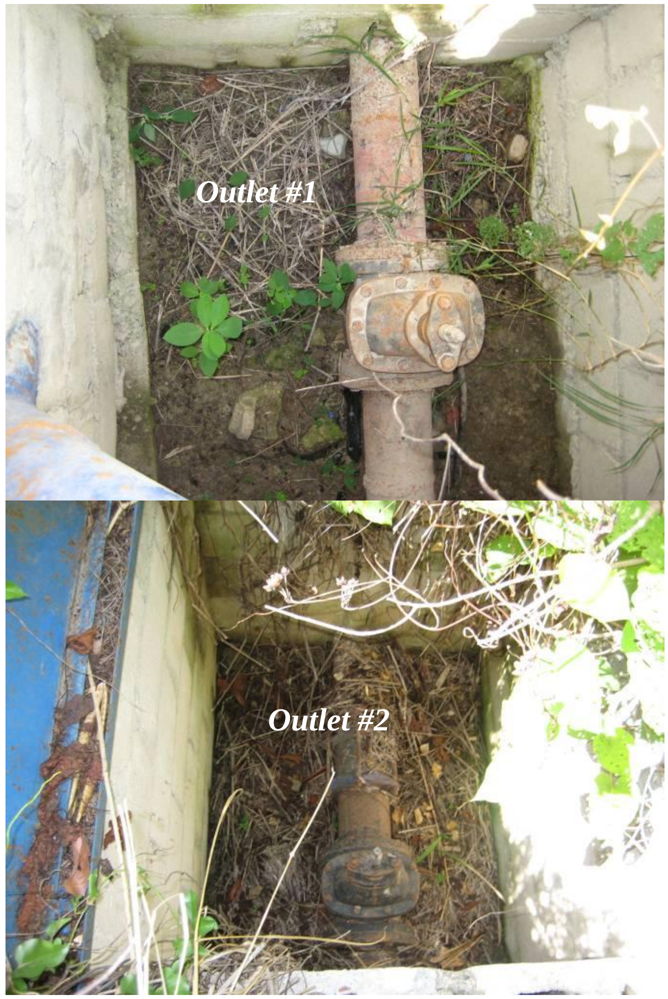


Figure 3-09: Chlorine Contact Tank Outlet Valves (out of service)

3.2 Conveyance to Los Toros

The pipe from the chlorination tank joins up to a Y fitting and proceeds along the road to the main highway. The distribution pipe is PVC from the chlorination tank. This pipe is 6” in diameter. The pipe then travels under the highway and follows the second dirt road into Los Toros (near the cell phone tower). It is unclear how the main water line is then routed to each section of the town, however after surveying the houses that border Los Toros, it was determined that all homes have some access to the aqueduct water via a ½” water line. Most homes were within 40 ft of a main 6” line, however some of the newer houses developing in the south have a ½” pipe traveling longer distances to convey the water.

Kinko has also been building “registros” or manholes around the village in order to isolate off the system for maintenance. Two of the three manholes that he has built are displayed below:

Figure 3-10: Distribution System Manholes

3.3 Water Access

Although all of the homes seem to have access or will have access in the near future based upon door to door inspection, the physical condition of the distribution system in Los Toros is questionable. Poor maintenance, design, and usage could be contributing causes. Although Kinko only mentioned 2 breaks in the aqueduct at the time of the assessment trip (after the highway), a number of other breaks in the piping were found while surveying the system. Some were minor, such as broken ½” lines with electrical tape around the piping, and some were major, with large pools of water forming around the broken 6” line. Combined with the fact that there isn’t constant positive pressure of the water inside the aqueduct, and there is a distinct possibility that contaminants can back-flow into the distribution system. For this reason, contamination may be an ongoing problem without resolution of the physical condition of the piping, due to constant.

According to members of the water committee, after a hurricane damaged the aqueduct system, INAPA commenced repairs on the aqueduct. However, it was left half-completed, with the rest of the development (in Los Toros) in the hands of the local village workers (Kinko and the Syndico). This highlights another challenge to the village of Los Toros, in that a significant part of the funding for a comprehensive overhaul of the distribution piping would likely need to come from an established organization such as INAPA or the local Syndico.

3.4 Water Committee

The water committee has 6 members from the Los Toros community. The water committee is in charge of allocating funds from the Los Toros Foundation to the water quality initiatives in the community. Currently, the Los Toros Water Committee is focused on procuring the string/carbon filters and distributing them to families most in need. They are also responsible for generating proposals to present to INAPA and PLAN International in order to continue improvements to the system.

Kinko is one of the members of the water committee; however it seems that decisions about the physical water distribution system are not approved by the committee. Rather, the committee discusses long term initiatives aimed at public health which relate to water quality and quantity. Kinko makes the decisions about improvements to the distribution system.

4.0 On-Site Water Testing

4.1 Overview

While in Los Toros, one of the principle objectives was to determine the level of harmful organic and inorganic material in the water supply. The primary test method utilized was the Coliscan® Easygel® coliform testing media by Micrology Laboratories, Inc. The test essentially utilizes a 1- 5 mL water sample combined with a liquid medium in a Petri dish. 5 mL samples of water were extracted using sterile droppers at selected locations within the village. They were then added to the pre-filled Easygel® containers, mixed, and placed in the Petri dish, where

Figure 4-01: Hovabator Incubator

the mixture solidifies after approximately 1 hour. The Petri dishes were placed in a Hovabator® Incubator at between 35 and 40 degrees C for a 24-hour period of time and examined to quantify coliforms, fecal coliforms (e. coli presence), and bacteria in the solidified medium. There were some periods where the power went out for a long enough time to discharge a small uninterruptible power source connected to the incubator, however the temperature stayed above 27 degrees C, therefore the samples were allowed to sit for an additional 6-12 hours. The user can then count the number of contaminants found per sample and compile data about the concentration of these potentially harmful organisms in the water.

4.2 Results & Discussion

The findings from the Easygel® coliform testing are tabulated below:

Table 4.1: Easygel Testing Results

Sample Time	Source Number	Source Description	Treatment Description	Pink (Coliform) Count (CFU/mL)	Blue (Other Organism) Count (CFU/mL)	Purple (Fecal Coliform) Count (CFU/mL)	White (Other Organism) Count (CFU/mL)
5/25/2007 12:00	1	Casa 83	No Chlorine	700	80	60	0
	2	Casa 84	No Chlorine	540	20	0	140
	3	Casa 25	Chlorine (25 drops)	520	0	0	1800
	4	Casa 4	Chlorine + Vinegar	0	0	0	0
5/25/2007 3:00	5	Casa	Chlorine (12 drops)	720	20	0	0
	6	Casa	Chlorine (26 drops)	820	20	80	0
	7	Casa	Chlorine	1020	0	0	180
5/25/2007 4:10	8	Eastern Spring	N/A	2460	0	60	0
	9	Eastern Spring	N/A	2620	0	0	0
5/26/2007 10:00	10	Tabara Valve/Sahanoa Tank	N/A	-	-	-	-
	11	Source Sand Filter	N/A	-	-	-	-
	12	Spring before Source Tank	N/A	-	-	-	-
	13	West River (Sample 1)	N/A	0	100	0	160
	14	West River (Sample 2)	N/A	0	340	0	260
5/27/2007 1:00	15	Bottled Water	No Additional Treatment	300	0	0	560
	16	Bottled Water	No Additional Treatment	220	0	0	240
5/26/2007 13:00	17	East River (Sample 1)	N/A	TNTC	640	0	800
	18	East River (Sample 2)	N/A	TNTC	400	0	300
	19	Marquette Water Quality Center Verification	Chlorine (25 drops) + Filtration	0	0	0	0

Note that Easygel® tests were not performed on the source tank water due to the inability to transport the Petri dishes and liquid media on the motorcycles. Coliform presence/absence tests were performed at this location using the Millipore media. The

Millipore media was also used to support the results of the Easygel® testing at the other locations. The results of the Millipore testing is tabulated below:

Table 3.2: Millipore Testing Results

Sample Time	Source Number	Source Description	Treatment Description	Small Colony	Large Colony	Approx Count
5/25/2007 12:00	1	Casa 83	No Chlorine	X		50
	2	Casa 84	No Chlorine	X		30
	3	Casa 25	Chlorine (25 drops)	X		30
	4	Casa 4	Chlorine + Vinegar		X	10
5/25/2007 3:00	5	Casa	Chlorine (12 drops)	X		30
	6	Casa	Chlorine (26 drops)	X		100
	7	Casa	Chlorine	X		50
5/25/2007 4:10	8	Eastern Spring	N/A		X	50
	9	Eastern Spring	N/A		X	30
5/26/2007 10:00	10	Tabara Valve/Sahanoa Tank	N/A	X		10
	11	Source Sand Filter	N/A	X		10
	12	Spring before Source Tank	N/A	X		30
	13	West River (Sample 1)	N/A	X		30
	14	West River (Sample 2)	N/A	X		TNTC
5/27/2007 1:00	15	Bottled Water	No Additional Treatment	-	-	-
	16	Bottled Water	No Additional Treatment	-	-	-
5/26/2007 13:00	17	East River (Sample 1)	N/A		X	100
	18	East River (Sample 2)	N/A	-	-	3
	19	Marquette Water Quality Center Verification	Chlorine (25 drops) + Filtration	-	-	-

The Millipore testing confirmed the presence of coliforms in the water, although the quantification of fecal coliforms was not possible with this method. The method distinguishes between Small Colonies and Large colonies. Note that there was one location (the West River) that qualified as “Too Numerous to Count” by the Millipore method.

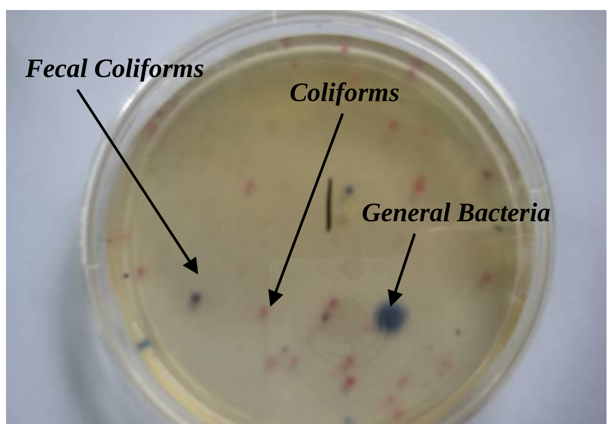


Figure 4-02: Easygel Sample-Location 1

For the most part, the concentration of colonies was in line with estimates made at Marquette University during the pre-trip filter testing (500-1000 CFU/mL). Interestingly, the West River tested positive for “other” bacteria that could not be qualified, but did not show significant levels of coliforms.

Nearly all of the houses where water samples were collected had significant levels of coliforms. There was one anomaly, where the fourth house tested showed no significant contamination. This may have been attributed to the family using an effective treatment regimen, or it could have been attributed to experimental error (i.e. using only the distilled water diluent in the liquid medium). The reader should also be drawn to the “Treatment Description” column and note the wide variability in water treatment method employed. This inconsistency is a contributing factor to the poor water quality being consumed by the families in Los Toros. Another point of interest for the testing was that in many of the tests, there were significant levels of the white “non-coliform” organic material present in the water. It is unknown whether or not this material poses a threat to the general health. Another troubling aspect of the analysis was that bottled water sampled from 2 houses tested positive for lower levels of coliforms (220 and 300 CFU/mL). It is unknown whether this is due to contaminants unintentionally being introduced into the experiment, or due to the actual water quality. In future trips, further investigation should be conducted in regards to this matter.

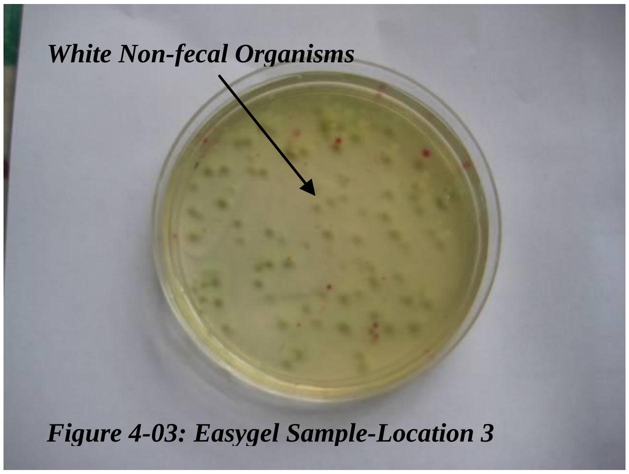


Figure 4-03: Easygel Sample-Location 3

Figure 4-04: Water Quality Center Verification Equipment

The last part of the water testing consisted of using the proposed treatment method which was generated at the Water Quality Center in the field. To that end, a string-carbon filter that had been in use for less than a year was obtained from a local family. The filter element was removed from the PVC casing, and shock chlorinated using the 4 oz chlorine bags (5.65 % Chlorine). The filter element was then flushed 7 times using purified water and hung to dry in front of a fan for a period of

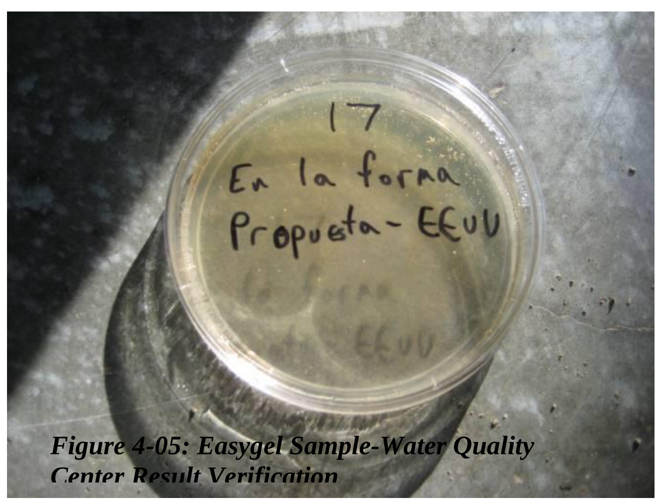


Figure 4-05: Easygel Sample-Water Quality Center Result Verification

2 hours. After this process, a 5-gallon bucket was filled with aqueduct water and treated with 25 drops of chlorine. The bucket was mixed gently and allowed to sit for a period of 1 hour. After this period, the water was passed through the dried and re-assembled filter and a sample was obtained for Easygel® testing. As hypothesized, this water showed no measurable coliforms or non-fecal organisms (see photo at right).

4.3 Conclusions

Overall, the water testing in almost all locations in Los Toros tested positive for coliforms, fecal coliforms, and/or other bacteria and organisms. It should be noted that only three of the locations tested positive for fecal coliforms. According to the Micrology Laboratories literature, non-fecal coliforms can be found both as naturally occurring soil organisms and in the intestines of animals and humans. Fecal coliforms are only found naturally in the intestines of animals and humans. Therefore, although e-coli is the strongest indicator for fecal contamination by animal or human waste, and in turn the possibility for waterborne diseases, the non-fecal coliforms and bacteria which showed up in the other locations can also be indicators for contamination that is harmful to public health. Based upon surveys on water usage and treatment, the majority of households either did not use enough chlorine in order to kill the coliforms, or simply did not use chlorine at all. In many cases, there was a false perception that the string filter alone would treat the water sufficiently. Common illnesses cited by families included diarrhea, abdominal pains, the flu, and contracting parasites. Many of these cases of illness could be directly related to improper water treatment prior to consumption.

Section 2 of this report cited 100 gallons per day as an estimate for total household water usage. In reality, most homes surveyed during the assessment trip did not appear to come close to attaining 100 gallons/day of water usage, mainly due to supply shortages. Most families that were surveyed cited 1 *botalón* (or 5-gallon jug) as their daily average drinking water consumption. Besides drinking water, one must factor in additional quantities for bathing, cooking, washing produce, cleaning around the house, all of which drive up the usage. Common methods for storing excess water included 13-gallon plastic buckets and large barrels. The term excess in this context is water which is available during rainy periods (which feeds the aqueduct) and is stored for miscellaneous usage when the aqueduct runs dry, which happens frequently. According to survey respondents, the town can go for up to 5 days without aqueduct service. While on the implementation trip, most members of the EWB Marquette team and Los Toros Foundation team experienced up to 4 ½ days without water from the aqueduct.

It should be noted that Marquette EWB planned to rent a portable HACH MEL850 water testing kit from another EWB-USA chapter, however the kit was in use at the time of the Los Toros assessment trip. The HACH kit has additional capabilities beyond coliform testing, such as pH, Nitrate, Phosphate, and other parameters. Although coliform levels were of the most interest due to their direct relation to illness, these other parameters may be of interest on future assessment trips. To this end, a HACH MEL850 kit, Oxfam DELAGUA kit, or separately purchased reagent media should be utilized for the next round of on-site water testing.

5.0 Health Assessment

5.1 Basic Information

In order to perform a baseline health assessment of the community, a survey was developed with the intent of holding short interviews with a cross-section of the community. The Los Toros Foundation has instated a number of beneficial community health programs such as donation of medical supplies and equipment, distribution of oral hygiene equipment (toothbrushes, toothpaste, and floss) The aim of the survey was to gauge some of the major indicators of general health while ensuring not to inundate the interviewees with questions that they could not answer accurately. The questions posed were as follows:

1. How many people do you have in your family? Males? Females?
2. What are your biggest concerns about water? Quality? Quantity? Other?
3. Do you have a latrine or a toilet?
4. Do you have health problems in your household? Describe them.
5. Where do you put your garbage?
6. How many liters does your family use per day (approximately)?
7. Do you buy purified water or do you filter and disinfect it prior to drinking? Describe the purification method employed.

All responses to these questions can be found in the *Marquette EWB-Los Toros Health Survey Results*. The summarized results of the sanitation and water-related illnesses can be found in the following sections of this report.

5.2 Water-Related Illnesses

One of the most common responses to the question regarding illnesses within the family involved some sort of gastrointestinal problem. 66% of the respondents mentioned some recent illness or continual health problem. Common responses included abdominal pains, bouts of parasite infection, diarrhea, and the flu. It is likely that there is a strong correlation between the water consumed by the families polled and the recurring illnesses they are experiencing. The problem continues to persist because in many cases the families cannot afford an alternative to the aqueduct water, such as purified bottled water, due to financial shortcomings.

Figure 5-01: Water Storage Container

Although the quality is poor, most families surveyed seem to be meeting their basic needs in terms of the quantity of *drinking water* through saving water in plastic buckets and barrels. A typical storage container is shown at right. One possible problem that arises is a lack of cleaning and maintenance on these containers, as well as the possibility of creating a place for water-borne bacteria to thrive. Beyond drinking purposes, water availability for bathing, cooking, washing produce, and general sanitation is another matter. Most homes evaluated were not equipped to store larger amounts to last through dry periods.

5.3 Sanitation

Sanitary practices, both at the household level and at the community level were another major point of interest. A high point of the investigation was that all respondents utilize the garbage pickup service, which runs twice a week (Monday and Thursday). Prior to pickup most respondents either used a waste bin or a woven sack to store their garbage. On a community level, however, garbage could be found collected in certain areas, particularly just outside the bounds of the community. In some cases, bundles of garbage were found in local waterways and streams and in some fields. It is unknown who is disposing of the garbage in these areas, however this is an example of how waste disposal services still need to make more progress.

Figure 5-02: Garbage Pit near Baseball Diamond

Another area of concern while in Los Toros was the construction of pit latrines that may be introducing fecal matter into groundwater sources. According to members of the water committee, there is no set standard for latrine depth and builders many times dig until they hit a water source. Once the water source has been reached, they construct the latrine on top of the pit. Some members of the community are exploring digging wells for their water sources, therefore further investigation into the health risks of the latrine construction practices need to be made.

6.0 Corrective Actions and Future Recommendations

6.1 Water Treatment

In order to address the issues of water quality in the short term, meetings were held with the Los Toros Water Committee during the assessment trip to report EWB Marquette's experimental findings. Members of the committee live in different sectors of the village, and were placed in charge of educating their neighbors who have the string-carbon filters. Since the Water Committee distributed the filters, they have the most accurate knowledge of which families have them and approximate age of the individual filters. They are tasked with showing them proper chlorination regimens, informing them of the need to replace the filter element on an 8-12 month interval, and how to periodically shock-chlorinate the filter. The team also met with the nurses and doctor at the community clinic to present the water testing findings and discuss future strategies to mitigate waterborne illnesses in Los Toros. A poster with the recommended treatment method was created and will be displayed in the clinic for patients with water-related illnesses to make the correlation between their families' water treatment practices and personal health. In this way, the education process is long term and promotes individual motivation for being more active in improving their water quality.

In order to address the two issues of water quantity and quality in medium and long terms, there are some further investigations that should be performed. One perception that was very common in Los Toros was that filtration was sufficient to make the aqueduct water drinkable. For this reason, an ideal solution would be to find a physical filtration method that cleans the water to an acceptable level without the need for much maintenance or additional additives and chemicals. To that end, EWB Marquette plans to purchase and test ceramic filters which use a technology recognized by a number of international aid organizations[2]. The filters are comprised of a mixture of red clay and sawdust, and fired in a kiln to produce small pores in the material. These small pores are designed to allow clear water to pass through the filter and inhibit bacteria from passing through the filter. While on the assessment trip, PLAN International displayed one of these filters and made a recommendation for an in country vendor of the ceramic filters. PLAN International purchased the filter for $450 pesos. The string-carbon filters used currently cost approximately $350 pesos, however the effectiveness is dependent on the adherence to recommended treatment protocol. In addition, the purported lifecycle of a ceramic filter is around 2-3 times as long as the string carbon filters (2-3 years). If laboratory testing indicates that the ceramic filters are at least as good at removing harmful contaminants from the water sources as the string-carbon filters with chlorination, then the next step would be to introduce the ceramic filters on a trial basis to gauge in-field effectiveness and acceptance by the community.

Figure 5-03: Ceramic Filtration Unit

Beyond ceramic filters, a large scale treatment process may not be effective until the issues hampering the distribution system are resolved. According to survey respondents, during heavy rains large particles and insects are flushed through the aqueduct. The water is also reported to have a brown color to it at this time, indicating that pollutants are entering the aqueduct at some point in the system. Large scale chlorine treatment is a solution favored by many individuals, including the plumber Kinko, however the infiltration of dirty water into the piping system would likely counter any effects that the residual chlorine would have. Furthermore, the chlorine addition would have to be more closely monitored and metered to ensure proper dosage in a variety of flow conditions. For these reasons, point-of-use treatment seems to be the most feasible and cost effective solution in the immediate term. In the long term, a large scale treatment system would need to address the sediment problems in addition to the suspended organisms and harmful dissolved compounds that may be present in the water.

6.2 Water Supply

The need for constant water supply is arguably the biggest priority for the Water Committee. The system is designed in such a way that large influxes of water are sent to the community when it rains and little to no flow occurs during dry periods. There are a number of breaks in the pipeline both within the village of Los Toros and in the ductile iron pipe leading to the village from the mountain. Furthermore, water lines that are left opened and misused exacerbate the problem. To this end, a number of physical modifications may help with increasing the supply of usable water to the community.

The first step in improving the available water is to address homes that have open water hoses and piping. As shown at right, there were some homes where the water ran freely without being use for any specific purpose. In these cases, additional valves that can be purchased locally should be installed in order to minimize wasted water. A reporting system such as a community bulletin board for the plumber may be helpful in being able to more quickly react to these failures in the system, due to the size of the population that he has to serve.

Figure 5-04: Water Misuse

In order to quantify the amount water flowing through the aqueduct to the village, a form of flow monitoring could be installed on the aqueduct prior to branching off to the separate parts of Los Toros. There are a variety of possible locations for a flow meter, as it would just need to be mounted directly to the pipe. For example, the first manhole pictured above is ideally located, as all the water from the mountain flows through this location before branching off to the separate sections of the village. There are a number of commercially available flow meters that could be used in this application, with purely mechanical devices in the $70-$200 range. This would require an individual on the Water Committee to monitor the flows in a number of different conditions and compile this data to calculate average total daily usage. Besides flow monitoring, the Water Committee could begin to compile data on average household water usage based upon continued surveying of their sectors. Being able to better quantify the community's water usage is an important step toward determining whether additional sources of water (such as wells and nearby springs) should be pursued and developed.

Related to infrastructure, the villages of Sahanoa and Tabara Arriba benefit from having a fairly large cast water tank, which helps to provide more consistent water flows to their system. In the case of Los Toros, the water is essentially conveyed directly from its source to the town, with no intermediate storage device. To this end, employing some form of storage could help to provide more consistent flow of water to the village. Although the chlorine tank is not currently used for treatment, it could serve useful as a storage device to help dampen out the surges in water flow and store the excess water during dry periods. If this does not produce the desired results, investigating the cost and feasibility of water tower in the town could be a further investigation.

The distribution system in general needs a more in depth engineering review to determine if the construction practices and hardware need to be modified in order to avoid future system failures. Although the system has been surveyed along the aqueduct leading to the village, more detailed surveying within the village can help to determine why certain sections of the village have water pressure for longer periods of time than others. Marquette EWB will work closely with their professional mentors to perform these evaluations. Being able to better document what areas need to be addressed within the distribution will be instrumental in lobbying INAPA or the Syndico to support improvements to the system.

References

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