Technical report: ClearWater Domestic rainwater harvesting systems evaluation

Submitted to Alianza Ceibo
By Jena Webb, PhD
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"You have to really take care of water, care for it more than gold."

- Community member from San Victorian

About the Author

Dr. Jena Webb has been working with indigenous communities in the Ecuadorian Amazon since 2001 to better understand and respond to contamination in water and one of the most important food sources in the region - fish. She earned a doctorate from McGill University conducting a study on mercury and hydrocarbon pollution in three watersheds of the Upper Amazon. Dr. Webb is committed to conducting and sharing research in a way that is both rigorous and beneficial to indigenous people.

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SUMMARY OF EVALUATION

This report presents the results of an evaluation of the joint Ceibo Alliance and ClearWater (a project of the non-governmental organization, Amazon Frontlines) domestic rainwater harvesting system program which, from 2012 to 2018, provided domestic rainwater harvesting systems to 1164 households in 78 communities of the Northeastern Ecuadorian Amazon benefiting over 6000 people. The study evaluated three general aspects of the program 1) the quality of the water, 2) the acceptability of the project and 3) impacts of the water systems on people's livelihoods and health.

Summary of Results

The study evaluated water quality and user observations in a representative sample of the communities visited. Sixty-two household heads (39 men and 23 women) responded to a short questionnaire on use, maintenance, health and satisfaction of the water and systems. One hundred percent of the respondents were satisfied with the taste of the water and the functioning of their system. 86% of people reported observing improved digestive health (reduced diarrhea, vomiting and stomach pain) since the installation of the systems. None of the drinking water samples had detectable levels of polycyclic aromatic hydrocarbons (PAHs) or the heavy metals, mercury and lead. Zinc levels in all samples were below a level which occasionally leads to unpleasant taste (4mg/l). 85% of systems had ideal water quality as indicated by the absence of fecal coliforms, 4% had satisfactory water quality and 11% showed signs of fecal coliform levels higher than indicated by health advisories. Water from the alternative sources (rivers, streams and springs) had lower water quality as indicated by high levels of fecal coliform. People clean their systems on average 4 times per year. 70% of the water systems were rated as in very good (46%) or good (24%) condition.

The qualitative analysis showed a high level of satisfaction with the water and the systems. Comments pointed to improvements in health and workload, with the system reducing the number of hours and the effort required to collect water. Small critiques and user problem-solving techniques were collected and can be elaborated on in subsequent information sharing with communities. A series of recommendations are presented.

INTRODUCTION

Although water abounds in the Ecuadorian Amazon, local communities face numerous challenges to securing a safe water supply for their families. Over the past half-century, the Ecuadorian Amazon has been crisscrossed by more than **9500 km of roads** – or **1.5 times the Earth's radius** – built to connect the more than **3430 oil wells** to market via pipeline. In the period from 2005 to 2015 alone, oil companies released over 350,000 barrels of crude oil into the rivers, streams and soils of the Ecuadorian Amazon, amounting to an average of 4000 barrels of a toxic chemical mix released every day into the environment[1]. Hydrocarbons are known carcinogens.

Concurrently, African palm plantations have led to the deforestation of an equivalent of 100 000 soccer fields (according to GFW)[2] and the use of a large quantity of pesticides and fertilizers, some of which end up in the local waterways. Some pesticides are considered carcinogenic. Access roads entice colonists to set up small farms, resulting in the deforestation of vast tracts of land. Amazonian soils contain large amounts of naturally occurring mercury, accumulated there over centuries of nearby volcanic activity[3]. Mercury exists in the soils in a harmless form, but once soils erode into waterways following deforestation, the mercury is converted into a toxic form, easily entering the aquatic food chain and humans via fish consumption[4]. Illegal gold mining, booming in certain areas of the Amazon, can also be an important source of mercury into aquatic ecosystems.[5]

Further, erosion provoked by deforestation and mining has led to changes in the water chemistry of local streams and rivers[6]. Meanwhile, increasing population and inadequate sewage-water treatment has led to an increase in exposure to fecal coliforms. Fecal coliform ingestion leads to stomach pain, diarrhea, and, in extreme cases, death.

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1 MAE PRAS: SUBSISTEMA DE INTELIGENCIA DE ESTADÍSTICAS SOCIO AMBIENTALES DE LAS ACTIVIDADES PRODUCTIVAS (SIESAP) http://pras.ambiente.gob.ec/web/sinari/siesap

2 http://www.ecuadorencifras.gob.ec//documentos/web-inec/Estadisticas_agropecuarias/espac/espac_2014-2015/2014/Presentacion%20de%20resultados%20ESPAC_2014.pdf

3 Mainville, N., J. Webb, M. Lucotte, R. Davidson, O. Betancourt, E. Cueva and D. Mergler (2006). "Decrease of soil fertility and release of mercury following deforestation in the Andean Amazon, Napo River Valley, Ecuador." Science of the Total Environment **368**: 88-98.

4 Webb, J., N. Mainville, D. Mergler, M. Lucotte, O. Betancourt, R. Davidson, E. Cueva and E. Quizhpe (2004). "Mercury in fish-eating communities of the Andean Amazon, Napo River Valley, Ecuador." EcoHealth **1**(suppl. 2): 59-71.

5 Akagi, H., O. Malm, Y. Kinjo, M. Harada, F. J. P. Branches, W. C. Pfeiffer and H. Kato (1995). "Methylmercury pollution in the Amazon, Brazil." Science of The Total Environment **175**(2): 85-95.

6 McClain, M. E. and R. J. Naiman (2008). "Andean Influences on the Biogeochemistry and Ecology of the Amazon River." BioScience **58**(4): 325-338.

In 2014, Ecuador was among the five countries in Latin America with the lowest drinking water coverage.[7] The United Nations named **access to clean drinking water a basic human right** in 2010. In that same year, 89 million people across the globe depended on rainwater as their main supply.[8] **Rainwater is largely free of impurities[9]**. When properly installed and managed, **Domestic Rainwater Harvesting (DRWH) Systems are considered inexpensive and low-tech;** and vastly superior to most alternatives, such as surface water, which contain high levels of contaminants and fecal coliforms. Ecuador is one of the few countries in which bottled water is an important source of drinking water[10]. Buying bottled water, whether it be single use or in larger quantities, is not an option for most of the communities in the Amazon because it is cost prohibitive and access is low. Bearing in mind the benefits of rainwater harvesting, expanding capacity in developing countries has been set as a new World Health Organization goal (6.a).[3]

According to the World Health Organization (WHO), the biggest preoccupation with water for human use in rural communities is via contamination by coliforms from human or animal feces[11]. Consumption of these bacteria in drinking water, and especially those from the family of *Escherichia coli,* can cause diarrhea, blood in the feces, vomiting, kidney damage and urinary tract infections. Fecal coliforms can enter rain-harvested water through the feces of animals spending time on the roof or bird droppings on the roof. If the system is not well closed, fecal coliforms can also originate from animals that obtain access to the system.

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[7] World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) (2014) Progress on drinking water and sanitation. 2014 Update WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. Geneva.

[8] World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) (2012) Progress on drinking water and sanitation. 2012 Update WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. Geneva.

[9] World Health Organization. (2008) Rainwater Harvesting. Chapter 6.11 In: Guidelines for Drinking-water Quality, Second Addendum to the 3rd Edition. Geneva.

[10] World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) (2017) Progress on drinking water and sanitation. 2017 Update WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation. Geneva.

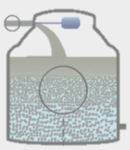
[11] WHO. (1997) Guidelines for drinking-water quality. SECOND EDITION. Vol 3: Surveillance and control of community supplies. Geneva. http://www.who.int/water_sanitation_health/dwq/gdwqvol32ed.pdf

Quality of Rain-harvested Water

Four factors affect the quality of harvested rainwater: 1) the air; 2) the roof; 3) filtration methods; and 4) the storage tank.

Most studies have reported **levels below maximum permissible concentrations** for metals, hydrocarbons and pesticides in rain-harvested water[12]. Surface water, and *not* rainwater, was found to be a source of mercury and hydrocarbons amongst Amazonian women[13],[14].

Studies have shown that one of the **most appropriate roofing materials for capturing rainwater are zinc roofs**, such as those commonly used in the Indigenous villages where Ceibo and AF work, because zinc, while not harmful to humans, is effective in reducing microbial activity[15].



Sand filters eliminate the vast majority of bacteria and particulate bound pollutants in rain-harvested water[16]**.** Microorganisms that may enter the first tank from roofs and other sources are removed by as much as 81-100% by filters such as those used by the Ceibo/AF systems[17].

In general, **storage purifies water** due to a settling out of contaminants and the creation of a nutrient poor environment unfavorable to bacterial growth. This effect is enhanced in large tanks, such as the ones installed by Ceibo and AF[11].

Very few studies on the quality of rainwater have been conducted in the Amazon. Some studies show that rainwater contains very little contamination at the moment that it precipitates out of

[12] Abbasi, T. and S. A. Abbasi (2011). "Sources of pollution in rooftop rainwater harvesting systems and their control." Critical Reviews in Environmental Science and Technology **41**(23): 2097-2167.

[13] Webb, J., O. T. Coomes, D. Mergler and N. Ross (2016). "Mercury Concentrations in Urine of Amerindian Populations Near Oil Fields in the Peruvian and Ecuadorian Amazon." Environmental Research **151**: 344-350.

[14] Webb, J., O. T. Coomes, D. Mergler and N. A. Ross (2017). "Levels of 1-hydroxypyrene in urine of people living in an oil producing region of the Andean Amazon (Ecuador and Peru)." International Archives of Occupational and Environmental Health **91**(1): 105-115.

[15] Stewart, C., N. D. Kim, D. M. Johnston and M. Nayyerloo (2016). "Health Hazards Associated with Consumption of Roof-Collected Rainwater in Urban Areas in Emergency Situations." International Journal of Environmental Research and Public Health **13**(10): 1012.

[16] Helmreich, B. and H. Horn (2009). "Opportunities in rainwater harvesting." Desalination **248**(1): 118-124.

[17] Peter-Varbanets, M., C. Zurbrügg, C. Swartz and W. Pronk (2009). "Decentralized systems for potable water and the potential of membrane technology." Water Research **43**(2): 245-265.

the atmosphere[18], even in areas close to petroleum operations[19]. However, the practice of flaring off unwanted gases that escape during the extraction process could be a source of hydrocarbons to rain-harvested water. More recent studies, using new technology, show that flares let off more pollution that calculated using traditional techniques[20]. This process could also be releasing heavy metals, such as mercury and lead, into the atmosphere, where they could adhere to rain droplets. Several studies have shown that rain harvested from zinc roofs can lead to high levels of zinc in water destined for human consumption[21]. However, according to these same studies, there is no negative health consequence from consuming zinc. Where zinc can have an impact is in the taste of the water and, therefore, the acceptability of the systems.

The expected impact of the Ceibo/AF project is an **improved quality of life and health** through a secure and accessible source of clean water**.** Improved health is expected through the elimination or reduction in diseases and illnesses associated with substandard drinking water, primarily digestive troubles, such as diarrhea. In 2016, water, sanitation and hygiene (WSH) was responsible for 1.9% of the global burden of disease[22]. The latest data available for Ecuador estimates the total WSH-related deaths at 88,200, or 3.9% of the deaths in 2004. Chronic diarrhea, especially in children, can lead to malnutrition. Treatments for stomach complaints can sap scarce economic resources from rural families with limited revenue, forcing them to work longer hours, go without other essentials or exploit natural resources. Finally, the work associated with collecting water from traditional sources is tiresome, lengthy and sometimes dangerous[23], such as when heavy rains make climbing river banks slippery. This burden is disproportionately carried by women. It has also been shown that programs such as community installation of rainwater harvesting systems in polluted areas accompanied with information on health risks, leads to greater awareness about environmental health in general, with associated improvements in health and wellbeing[24].

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[18] Bendix et al. (2004) Gradients of fog and rain in a tropical montane cloud forest of southern Ecuador and its chemical composition. Proceedings 3rd Int. Conf. on Fog, Fog Collection and Dew.

[19] Lewis et al. (2012) Airborne concentrations of metals and total dust during solid catalyst loading and unloading operations at a petroleum refinery. International Journal of Hygiene and Environmental Health Volume 215, Issue 5. Pages 514-521

[20] Conrad, B. M. and M. R. Johnson (2017). "Field Measurements of Black Carbon Yields from Gas Flaring." Environmental Science and Technology **51**(3): 1893-1900.

[21] Stewart et al. (2016) Health Hazards Associated with Consumption of Roof-Collected Rainwater in Urban Areas in Emergency Situations. International Journal of Environmental Research and Public Health. 13, 1012

[22] http://www.who.int/gho/phe/water_sanitation/burden_text/en/

[23] Inter-agency Task Force on Gender and Water (GWTF) (2015). Gender, Water and Sanitation: A Policy Brief, United Nations.

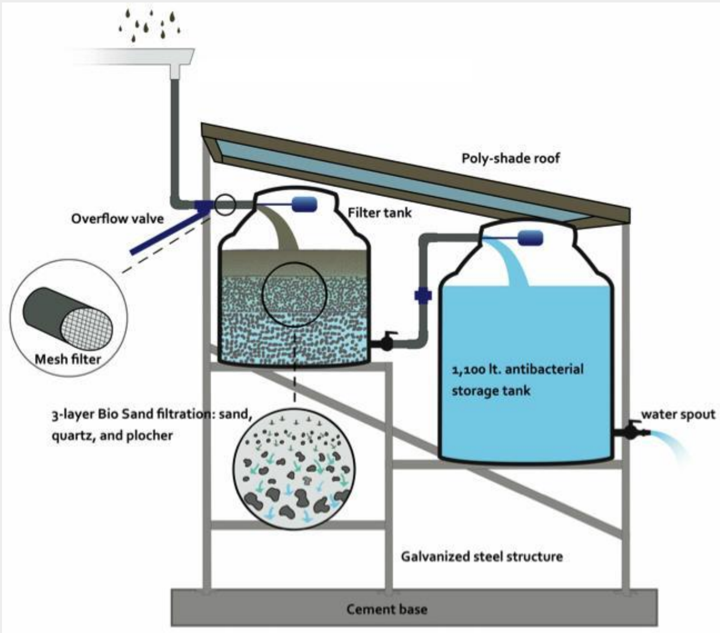
[24] Davis, L. F., M. D. Ramirez-Andreotta, J. E. T. McLain, A. Kilungo, L. Abrell and S. Buxner (2018). "Increasing environmental health literacy through contextual learning in communities at risk." International Journal of Environmental Research and Public Health **15**(10).

The Ceibo Alliance and ClearWater's Water Program

The mission of the Ceibo Alliance and ClearWater's Water Program is to **improve the health status and the quality of life of indigenous communities in the Amazon through a reliable and safe water supply**. Based on the suitability of rainwater harvesting in such a humid environment as the Amazon, the Ceibo Alliance and ClearWater (now a sub-project of Amazon Frontlines) aimed to **provide the indigenous people of this contaminated region with domestic rainwater harvesting systems**. Between 2012 and 2018, more than 1164 water systems were installed in 78 communities, providing more than 6000 people with clean water to drink and use domestically.

In the systems installed by Ceibo/AF, rainwater is harvested from rooftop gutter-spouts on people's homes, with the flow diverted into a first tank where the water passes through a specially-designed biosand filter. The water passes through four layers of filtration:

1. a biologically active surface layer,
2. a fine sand layer,
3. a layer of crushed quartz, and finally,
4. a layer of coarse gravel.



The top hypogeal layer (called a "Schmutzdecke"), contains microorganisms that remove bacteria, trap contaminants, and break down other incoming organic material. The next two layers work together to create a complex maze of sand grains that microbes get trapped in and die. They also trap contaminants such as toxic metals and petroleum pollution, which stick to the sand as they flow by in a process called adsorption. Finally, the layer of gravel serves as a support to the sand and quartz layers so nothing flushes out of the tank as the clean water flows into a second, large anti-bacterial storage tank.

AIMS AND OBJECTIVES OF THE EVALUATION

Aim

The purpose of this evaluation is to provide a rigorous and systematic evaluation of the domestic rainwater harvesting systems installed by the Ceibo Alliance and ClearWater. The aim was to design an evaluation which would provide information on the:

- Quality of the water;
- Efficiency of the filters;
- Health and quality of life benefits of the systems;
- Level of user satisfaction;
- Use and maintenance of the systems.

Objectives

The Ceibo Alliance and ClearWater's water program evaluation has several general objectives:

1. Evaluate the water quality of rain-harvested water from systems installed by the Ceibo Alliance and ClearWater since 2012;
2. Compare the quality of filtered water with the un-filtered water (from the first tank);
3. Compare the quality of the water from the systems with the water from rivers, streams and springs constituting the previous/alternate source of water for the communities;
4. Determine if use of rainwater has led to health and quality of life improvements;
5. Determine the level of user satisfaction; and
6. Evaluate the state of the systems.

METHODOLOGY

This mixed-method design combines indicators from quantitative data and insights from qualitative data in order to respond to the general objectives above. The specific objectives of the evaluation were the following:

1. Measure a) the levels of fecal coliforms in the unfiltered and filtered water of a representative sample of systems and b) the levels of PAHs, mercury, lead and zinc in a subsample of filtered and unfiltered water;
2. Measure levels of fecal coliforms, PAHs, mercury, lead and zinc in the previous sources of water;
3. Carry out a survey among a representative sample of users addressing quality of life, health and maintenance issues;
4. Carry out in-depth interviews with a subsample of users to delve more deeply into issues surrounding health, quality of life and sustainability; and
5. Inspect the state of a representative sample of systems.

Choice of Indicators

Since the water in the systems installed by the Ceibo Alliance and ClearWater comes from rural areas, the main health concern with rain-harvested water in the area is through fecal coliforms entering the systems from animal feces on the roof or in the piping used to collect rain. Raw, un-treated water (from different sources) generally contains 100-100,000 *E coli* per liter.[11]

Water temperatures and nutrient conditions in the type of biofilm created by the water systems are not conducive to the *E coli* strain of bacteria and, therefore, the presence of *E. coli* is considered as evidence of recent faecal contamination.[25]

This was, therefore, the primary focus of the present evaluation. Our first indicator for this measure was number of fecal coliform colonies in drinking water from the systems. The objective for drinking water supplies is zero fecal coliform; however, anything less than 10 is considered passable and the WHO recommends setting intermediate goals in underserved areas so as to not condemn water sources that are otherwise superior to alternatives. The World Health Organization maintains that:

> "In many developing countries, high quality water meeting the E. coli criterion is not readily available, and uncritical enforcement of the guideline may lead to condemnation of water sources that may be more appropriate or more accessible than other sources, and may even force people to obtain their water from more polluted sources. Under conditions of widespread faecal contamination, national surveillance agencies are recommended to set intermediate goals that will eventually lead to the provision of high-quality water to all, but will not lead to improper condemnation of relatively acceptable supplies."[26] (p.21)

Our second indicator for this was information from several survey questions: "Do you suffer from digestive problems? Stomach pain? Diarrhea? Vomiting?" and "Have you noticed a change in the amount or type of digestive problems since the installation of the rainwater harvesting system?" Samples taken before and after filtration and from previous sources of drinking water allowed for comparisons.

A sub-sample of water was analyzed for PAHs, mercury, and lead to evaluate the impacts on air and rainwater quality of the oil industry activities close to indigenous communities. Finally, this same subsample was analyzed for zinc to understand whether zinc levels are affecting the taste of the water. At levels of 4mg/l, zinc leaves an unpleasant, astringent taste to the water.[11] A question on the survey, likewise, assessed people's satisfaction with the taste of the water.

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[25] WHO. (2011) Guidelines for drinking-water quality. FORTH EDITION. Geneva.

[26] Fewtrell, Lorna & Bartram, Jamie. (2001). Water quality : guidelines, standards and health : assessment of risk and risk management for water-related infectious diseases / edited by Lorna Fewtrell and Jamie Bartram. Geneva : World Health Organization. http://www.who.int/iris/handle/10665/42442

Sampling and Questionnaires

Over six months, teams of monitors and one of two project leads (Jena Webb and/or Nicolas Mainville) went to 17 communities to take samples of water (see table 1 for a summary of samples taken), conduct a short questionnaire and appraisal of systems and carry out in-depth interviews. A standardized procedure for collecting samples (see Appendix 2) and carrying out the basic questionnaire and appraisal of the systems was developed. In-depth interviews were carried out by the same investigator (JW) on a variety of topics. The questionnaire and all interviews were conducted in Spanish with a translator from the Ceibo Alliance team, on hand to translate into native languages when necessary. In each community, roughly 15% of the systems were sampled.

Pilot Project

A first iteration of the evaluation was carried out in November 2017. In this phase, several members of the Ceibo Alliance carried out the sampling and the questionnaire in several households of their own communities. A total of 24 households were sampled and surveyed in this first phase. This phase allowed us to evaluate the feasibility of the full evaluation, to adjust the sampling procedure and validate the questionnaire.

Total and Fecal Coliform Analysis With a Portable Lab

Seven systems were also analyzed using a Hach© MEL/MF Total Coliform
portable laboratory. One sample from the first tank and two samples from the second tank at each system were collected in sterile filtration units (Filter: GN-6 Metricel with 0.45 µm pore size and 47 mm diameter. Funnel: Polypropylene Petri Dish: polystyrene lid and polypropylene base Nutrient Pad: Cellulose.). The samples were kept in a cooler on ice until returning to Lago Agrio, approximately 2-3 hours after collection. Once in Lago Agrio, water samples were filtered through the petri, the reagent was added and petries were stored at 37°C for 24 hours. After 24 hours, the number of bacterial colonies (red) and fecal colonies (blue) were counted and recorded. A water engineer from Rainforest Flow, Caleb Matos Chávez, was responsible for taking the samples and provided us with the results and recommendations (see appendix 6).

Questionnaire

A questionnaire was conducted with the owner of each system sampled and consisted of questions on the use of the systems (number of users, number of liters per day, etc.); Maintenance of the systems (how often, etc.); the roof; previous sources of water collection; health (digestive problems, infections, etc.) and satisfaction. (see Appendix 3)

In-Depth Interviews

In-depth interviews were carried out by Jena Webb with at least one member of each community where sampling took place. The topics covered included: use of the systems (ease, installation, maintenance, etc.); health (changes in health, types of health issues, etc.) and general observations. An interview guide was created (see Appendix 4) and used to orient discussion but not adhered to strictly. Conversations were recorded and listened to by the interviewer to glean the most salient topics. The most representative quotes were then selected and are presented in the results section. Interviews were conducted until saturation of issues was reached.

Ethics Approval

This evaluation represents a **Quality Assurance, Testing and Performance Review** of the Ceibo/AF run domestic rainwater harvesting system and as such did not require ethics board approval (according to Canadian Panel on Research Ethics Module 2 TCPS 2).

Use of Data

The results from this evaluation were intended to be used in four distinct ways. 1) to inform the users of their water quality, 2) to inform users of common maintenance issues and how to prevent or resolve them, 3) to orient new iterations of the Ceibo/AF water program (see recommendations in Appendix 1), and 4) as a communications tool in outreach.

RESULTS AND DISCUSSION

Table 1 summarizes the samples taken and the interviews conducted in the context of this evaluation. Sixty-two household heads (39 men and 23 women) from 17 Kofan, Siona and Seikopai communities responded to the short questionnaire on use, maintenance, health and satisfaction of the water and systems.

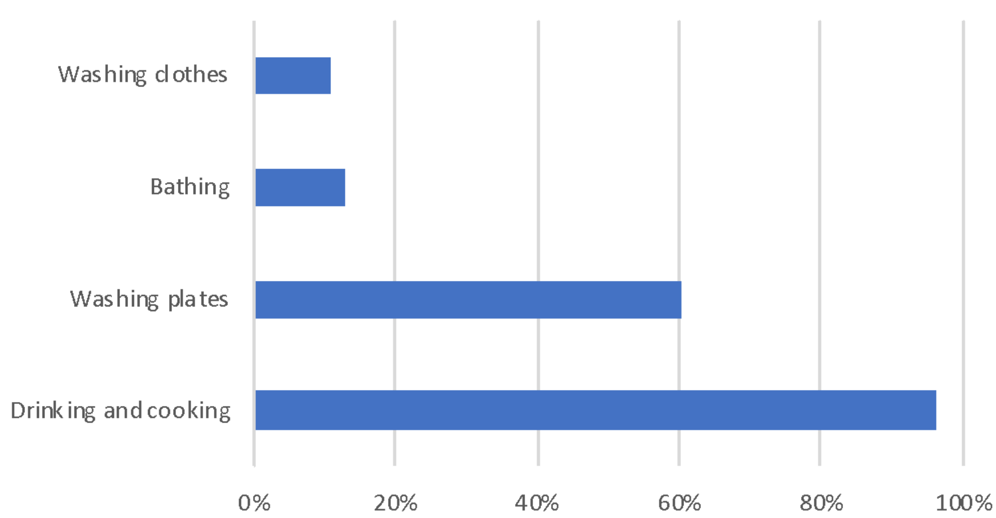
Table1: Summary of Water Samples and Interviews Conducted

	Kofán	Siona	Seikopai	Total
Water samples for fecal coliform, pre-filter	18	20	14	52
Water samples for fecal coliform, post-filter	22	17	15	54
Water samples for fecal coliform, previous drinking water source	11	9	4	24
Water samples for PAHs, pre-filter	6	3	7	16
Water samples for PAHs, post-filter	5	3	15	23
Water samples for PAHs, previous drinking water source	4	9	3	16
Water samples for metals, pre-filter	6	3	6	15
Water samples for metals, post-filter	5	3	14	22
Water samples for metals, previous drinking water source	4	9	4	16
Short interviews	22	17	18	57
In-depth interviews	4	3	4	11

Use of the Systems

On average there are 5 people per household and families use the system 4 times per day, consuming a mean of 46 liters per day. 96% of families use the water for drinking, 60% for washing plates, 13% for bathing and 11% for washing clothes (see Figure 1). Only two families did not drink the water. One family in Puerto Bolivar had a municipal rainwater harvesting system installed which they preferred because it was closer to the kitchen. The second family, from Tarabiaya, reported not drinking the water and that the water had little red worms in both tanks.

Figure 1: Use of the Systems



Maintenance of the Systems

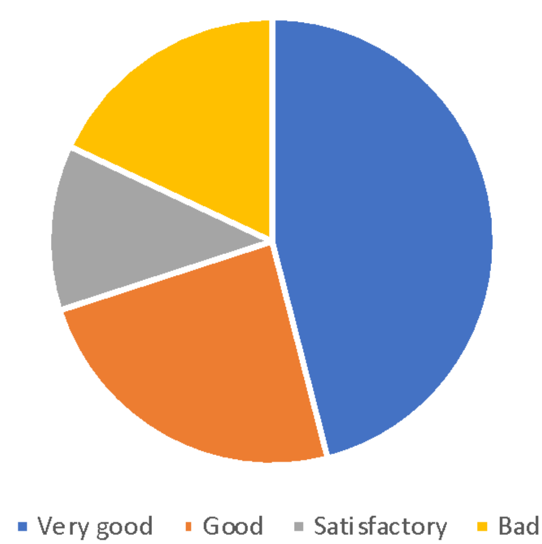
Three quantitative questions addressed user maintenance of their system: “When was the last time you cleaned the tank (days)?” “When was the last time you cleaned the drainage pipes (days)?” and “How many times per year do you conduct maintenance/cleaning of the system?”

The cleaning of the tanks and the tubing was quite variable ranging from never to yesterday, and 0 to 12 times a year. 40% of the people reported never cleaning their tubing and 13% reported never cleaning the tanks. On average people cleaned their systems 4 times/year.

State of the Systems

The person filling out the questionnaire reported on two questions evaluating the state of the system: one addressed the roof of the house (installed by the owner) and the other the water system, both on a scale of 1 to 4, with 4 being very good, 3 good, 2 satisfactory and 1 bad. 46% of the systems were judged to be very good, 24% were deemed good, 12% were satisfactory and 18% were in bad condition (see Figure 2). Many of the systems had fallen roofs. The system roofs serve to cool the system so that the water doesn’t get hot. Further, bacteria reproduce less quickly in cooler water. 34% of the house roofs were judged to be very good, 23% were deemed good, 14% were satisfactory and 29% were in bad condition.

Figure 2: State of the Rainwater Harvesting Systems



Health

This section presents quantitative data from the short questionnaire pertaining to health questions. Two sections of the questionnaire dealt specifically with health: digestive troubles and infections.

86% of people reported observing improved digestive health (reduced diarrhea, vomiting and stomach pain) since the installation of the systems, while the rest, except for one who reported worsened health, reported no change (see Figure 3).

The results on infections (ear, urinary and skin) were more mixed: 44%, reported an improvement, while 56% had not observed a change in infections since the systems were installed. No one reported worsening infections since installation (see Figure 4).

Figure 3: Digestive Health

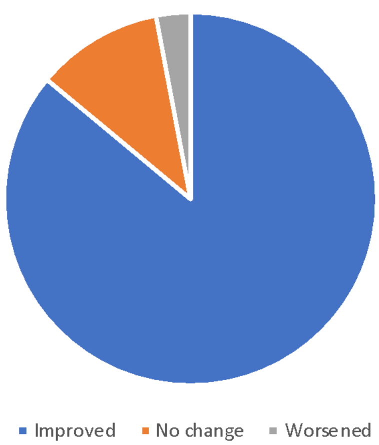
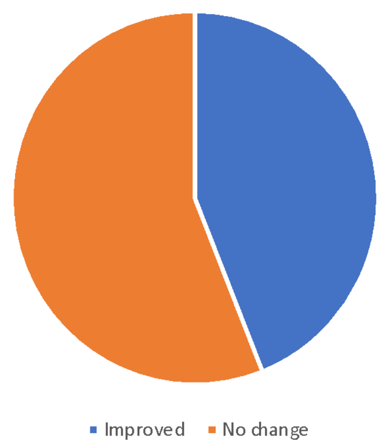


Figure 4: Infections



Program Acceptability

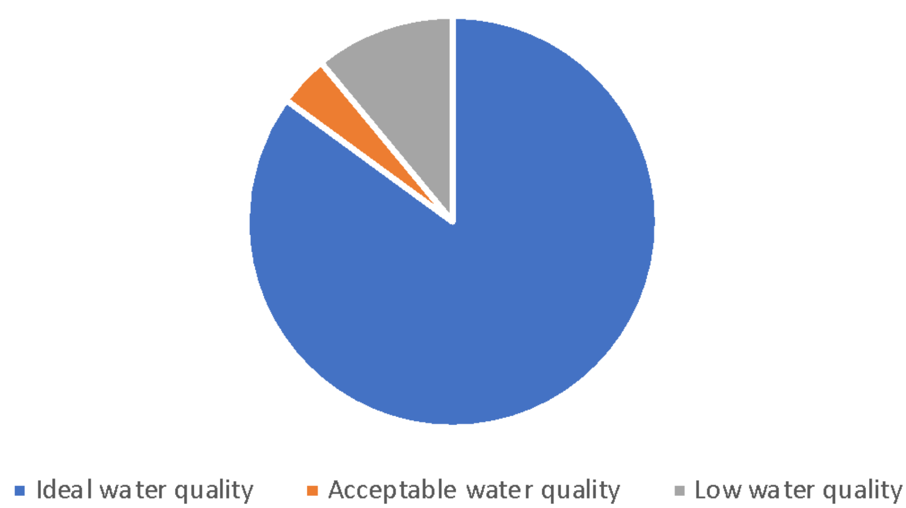
Two questions, “Are you satisfied with the taste of the water?” and “Are you satisfied with the overall functioning of your system?” yielded quantitative data (yes/no) regarding the acceptability of the water systems. 100% of people responded yes to these quantitative questions. The aim of the evaluation, namely to report back on the quality of the water and to incorporate user feedback to improve the program, was explained to all respondents and people generally, freely provided suggestions, small criticisms and both positive and negative feedback, therefore, it does not appear that the response to these questions were designed to please. The results seem to represent a genuine, overall satisfaction with both the taste and the general functioning of the water systems.

Sample analysis of domestic rainwater harvesting systems and alternate sources of water

Fecal and Total Coliform

The majority of drinking water samples collected for this evaluation contained no fecal coliforms. 83% of pre-filter samples and 85% of post-filter samples had no fecal coliforms. The findings were grouped in a three-tier classification[27]: zero fecal coliform/100 ml for "Ideal water quality" (class one), one to ten fecal coliform/100 ml for "acceptable water quality" (class two) and more than ten for fecal coilform/100 ml for "low water quality" (class 3). On a total of 54 samples, forty-six of the post-filter samples (85%) were of ideal water quality, 2 were acceptable water quality (4%), and six of the post-filter samples would be classed as low water quality (11%) (see Figure 5).

Figure 5: Three-tier classification of post-filter samples



There is an average decrease of 68% fecal coliform between the pre-filter tank (mean fecal count=27.5) and the post-filter tank (mean fecal count=8.7), although this difference is not significant (Wilcoxon test P=0.58). The high percent reduction probably does not yield a significant result because of the low number of post-filter systems (n=8) in which fecal coliform is present; with a higher sample size this might become significant.

[27] Gould, J. & Nissen-Petersen, E. 1999 Rainwater Catchments Systems for Domestic Supply: Design, Construction and Implementation. Immediate Technology Publications Ltd, London

There was no association between the level of water in the water tanks (evaluated as full (2), part full (1) and empty (0) by the person taking the sample) and the amount of fecal coliform observed in either the pre- or post-filter samples. In other words, empty systems did not have higher levels as might be expected since as the biofilter dries up its ability to filter out bacteria is reduced. Neither was there an association between the "state of the system" and the amount of fecal coliform. This could be either due to the low number of systems with presence of fecal coliform, as above, or because the evaluation given to the system by different members of the team varied. The state of the roof, as evaluated by the team member taking the water sample, also was not associated with fecal coliform levels.

No significant relationships were found between the levels of fecal coliforms in the pre- or post-filter samples and either of the categories "last time the system was cleaned," "last time the tubing was cleaned," "last time the tank was emptied" or "number of times the system is cleaned per year." This could be due, again, to the small number of systems that tested positive for fecal coliforms or recall error on the part of informants.

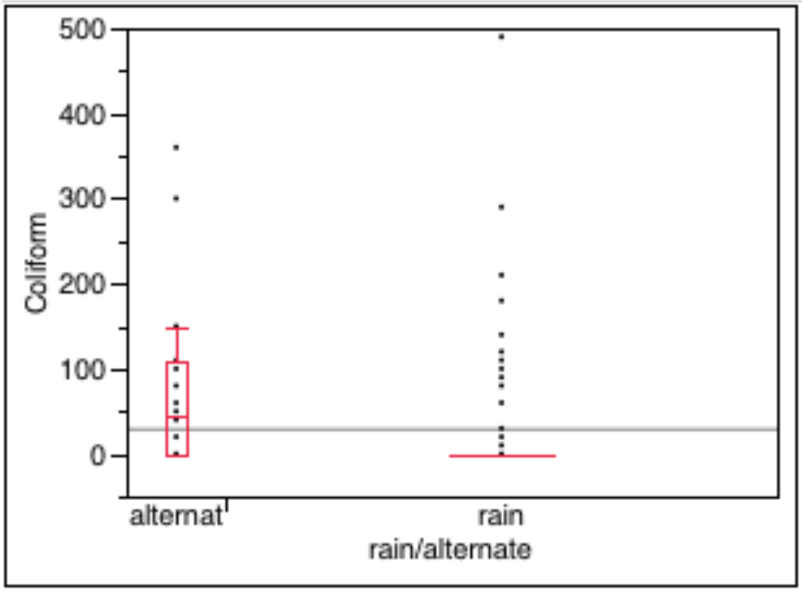
The external observers also measured fecal coliform levels in pre-filter and post-filter tanks. They found acceptable levels in the pre-filter tanks (average= 5.14 counts; where anything below 10 is passable) and a complete absence of fecal coliforms in the post-filter reservoirs.

Our sampling strategy did not systematically analyse samples for total coliforms. Total coliforms are not harmful to health but are sometimes used as an indicator for the overall cleanliness and integrity of systems.[28] The external observers (NS and CMS) were able to test for total coliforms and all samples had a relatively high total coliform count in both the pre- and post-filter tanks, indicating that a substantial amount of organic matter is entering the systems (see Appendix 5). Functioning mesh filters at the entrance to the system and a first-flush apparatus would reduce the amount of organic matter entering the system, improving water quality and increasing the life-span of the systems (see recommendations in Appendix 1).

The alternative water sources were classified into surface (rivers and streams) and sub-surface (springs) sources. On average the surface sources had 79 fecal coliform counts and the sub-surface had 12.5, both would fall into class three (water unacceptable for drinking purposes). Comparison of the means using the nonparametric Wilcoxon test ($P<0.0001$) shows that there is significantly less fecal coliforms in both the post-filter and pre-filter rain water than in the alternate water sources (see figure 6).

[28] WHO. (2011) Guidelines for drinking-water quality. FORTH EDITION. Geneva.

Figure 6: Box-plot of fecal coliforms in alternate surface water sources vs. rain water.



This evaluation found that the vast majority of rainwater harvesting systems had levels of fecal coliforms ideal for drinking water and that the systems overall are significantly better sources of drinking water than the available alternatives, be it surface or sub-surface. Some simple adjustments and maintenance could improve the situation for those households where levels were less than ideal (11% of systems) (see Appendix 1: Recommendations).

Hydrocarbons

Levels of Polycyclic Aromatic Hydrocarbons (PAHs) were measured in a subset of the water systems (n=39) and alternate water sources (n=16). None of the samples, whether they were from the pre-filter, post-filter, or alternative water sources, had measurable amounts of PAHs (detection limit=0.00012). These results do not indicate that there is no petroleum contamination in the water, but rather that levels are below the detection limit *in water*. Other compartments of the ecosystem where hydrocarbons accumulate, such as sediments and bottom feeders, are better indicators of petroleum pollution in the ecosystem. These results only indicate that even in the communities closest to oil operations where gases are openly flared, there is no health concern from PAHs in rain water.

Metals

Mercury and lead

Similarly, none of the rainwater harvesting systems samples (n=37) or alternative water source samples (n=16) had detectable amounts of mercury (detection limit=0.005 mg/l) or lead (detection limit=0.05 mg/l). These results do not indicate that there is no mercury or lead in the water. Levels of mercury in water are often very low; however, predatory fish are more responsive to differences in environmental Hg levels, concentrating up to 10^6 times the levels found in water[29] These results indicate only that rain water represents no health hazard in terms of mercury or lead consumption.

Zinc

Most samples (n=53), both pre- (n=15) and post-filter (n=22) and the alternate water source (n=16), had detectable levels of zinc. All the samples, however, had levels below that associated with an unpleasant taste (4mg/l). Pre-filter levels were higher (mean = 1.7 mg/l) than post filter levels (mean = 1.5 mg/l), but this difference was not significant (Wilcoxon P=0.37). The filters removed on average 12% of the zinc that entered the first tank. The state of the roof was not associated with zinc levels in either the pre- or post-filter tank. The material of the roof (zinc vs. *duratecho*) was also not a determinant of zinc levels, possibly because only 3 people reported having only *duratecho* on their roof. There was a negative association, but not significant, between years since the roof was installed and the amount of zinc in the water.

Qualitative Analysis

This section presents observations made by interviewees either during the short questionnaire or the in-depth interviews and is organized into the following sections: Health, The Rainwater Harvesting System, Security and Ease of the System, and Other Benefits of the Program. The comments were overwhelmingly positive. Several recommendations were given and have served to orient the recommendations section below (see Appendix 1).
"People are very satisfied with the rainwater harvesting program. Because before, local and national governments didn't focus on water collection. And thanks to the Ceibo Alliance they have gained this tremendous benefit for their families and for all of the Siona of the Cuyabeno region. People are very satisfied with these systems." (Vic-01-A,D)

Health

An overwhelming majority of people commented on improved health since the installation of the water systems and explicitly associated this improvement with the systems.

"The system has changed everyone's life, because now we don't get sicknesses: we don't throw up, we don't have stomach aches anymore, so it has changed, now we live better. The kids live well and my wife too." (SP-01-A,D)

A grandmother (SP-04-A,D) explained that when she was little, they didn't suffer from stomach pain, fever and diarrhea, but that her children did. She associated the change with the contamination of the rivers. She then explained that her grandchildren, who drink water from the rain water harvesting systems, do not suffer from these ailments.

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[29] Baudo R, Giesy J, Muntau H (1990) Sediments: chemistry and toxicity of in -place pollutants. CRC Press, Norvara

"What would we do if we ran out of water? We'd have to suffer, like we did before…it was very difficult…" (SP-04-A,D)

People also appreciated the taste of the water, an important criterion in the acceptability of a clean water program, which also has health promotion effects through the consumption of adequate quantities of water.

"It gives a good feeling when you drink it. It doesn't have that smell that it has when it comes from a spring, when a muddy odor comes with it. It's not like that. It has a healthy taste, sort of perfumed." (UK-01-02)

The only health issue that was raised and associated with the system was stomach trouble when the system dries up, and this only by two people from the same community (BV).

"Our health is better now, but it is possible that there are more digestive troubles when it doesn't rain." (BV-01-AD)

The Rainwater Harvesting System

When asked about the functioning of the systems the majority of people were satisfied and had only minor complaints with certain aspects of the system, namely the roofs and the mesh filters. At the same time, people recognized that they were responsible for the upkeep of their own systems. Several interviews addressed the information that people received during the initial workshops. Those who spoke of this were generally satisfied with the information that they received. Several people mentioned that it would be useful to provide information to new arrivals in a second workshop; however, new arrivals explained that they did receive information about the system either from family members or, in the case of one interviewee who was not living in the community when the systems were installed (Vic-01-A,D), from the president of the community. This indicates that information about the systems circulates in the communities independent of interventions by Ceibo/AF. In in-depth interviews people gave their systems an average of 20 years.

"The tank is functioning well…this is so important for drinking water. That is why I'm clearly telling you that it is so helpful that you built these systems like this. Because they get really full. It is so easy for me. I can't say that they don't help. Really, I say they are working well, perfectly." (SP-04-A,D)

"My criteria is that it depends on each of us how we maintain the system, because if we don't keep that up, that's the point. It someone gives you something, if you maintain it, it lasts longer. But if you don't take care of it, it will break, right." (Bol-03-A,D)

"We have to take care of our own systems…this is what was explained in the workshop…take care of it, clean it, it's for drinking." (Bol-03-A,D)

Many people noted that the most difficult part to upkeep was this plastic roof over the system. In a long interview (SP-04-A,D) a respondent with a fallen roof explained that they were hard to maintain because the structure of the roof is made of wood, which rots, and that the plastic rips. But she also confirmed that the taste of the water does not change when it is warm. Other people recognized that they simply hadn't had the time to fix it after it had gotten out of place. E.g SP-07-A,D said that he himself was fully responsible and that there was really not a technical issue there.

Another issue with the systems that came up was the mesh filter at the entrance to the first tank. Several respondents commented that they ripped or that they clogged up too quickly.
"Yes, there was a mesh when the system was installed, it was kind of delicate, white, but it didn't last, just two months and then it was all ripped. I changed it to a fine cloth, not so fine as clothing, but almost. It lasted three months. When it is delicate, it has to be changed often, so that frogs don't get in." (SP-01-A,D)

The only negative comments about the system came from several residents of Puerto Bolivar and Tarabiaya who were skeptical of the sand filters. It would be important to re-explain to these communities the importance of the filters in the filtration process and their benign nature.

Security and Ease of the System

Another point that was repeatedly made in the interviews was the contribution of the systems to reducing the time required and the energy necessary for collecting water. Irrespective of where the previous water source was located, the systems being right by the doorstep constituted an improvement.

"The tanks make it easier because we have water right here. Before we had the tanks, we had to go down to the river, lug up buckets, and go back, up and down, often. We had more work. But now, no, we have the tank right at the foot of the house. I used to get tired." (Bol-03-A,D)

The systems also contributed to a sense of water security which was commented on by several respondents. People were able to identify when they were at risk of running low on water (December, January and February, at the end of the dry season) and also water consuming behaviors to reduce the inconvenience of lacking water. For example, Vic-01-A,D, from San Victoriano said, "Here in December, January and February it's the most complicated, because the river gets totally dry, just 50cm. It depends on each family's [use], to not be washing plates, only for drinking and cooking, then wash the plates in the river, as we do for the clothes. You have to really take care of the water, care for it more than gold." (Vic-01-A,D)

"Having rainwater harvesting tanks is really practical for the family because then you're sure that you're going to collect water when it rains. And if we didn't have the system you don't know what to collect the water in, you could be using tanks that aren't suitable for collecting rainwater. We used to collect water in metal tanks and you know metal lets off an acid or some [chemical]. This system is better because the tanks are suitable for drinking water." (Vic-01-A,D)

“We feel secure with the system.” (Bue-01-A)
“Kids just come and drink water.” (Bue-02-A,D)

Other Benefits of the Program

Our results did not allow us to determine if the rainwater harvesting program led to increased awareness of environmental health, as has been shown in previous studies[30], since no pre-training baseline information was collected. However, respondents appeared to have a sophisticated understanding of the connections between the environment, water and health, as the following quotes demonstrate:

“Now there are so many people, so much contamination, open gas-flares right nearby, sometimes it rains and the open-pit waste pools drain the wastes, the black petroleum, right into the river.” (SP-01-A,D)

An interviewee (Vic-01-A,D) explained clearly that he knew that owners of the systems should not keep soap or pesticides near the system. He laughed sheepishly as he motioned to his own system where a pesticide tank was resting on the base of the water system. This indicates that while the information has been assimilated the associated behavioral changes have not always followed.

In response to a question on changes in the local River, Waiya, since the installation of two oil platforms in the headwaters an informant said “Yes, it’s changed. Mostly in terms of skin infections. That’s why we don’t bathe there much. Just a little.” (WY-02 A,D)

“Before we lived better, because there was no contamination by Texaco. We didn’t suffer from illnesses. My grandmother lived to be like 100. But she walked well, and she worked. And now with this contamination, it is worse…[the elders] ate right from the river, drank right from the river, but it wasn’t contaminated, there was no petroleum in it. They didn’t get fevers, stomach aches, diarrhea. That’s why she lived to be 100, and walked without a cane.” (SP-04-A,D)

In communities with roads nearby, such as Bella Vista, residents spoke of concern over dust billowing up from the passing traffic. One resident (BV-04-A,D) explained though, that this dust is a problem when they collect rain water in a tank without a filter, but that in the systems installed by Ceibo they do not note the dust in the filtered water.

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[30] Davis, L. F., M. D. Ramirez-Andreotta, J. E. T. McLain, A. Kilungo, L. Abrell and S. Buxner (2018). "Increasing environmental health literacy through contextual learning in communities at risk." International Journal of Environmental Research and Public Health **15**(10).

CONCLUSIONS

The results from the quantitative and qualitative data collected in this evaluation point to high water quality, improved health since the installation of the systems, ease of use and resounding user satisfaction. 85% of systems had no fecal coliforms whatsoever and only six systems had unsatisfactory water quality. A majority of people (86%) pointed to improved digestive health since the installation of the systems. In-depth interviews, especially those carried out with women, indicated that the systems have reduced their workload. Finally, 100% of respondents reported being satisfied with both the taste of the water and the system itself. Small adjustments which would reduce both the amount of total and fecal coliforms in the water could be implemented to aim for 100% Class 1 water, ideal for drinking (see Appendix 1); however, even as is, the drinking water represents a substantial improvement over alternate sources of water, which were found to be, on average, unacceptable for human consumption. In closing, the *ensemble* of this evaluation reveals a program that is working to provide excellent drinking water to some of the Amazon's most remote communities.

APPENDIX 1: RECOMMENDATIONS

This appendix presents some recommendations for the direction of the Ceibo Alliance/AF water program. They are categorized into high, medium and low priority.

Second Wave of Maintenance Workshops

Priority: high

Despite the fact that interviews with new-arrivals indicated that there has been sufficient uptake of the program for the auto-circulation of necessary information on the use and maintenance of the systems, several people mentioned that it would still be good to have another workshop so that people who married into the community or youth who recently came of age could get training in the use and maintenance of the systems. One women (Bol-03-A,D) mentioned that while she thinks that she understood all the instructions in Spanish, Spanish is not her first language. Therefore, the results of this evaluation point to the need for a second set of workshops on the use and maintenance of the water systems and that these workshops be fully translated in the local language. A maintenance video could be made to show the exact steps necessary for regular maintenance.

This workshop could include information on:

- The purpose and non-toxic nature of the quartz and filter components
- The biological layer and the importance of keeping it wet
- Common technical difficulties (mesh, roof, dripping, sand in second tank)
- Best maintenance practices (how to access and clean the tanks, tubing, etc.)
- What to do in case of major damage

Maintenance Guide

Priority: high

The steps for regular maintenance and how to resolve common problems should be written up into a short and easy to read guide with ample images to accompany descriptions. Much of the same information shared in the workshop should be included in this guide and left with each household.

Needs Analysis, Sampling, Interviews and Training in Waorani Territory

Priority: high

Sampling and interviews need to be conducted in Waorani territory.

A program to return to Waorani communities and carry out an evaluation similar to the one conducted here as well as further training (as above) and a needs analysis would be important as a next iteration of the Ceibo Alliance/AF water program.

Training and Proper Installation of Systems in Tarabiaya

Priority: high

Through interviews and inspections of the systems we learned that many of the systems were not properly installed in Tarabiaya. The Ceibo Alliance/AF should plan to return to this community and assist residents in the proper installation of their filters. According to interviewees, the initial technician is no longer available to help residents of this community with their systems and therefore, a new technician should be trained.

Women Community Water Technician Training

Priority: medium-high

Many studies have shown that including the active participation of women in WASH projects greatly increases their sustainability due to women's central role in household water management and their greater likelihood to remain in their native communities. "A study by the International Water and Sanitation Centre (IRC) of community water and sanitation projects in 88 communities in 15 countries found that projects designed and run with the full participation of women are more sustainable and effective than those that do not. This supports an earlier World Bank study that found that women's participation was strongly associated with water and sanitation project effectiveness."[31] It would be advisable, in a second iteration of the project, to actively recruit and train women from the communities as water technicians and have these women participate actively in the workshops as native language facilitators. This could be a program wide activity or it could begin with the communities which, for one reason or another, no longer have a technician (e.g. Tarabiaya).

Acquisition of a Portable Laboratory and Regular Evaluation of Systems

Priority: medium

A portable lab would facilitate a continuous evaluation of the systems, especially in communities more than 6-hours from Coca. It would be advisable to sporadically test systems in each of the communities at least once a year. Realistic goals for progressive improvement of water quality indicators could be set and monitored through a yearly quality rating (for an example see WHO, 2011, p. 91). With a portable lab this could be done in conjunction with other activities.

The external observers who came to see the water systems (NS and CMC) have a HACH MEL lab and recommended it to us. The HACH MEL lab is valuable tool to monitor water quality and to educate the people about unseen fecal and total coliforms in the water. They shared the name of the HACH Donation Committee Chair and suggested to get in touch to see if they could give Ceibo Alliance/AF an In-Kind donation of a MEL Laboratory and supplies. **TIM SCHMITT** | Technical Support/Donations Committee Hach Community Outreach hachhelps@hach.com **P** 970.669.3050 x 6210 | **F** 970.619.5058 Hach Company | www.hach.com |

Install a First-Flush System

Priority: medium

[31] Inter-agency Task Force on Gender and Water (GWTF) (2015). Gender, Water and Sanitation: A Policy Brief. UN-Water and the Interagency Network on Women and Gender Equality (IANWGE), United Nations.

All literature consulted for this report indicates that first-flush systems improve water quality. A first-flush system, which would ideally divert the first 5mm of rain, prevents organic material accumulated on the roof since the last rain from entering the first tank or clogging up the mesh filter at the entrance to the tank. The high levels of total coliforms observed in the samples collected with the external observers (NS and CMC) could be avoided by diverting the first rain and the organic material that comes with it. The system maintenance is also reduced by avoiding the entry of a substantial part of the organic matter found on the roof[32],[33]. First-flush systems are not difficult to install. Abbasi[34] suggests how to calculate and install first-flush systems. It would be advisable to install a first-flush system on all new systems and conduct an evaluation of the new systems specifically accessed to collect user feedback on the first-flush system. If there is user acceptability of the first-flush, it would be advisable to retro-fit a first-flush on previously installed systems.

System Database

Priority: medium

A database of all the systems would facilitate maintenance, future evaluations and planning. The Blue Planet Network provides a free platform for clean water organizations to store and easily update water system information (http://blueplanetnetwork.org/programs/platform). The platform seems to be available only in English, but something similar would allow for the input information on the systems from the field via cell phones. Consultation of the database prior to scheduled visits would alert technicians to any recent needs.

New Round of Rainwater Harvesting Systems in Communities Already Served

Priority: medium

Since installation, some communities have grown and new arrivals don't always have a system. At some point it would be good to do a second round of installations in each of the communities because people have grown up and moved in since the first installation. It would be good to give ample forewarning that people can build pillars to put the system up higher before the installation team comes. In new systems, it is more efficient to increase the size of reservoir than the filter tank because then people don't ever have to wait for water. A common calculation is that the reservoir is 8 times the surface area of the roof.

Overflow Mechanisms

Priority: medium

While conducting interviews, we learned that there were no overflow mechanisms (tubo de desfogue), that control the level of water automatically, installed on the systems in San

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[32] de Kwaadsteniet, M., P. H. Dobrowsky, A. van Deventer, W. Khan and T. E. Cloete (2013). "Domestic Rainwater Harvesting: Microbial and Chemical Water Quality and Point-of-Use Treatment Systems." Water, Air, & Soil Pollution **224**(7): 1629.

[33] Helmreich, B. and H. Horn (2009). "Opportunities in rainwater harvesting." Desalination **248**(1): 118-124.

[34] Abbasi, T. and S. A. Abbasi (2011). "Sources of pollution in rooftop rainwater harvesting systems and their control." Critical Reviews in Environmental Science and Technology **41**(23): 2097-2167.

Victoriano, so they have to turn it on and off according to the rain. (Vic-01-A,D) Several of the houses in Daipare also didn't have the overflow mechanism. It would be good to verify this in all houses in San Victoriano and other communities susceptible to have had a similar installation method and retro-fit the systems with the overflow mechanism.

Stagnant Water Control

Priority: low

Stagnant water was observed near water systems in many households. Stagnant water is a vehicle for water borne diseases and also creates breeding habitats for vectors, such as mosquitos, of vector borne diseases, such as dengue. It would be good to dig a 1.5 by 2 foot hole in front of the faucet and fill it with river rocks to avoid pooling below the faucet. If the Ceibo Alliance/AF does not take this task on, it could be something that is recommended that users do themselves at the workshop.

APPENDIX 2: WATER SAMPLING

A standardized sampling procedure was established and consisted of the following:

1. Put on gloves
2. Take out a new, clean bottle and cap
3. Open the first tank and fill the bottle by inserting the bottle under water until it is completely full
4. Dry the bottle
5. Identify the bottle with the sample number, date and time
6. Seal the bottle with tape
7. Put the sample immediately on ice
8. Take out a second bottle and cap
9. Turn on the tap of the second tank and let it run for 5 seconds
10. Fill the bottle until it overflows
11. Repeat steps 4-7
12. After each house, dispose of gloves
13. Once all samples are taken go immediately to the LABSU laboratory to deliver samples for *E. coli* analysis and within no more than 6 hours of sampling.
14. Samples for PAH and metal analysis are kept in a refrigerator until being sent to Quito by bus for analysis at LABANCY

To take samples of the rivers and streams a similar procedure to sampling the first tank was used. Three samples were taken several meters apart. GPS points were recorded.

The fecal coliform analysis was carried out the the laboratory LABSU, Coca, Ecuador and the PAH and metal analysis were conducted at LABancy, Quito, Ecuador.

APPENDIX 3: QUESTIONNAIRE

de muestra: ___________________Fecha: ______________Hora de toma de muestra: _______

Comunidad: ___________________Coordenadas GPS del sistema: _________________________

Nombre y apellido del dueño del sistema: ____

¿Viven permanentemente en la casa? Si No : ¿Con qué frecuencia están?__________

Uso del sistema

¿Cuantos usuarios del sistema?: _____________ Año de instalación del sistema: ______________

¿Cuántas veces al día se usa el sistema? ____

¿Para que se use el sistema? ____

¿Cuantas ollas (o galones) de agua se usa diario aproximadamente? _______________________

¿Cuántos días desde la última lluvia? ____ El sistema está: lleno ___medio vacío ___vacío ___

Mantenimiento del sistema

¿Cuándo fue la última vez que se limpió el sistema? ____________________________________

¿Cuándo fue la última vez que se limpiaron los tubos y canales para recolectar el agua del techo?

____

¿Cuándo fue la última vez que se vació el segundo tanque? ______________________________

¿Cuántas veces al año usted hace el mantenimiento del sistema? _________________________

Estado del sistema: Muy bueno Bueno Satisfactorio Mal

Techo de la casa

¿De qué está hecho el techo? ____

¿El techo fue pintado? Si No ¿Cuándo? _______________________________________

¿Cuándo fue instalado el techo? ____

Estado del techo: Muy bueno Bueno Satisfactorio Mal

Ubicación: sombra sol

Observaciones y comentarios____

____

Otras fuentes de agua

¿Donde recolectaba el agua potable antes de la instalación de su sistema?

____

¿Usted sigue usando otras fuentes de agua potable? Sí No Si la respuesta es sí:

¿Cual fuente? ____

¿Con qué frecuencia? ¿Cual uso?

____

¿Hay una fuente de contaminación cerca de la casa? ¿Dónde está el mechero lo más cercano?

____

Salud

¿Ustedes sufran de problemas digestivas?: ¿Dolor de estómago? Si. No

¿Diarrea? Si. No ¿Vomitó? Si. No

¿Han notado cambios en la cantidad o tipo de problemas digestivas (después de la instalación del sistema)?____

¿Ustedes sufran de infecciones?: ¿Del oído? Si. No

¿Infecciones urinarias? Si. No. ¿Infecciones de piel? Si. No

¿Han notado cambios en la cantidad o tipo de infecciones (después de la instalación del sistema)?____

¿Cómo es el sabor del agua?____

¿Están satisfechos con el agua? Si. No

¿Están satisfechos con el sistema de agua (lugar, manteamiento, etc.)? Si. No

¿Cómo ha cambiado su vida desde la instalación del sistema? ___________________________

____

APPENDIX 4: INTERVIEW GUIDE

A continuación, encontrará una propuesta de guía de entrevista. Este es un marco de discusión general que es flexible y abierto. Hemos agrupado aquí las ideas de las preguntas. En este sentido, esta guía se puede adaptar o modificar según sea necesario, según las particularidades de cada comunidad y según las respuestas de los participantes. Existe también un cuestionario con preguntas más cerradas que todos deben responder y que debe ser hecho con cada familia que proporciona una muestra de agua (ver documento X).

Etapa 1: Describa brevemente el proyecto de evaluación
Etapa 2: La entrevista
Nombre y apellido: ____
Edad: _________________________. **Comunidad:** _____________________________________
Número de la muestra: _________________________ **Sexo: F M**

Nota: si una muestra no fue tomada a la casa, llenar el cuestionario también.

Dividimos nuestra entrevista en 3 secciones:
1. Los sistemas de agua lluvia
2. La salud
3. Conclusiones

Indica al inicio que "Se *puede hablar libremente, no hay una respuesta correcta o incorrecta. Los datos serán tratados confidencialmente para no asociar palabras con una persona y con fines de mejorar el programa*."

Sección 1 – Los sistemas de agua
Desde 2011 la Alianza Ceibo y Amazon Frontlines han instalado XX sistemas de agua en 72 comunidades.
¿Cuál fue el problema inicial o la solicitud inicial que ha llevado a la instalación de sistemas de agua lluvia en su comunidad? ¿Ha evolucionado esta solicitud con el tiempo? ¿De qué manera?

¿Ha participado/a usted mismo/a en alguna dimensión del proyecto? ¿De qué forma?

¿Cómo está funcionando su sistema? ¿Llena cada lluvia o no llena? ¿Cuántas veces se seca por año? ¿Cómo lo hace?

¿Recibió información sobre el mantenimiento del sistema? ¿Cuándo? ¿Se siente que tiene toda la información que necesita para el buen mantenimiento del sistema?

¿Cada cuánto hace la limpieza? ¿Quién hace la limpieza?

¿Qué se puede hacer cuando hay problemas? ¿Cómo usted se resuelva los problemas o inconvenientes que se encuentra?

¿Cuáles fuentes de agua alternativas utiliza usted? ¿En cuáles situaciones? ¿Qué tratamiento hace usted al agua alternativa?

¿Está satisfecho/a con el agua? ¿Con el sistema? ¿Qué opina usted de los sistemas de agua?
Mirando hacia atrás, ¿cuál fue el impacto de la instalación de sistemas de agua lluvia? ¿Para usted y dentro de su propia comunidad?
¿Ha visto una recepción positiva de los sistemas de agua lluvia? ¿Quién, qué actores estuvieron más a favor del proyecto? ¿Ha cambiado esta situación durante el proyecto?

Por el contrario, ¿presenció alguna disensión entre las partes interesadas en la conducción del proyecto?
a. ¿Qué actores tenían reservas acerca del proyecto?
b. ¿Qué reservas se expresaron?

Sección 2 - Salud
Desde que las compañías petroleras han llegado, ciertos miembros de las comunidades se han preocupada por la salud de la gente. Las siguientes preguntas son sobre esta preocupación.

¿Está preocupada por su salud, la salud de su familia o la gente de esta comunidad? ¿En cuál sentido?
¿Cómo va la salud de los adultos de la comunidad? ¿Ha notado algún cambio desde la instalación de los sistemas de agua de lluvia?
¿Cómo va la salud de las niñas y los niños de la comunidad? ¿Ha notado algún cambio desde la instalación de los sistemas de agua de lluvia?
¿Quién hace la recolección de agua en la familia? ¿Hubo cambios en el tiempo necesario en el esfuerzo necesario para recolectar agua?

Sección 3 - Conclusiones
¿Ha habido un impacto de los sistemas de agua a más largo plazo (meses, años después) en la comunidad? ¿para usted?

¿Cómo calificaría la satisfacción de su comunidad con el resultado del proyecto? ¿Y su satisfacción personal? Explicar.

¿Ha habido algún impacto del proyecto, a corto o largo plazo, con respecto a la sensibilización de la gente de cuestiones de la contaminación ambiental?

En retrospectiva, ¿qué podría haberse mejorado en la instalación o la participación de los socios durante el proyecto de sistemas de agua? ¿Tiene alguna sugerencia para mejorar el programa?
Gracias por su cooperación.

APPENDIX 5: SUMMARY OF RESULTS FROM THE EXTERNAL OBSERVERS (NS AND CMC)

	San Pablo			Bavoroe			Upiritu			Total		
	# samples	#samples test positive	Average count	# samples	#samples test positive	Average count	# samples	#samples test positive	Average	# samples	#samples test positive	Average count
Fecal coliform, pre-filter	3	2	11	2	1	1	2	1	0.5	7	4	5.14
Fecal coliform, post-filter	3	0	0	4	0	0	4	0	0	11	0	0
Total coliform, pre-filter	3	3	666.66	2	2	1000	2	2	1000	7	7	857.14
Total coliform, post-filter	3	3	40.66	4	4	538.5	4	4	105.25	11	11	245.18
Fecal coliform, municipal water	1	1	6	0	na	na	0	na	na	1	1	6

APPENDIX 6: RECOMMENDATIONS OF CALEB MATOS CHÁVEZ, RAINFOREST FLOW

El proyecto de agua de Amazon Frontlines es muy innovador y alternativo con una visión futurista, que podría ser replicado en las selvas de todo el mundo, creemos que las recomendaciones dadas, son para mejorar estos sistemas y que puedan ser replicandos de una mejor manera.

INSTALACION CORRECTA

1. El nivel de agua entre el ingreso (agua de lluvia) y la salida del bio-filtro no debe ser menos de 35 cm ni mayor a 40 cm.
2. En esta foto (abajo) se muestra que hay más de 1 metro de diferencia de altura, lo que crea una fuerte presión de agua en el fondo (carga hidraúlica) que permite ingresar bacterias orgánicas por encima de los rangos permitidos por Organización Mundial de la Salud (OMS).

INSTALACION INCORRECTA

Foto: Casa en San Pablo.

3. Es importante realizar un analisis físico químico de la sustancias de color negro acumuladas en la superficie de los bio-filtros, para descartar la presencia de aceites u algunos otros agentes contaminantes que esten alterando los altos niveles de coliformes totales.
4. Es muy importante descargar las primeras aguas de lluvia fuera del los bio-filtros por unos minutos, dependiendo del tamaño del techo, para evitar el ingreso de contaminantes adheridos en las calaminas que pudieran alterar el interior del filtro.
5. Cada filtro debe tener como mínimo 40cm de arena lavada de río, 15 cm de grava de 1cm y 10 cm de piedras de 5 cm.
6. Las muestras recogidas y analizadas arrojaron altos porcentajes de coliformes totales en los filtros, los cuales no son muy alentadores, esto se puede mejorar si seguimos las recomendaciones dadas enteriormente en la # 5.
7. Para monitorear la calidad del agua es necesario realizar análisis bactereologico como mínimo una vez al año.