Monitoring and Evaluation of CONAPAC Water Treatment Plants in the Peruvian Amazon

Water Quality and Community Perspectives Report

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Content

Executive Summary

During July and August of 2013, a multidisciplinary team of five students from the University of Colorado, Boulder, conducted research and monitoring and evaluation of water treatment plants (WTPs) that have been constructed by the Civil Association for the Conservation of the Peruvian Amazon Environment (CONAPAC) in the Peruvian Amazon. The research is supported by a National Science Foundation IRES grant and the 2013 visit is the third annual visit conducted under the grant. Since the last visit by the CU research team in 2012, CONAPAC has conducted operator training programs and implemented a pilot study of a point-of-use (POU) water filter.

The goals of the 2013 research study were to 1) assess the factors that influence the sustainability of water treatment interventions, 2) monitor and evaluate CONPAC's pilot study of a POU filter, and 3) measure the effectiveness of an operator training program that was implemented by CONAPAC in 2013 to improve the water quality and sustainability of community (WTPs). The results of the POU study are presented in a separate report.

A total of 16 CONPAC WTPs, 3 municipality WTPs, and 3 Rotary International (RI) WTPs were visited over four weeks. Data collection consisted of randomized household surveys designed for communities with CONAPAC, RI, or municipal WTPs, interviews with operators of WTPs, water quality testing at both the WTP and household level, and collecting GPS coordinates of households and water sources. Fourteen out of the 16 CONAPC WTPs visited were operational, two of the three RI WTPs visited were operational, and none of the municipality WTPs were operational. A total of 286 randomized household surveys were conducted in 21 communities, 194 of those surveys were conducted in communities with CONAPAC WTPs.

Use and Satisfaction

The self-reported use of CONAPAC WTP community members, 85 percent, is similar to rates reported in surveys conducted in previous years. Reported WTP use by community ranged between 50 and 100 percent, and one outlying community, Santa Teresa, reported use at 17 percent. Out of the survey respondents with a CONAPAC WTP, 39 percent reported being 'very satisfied' and 54 percent reported being 'satisfied' with their community WTP, a combined total 93 percent. The percentage of users drinking exclusively from WTPs and no other sources, i.e. 'consistent' users, is 60 percent. Distance continues to be one of the largest barriers to WTP use, with 60 percent of respondents who are non-users of the WTPs citing distance as their primary reason. Most respondents, 84 percent, expressed a willingness to pay a higher monthly fee.

Resilience of Systems

Twelve out of the 16 communities visited with CONAPAC WTPs, 75 percent, were not functional at some point during the last year. Of the 17 CONAPAC WTP operators

interviewed, six reported that they cannot treat water year-round, and their WTPs are offline for an average of three to six months out of the year. It was found that both the flooding of the WTPs during the high water season and the lack of pipes to pump water during the dry season are factors that contribute to the WTPs not functioning year-round.

Operator Proficiency

All interviewed operators were scored on a scale of 0 to 3 to measure level of understanding of the material taught in the CONAPAC operator training. Of the 17 out of 32 CONAPAC WTP operators interviewed, 24 percent scored a 3, suggesting excellent operator understanding, 41 percent scored a 2, suggesting an improved operator understanding, and 35 percent scored less than a 2, suggesting insufficient operator understanding. It was found that the score an operator received when taking the CONAPAC operator training examination does not always correlate with the score received during the follow up operator interview. Unique characteristics of the four communities with the highest scoring operators, San Luis, San Juan de Floresta, Irlanda, and Yanamono II are: mentorship, leadership, business experience, and age, sometimes attributed to higher education. When asked if there were topics on which operators would like more instruction, eight operators replied yes and mentioned topics such as how to improve sedimentation, how to use the pH kit, proper chemical doses, and most commonly, how to backwash and repair filters. Based on conversations and observations during visits with operators, WTPs in these communities do not appear able to function for the long-term without the continued monitoring and evaluation and support, even if minimal, of CONAPAC. This was found in communities with strong leadership and qualified operators as well as those without.

Water Quality

All WTPs tested negative for *E. coli* at the final collection tap, sample site 5, except for the community of Suni Caño. Meanwhile, 30 percent of water samples from households that collect water from a CONAPAC WTP tested positive for *E. coli* suggesting that recontamination is occurring and that behavior change is the limiting factor in achieving consumption of safe drinking water and the full benefit of the investments made into the water treatment process and operator training program.

CONAPAC versus RI and Municipality WTPs

Relative to the RI and municipal WTPs visited by the research team, CONPAC WTPs appear to be more sustainable, based on the fact that they are in operation for a longer period of time than the other WTPs. In the communities with CONAPAC WTPs that have been nonfunctional, the primary reasons for the lack of sustainability appear to be due to, in large part, a lack of savings for future repairs and a lack of knowledge of how to repair the WTP filters.

Recommendations

1) Based on observations in the field of operator turnover and a lack of understanding of material by certified operators, an annual operator training is recommended. While a one-time operator training program does not appear to guarantee that operators are able to properly treat water, an annual training will greatly help to reinforce proficiency and reach new operators. 2) Recontamination of water collected from the WTP appears to be the limiting factor to providing safe potable drinking water. In order to tackle this obstacle, it is suggested that CONAPAC work with communities to implement education of safe water storage and handling. Research on behavior change indicates the importance of repeated messages and CONAPAC's ongoing relationship with the communities allows for a successful campaign. CONAPAC is strongly encouraged to continue the annual monitoring and evaluation of their efforts in order to make the most beneficial impact in the most efficient way.

Introduction

The Civil Association for the Conservation of the Peruvian Amazon Environment (CONAPAC) is a Peruvian non-governmental organization (NGO) that seeks to promote the conservation of the Amazon rainforest through education initiatives in communities along the Napo and Amazon Rivers in the Loreto region of Peru. CONAPAC's primary focus has been an Adopt-A-School program but has also undertaken a Clean Water program. The Clean Water program has provided 30 rural communities with potable drinking water education, community water treatment plants (WTPs), and support in operating these WTPs through operator training.

Collaboration between the University of Colorado, Boulder, and CONAPAC began four years ago as part of an NSF - International Research For Students (IRES) grant (IRES: Toward Sustainable Water And Sanitation Infrastructure" National Science Foundation OISE–1065050; Karl Linden, PI). Monitoring and evaluation of CONAPAC's Clean Water Program has been carried out annually in cooperation with undergraduates from the Universidad Nacional de la Amazonia Peruana (UNAP) in Iquitos, Peru. The collective research of the students provides CONAPAC with valuable feedback regarding their Clean Water Program as well as a crucial opportunity for cultural exchange at a personal, community, and professional level. The partnership was created to connect U.S. students with an international organization whose work would provide a challenging opportunity to investigate a multifaceted, socio-economic problem. The IRES grant has allowed students to hone their research and analytical skills, while providing CONAPAC with monitoring and evaluation that can be used to improve their Clean Water Program.

Objective

The objectives of the 2013 research study were to 1) assess the factors that influence the sustainability of water treatment interventions, 2) monitor and evaluate CONPAC's pilot study of a point-of-use (POU) filter, and 3) measure the effectiveness of an operator training program that was implemented by CONAPAC in 2013 to improve the water quality and sustainability of community WTPs. The results of the POU study are presented in a separate report.

Research Team

Five CU students, eight UNAP students, and one CONAPAC staff member visited 24 communities between July 22 and August 6, 2013. The UNAP students were divided into two groups, with one group of four participating the first week and another group participating the second week. The CU students offered a wide range of background knowledge including Environmental Engineering, Geography, and Environmental Studies.

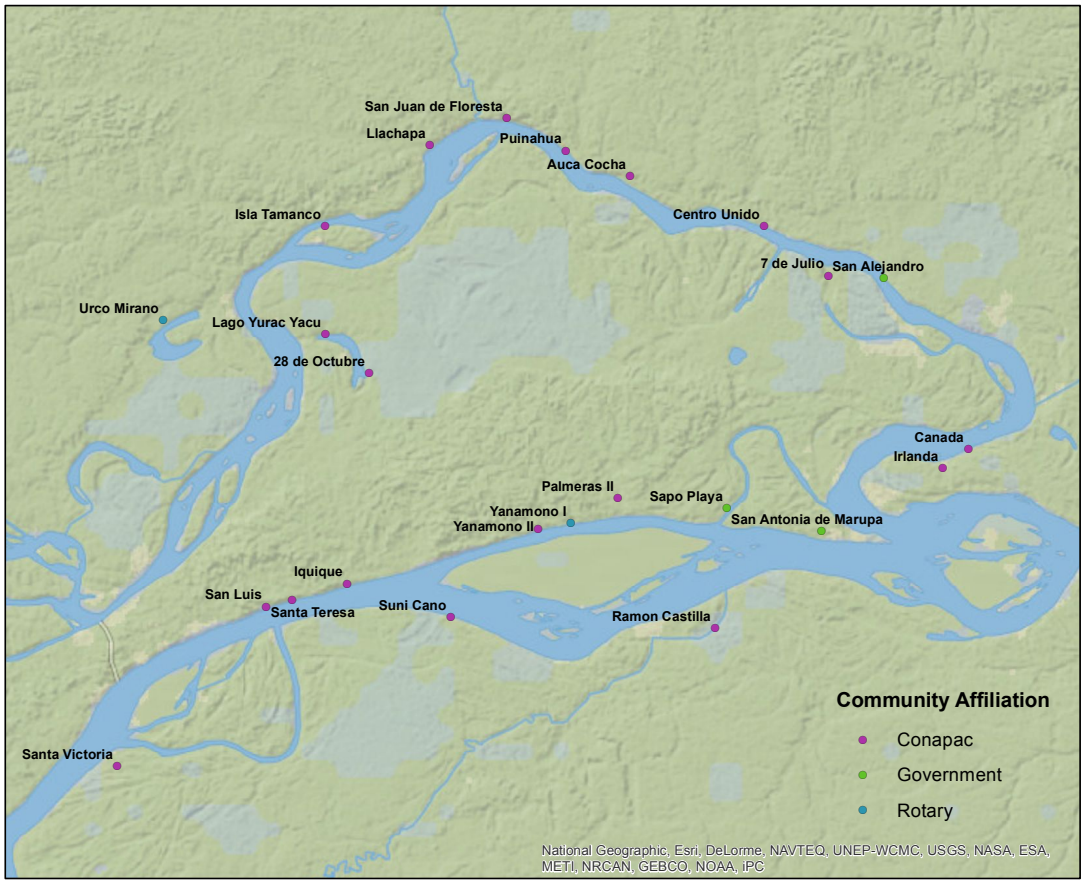

Figure 1 Aerial view of the CONAPAC, Municipality (Government) and Rotary International WTPs visited

Communities Visited

The communities visited were selected based on the input of CONAPAC staff, the logistics of travel on the river, previous monitoring, age of the intervention, and whether or not the intervention was functioning at the time of the visit. The communities were selected so as to have a representative sample of the varying water treatment options that exist in the communities of the area. A total of 16 CONPAC WTPs, 3 municipal WTPs, and 3 Rotary International (RI) WTPs were visited. An aerial view of the communities visited is displayed in Figure 1.

WTP Design

The WTP superstructure stands six meters in height and consists of three levels (**Figure 2**). The original WTPs constructed by CONAPAC were made of wood, while newer WTPs are constructed using concrete. The design is a batch treatment system and is gravity fed. Water is pumped from the source, usually a river or stream, to the first 1,000 L tank located on the top level of the WTP. A 5.5 hp motor and poly vinyl chloride (PVC) pipe are used to pump water from the source to the WTP. The treatment process consists of coagulation in the highest tank, followed by disinfection in a tank on the second level, and then filtration on the first level. The filtration

process includes four filters; gravel, sand, activated carbon, and a 50-micron membrane filter. Water is collected at the final tap by filling buckets, which are then carried to users' households for consumption.

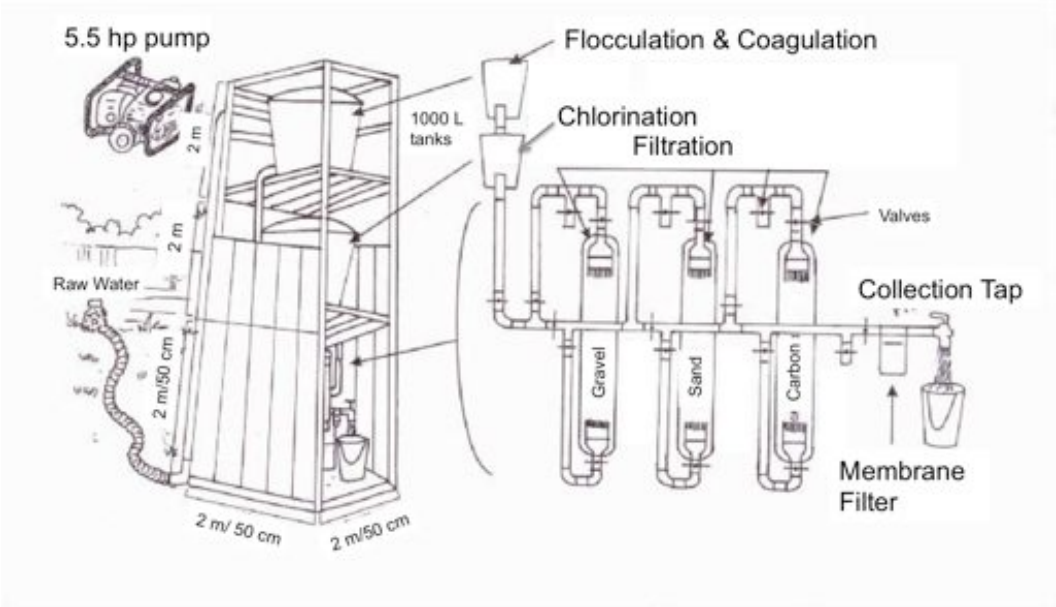

Figure 2 Schematic CONAPAC Water Treatment Plant

Research Methodology

Household Surveys

Randomly selected household surveys were conducted in all communities visited. The survey questions were developed to determine if identified factors such as community cohesion, community participation, community structure, user knowledge, distance, education, and age could be correlated to the long-term demand and use of community WTPs.

Prior to use in the field, the University of Colorado Institutional Review Board approved the household surveys. In addition, survey training was conducted prior to implementation in the field in order to avoid bias and satisficing. Every survey participant was informed of the contents of the survey and that the survey was voluntary, was asked to grant their permission before being interviewed, and was older than 18 years of age.

Our sampling methodology involved visiting every other house. A random sampling method was critical to guarantee that each house had the same likelihood of being surveyed. If a household was in the sampling plan but not interviewed for any reason, then the interviewer moved on to the house next door, which was not in the original sampling plan, for an interview. After this, the interview proceeded to the same houses that were in the initial sampling plan following that interview. The goal was to

interview between 30 and 50 percent of the households in every community. In small communities, the goal was to interview more than 50 percent of the community. Initially, students conducted surveys in groups of two. These groups were made up of one UNAP student and one CU student.

Operator Interviews & WTP Visits

Lia Brune, an environmental engineering graduate student at the University of Colorado, Boulder, conducted operator interviews in each of the communities visited. Lia spent four months living in the communities conducting one-on-one operator training during 2012, and used this training experience to develop an operator-training manual. CONAPAC used this manual to conduct three two-day workshops throughout CONAPAC communities during 2013. The workshop resulted in the certification of 35 operators and a more formalized water treatment process. The post operator training interviews consisted of qualitative and quantitative questions and visual observation of the water treatment process. Water quality testing was conducted in order to assess the effectiveness of the water treatment process.

Rubric

Table 1 Operator interview rubric developed to measure the effectiveness of the operator training

Score	Grade	Description
3	Excellent	• Fully understands purpose of pH adjustment, coagulation, and disinfection • Identifies and names which chemical corresponds to which treatment process; lime (pH adjustment), alum (coagulation), chlorine (disinfection) • Proper chemical addition (amount and location) • Correct water treatment process: proper mixing, settling time, contact time, backwash
2	Improved	• Rudimentary understanding of the purpose of pH adjustment, coagulation, and disinfection • Unable to identify and name which chemical corresponds to which treatment process; lime (pH adjustment), alum (coagulation), chlorine (disinfection) • Varied chemical addition (amount and location) • Difficulty with correct water treatment process: proper mixing, settling time, contact time, backwash
1	Insufficient	• No understanding of purpose of pH adjustment, coagulation, and disinfection • Unable to name the chemicals used or treatment processes • Improper chemical addition (amount and location) • Incorrect water treatment process

A rubric was created to measure the effectiveness of the operator training program; a subjective score of 0 to 3 based on knowledge of technical water treatment questions, observations made during the interview of the comfort level of the operator, and visual inspection of the WTP. A score of 3 is representative of an operator that demonstrates excellent understanding of the water treatment process, proper chemical dosing, and correct operation and maintenance practice. A score of 2 is indicative of a basic understanding that could be improved upon, and a score of 1 is

allotted for operators that lack an understanding of the purpose of chemicals, improper water treatment and operation, and maintenance (See Table 1).

Water Quality Testing

Test Methods

The Aquagenx Compartment Bag Test (CBT) was used to assess the presence and concentration of *E. coli*, an indicator organism for fecal contamination. The CBT consists of a bag with five compartments of varying volumes, with a total volume of 100 mL (**Figure 3**). The presence or absence of *E. coli* in each compartment is used to determine the probability that *E. coli* is present in the water sample and provides the most probable number (MPN). The CBT method was selected for microbial sampling in the field because it does not require refrigeration, is compact and light, and provides a quantitative most probable number rather than a qualitative presence/absence test.

Figure 3 Photograph of the compartment bag test in use in the field.

Turbidity was measured using a HACH2100P field turbidimeter at multiple points in the WTP. The turbidimeter was calibrated prior to going into the field and has a detection limit of 0.01 NTU. HACH 5-in-1 test strips were used to measure free and total chlorine at both the WTP and at random households.

Household Recontamination

Households that participated in the household survey were randomly selected to have their water storage bucket test for *E. coli*. Water quality was tested regardless of whether the household collected water from a treated or untreated source. This included raw river water, water treated at the point-of-use, or water collected from a WTP. Free and total chlorine was measured at the household level to test for residual chlorine.

Water Treatment Plant

During the operator-training interview, water samples were collected and tested for *E. coli*, pH, turbidity, alkalinity, and free and total chlorine. The sampling sites within the WTP are circled in red in Figure 4. Sample site 2 collects water that has gone through disinfection in the second tank and is about to pass through the filters. Sample site 5 is located at the final collection tap.

GPS

Geographic positioning system (GPS) units were used in the field to accurately represent the distance between households and drinking water sources. All of the houses in a community that the research team could reach by foot or boat in a

reasonable amount of time were mapped, not only the houses that were randomly selected for an interview. The goal of mapping out the communities was to aid CONAPAC in its decision-making regarding which of the communities are good candidates for WTPs and which are more appropriately suited for a POU system. Community dispersion and topography are large considerations when deciding on an appropriate water treatment technology and its location.

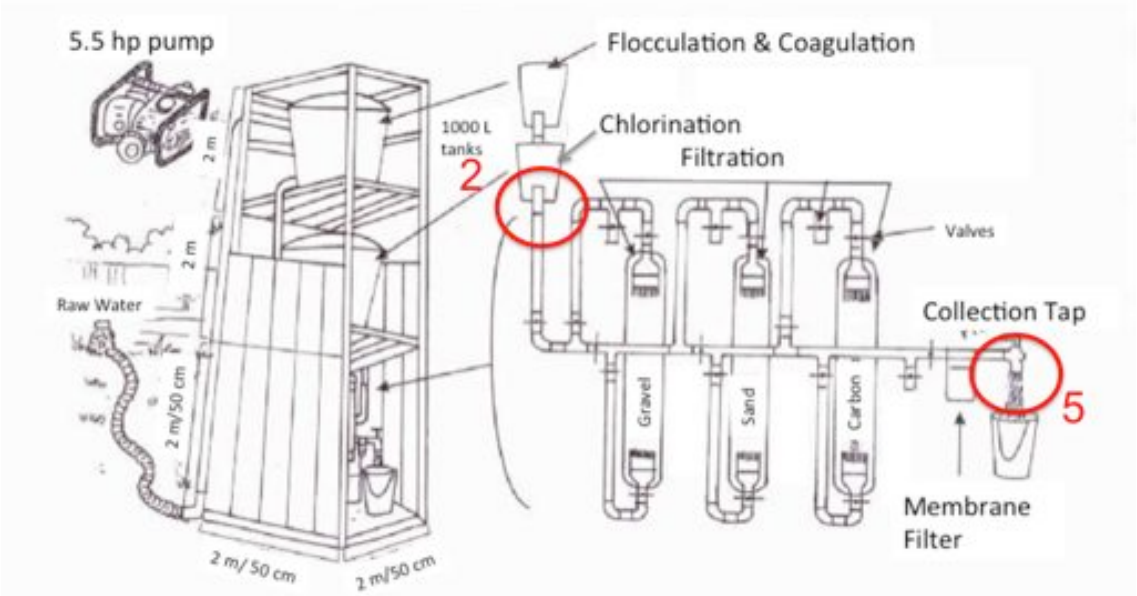

Figure 4 Sampling sites within the water treatment plant

Household Survey Results

A total of 286 randomized household surveys were conducted in 21 communities. A full list of the communities surveyed is listed in Table 2. Community summaries, including anecdotal findings, are presented in Appendix B. The following survey data analysis is based on survey responses from households in communities with WTPs constructed by CONAPAC. Anecdotal evidence of the WTPs built by the municipality and RI is discussed in a later section.

Satisfaction

Of 194 respondents in communities with a CONAPAC WTP, 39 percent reported being 'very satisfied' and 54 percent reported being 'satisfied' with their community WTP, a combined total 93 percent. Two of the 16 WTPs were not functioning at the

time of the visit: Suni Caño, and Lago Yurac Yacu. See the summaries of communities in Appendix C for further explanations of the general state of each WTP.

Table 2 Summary data of the communities visited and household surveys. State of the Plant: 0 = Not functioning; 1 = WTP functional, but inadequate; 2 = WTP functional & adequate, * When WTP is functional

Community	Plant Constructed by	Number of Surveys	Percent of Community Households Surveyed	State of the plant (0,1,2)	Reported Usage Rate (%)
Suni Cano	CONAPAC	9	50	0	86*
Lago Yurac Yacu	CONAPAC	16	31	0	50*
Llachapa	CONAPAC	22	45	1	75
Ramon Castilla	CONAPAC	7	25	1	75
Santa Teresa	CONAPAC	21	29	1	17
Auca Cocha	CONAPAC	8	40	1	75
Centro Unido	CONAPAC	16	53	1	93
Canada	CONAPAC	6	24	1	80
Irlanda	CONAPAC	12	33	2	100
Isla Tamanco	CONAPAC	16	38	2	68
San Juan de Floresta	CONAPAC	8	33	2	80
Puinauhua	CONAPAC	17	36	2	76
Yanamono II	CONAPAC	11	28	2	100
Santa Victoria	CONAPAC	11	61	2	80
San Luis	CONAPAC	19	48	2	95
Palmeras II	CONAPAC & RI	17	33	1	90
San Alejandro	GOV.	12	26	0	59*
San Antonio de Marupa	MUN.	7	32	0	NA
Sapo Playa	MUN.	14	33	0	63*
Urco Mirano	RI	23	28	0	50*
Yanamono I	RI	12	40	2	89

WTP Use

The self-reported number of CONAPAC WTP users, 85 percent, is similar to rates reported in previous years. Reported use by community ranged between 50 and 100 percent. The one outlying community, Santa Teresa, reported use at 17 percent.

WTP users were asked two questions in the survey to determine their level of use. 'Consistent users' only consume water from the WTP, while 'inconsistent users' consume water from the WTP and from other sources, i.e. raw river water or rainwater. The first question asked households how many times a week they consumed water from the river, rainwater, or the WTP. A second question, placed later in the survey asked households how frequently they consume water from the WTP: always, sometimes, or never. Seventy-three percent of respondents with functioning WTPs responded that they always drink water from the WTP. When participants who responded that they drink water from other sources and also responded that they always drink water from the WTP are removed, the percentage of users drinking

exclusively from WTPs, i.e**. 'consistent' users, dropped to 60 percent. The users that are collecting drinking water from a CONAPAC WTP and another source, such as a river, are not receiving the benefit of consuming drinking water that has been treated.**

Of all the reported users, both consistent and inconsistent users of the CONAPAC and RI WTPs, 67 percent collect water between one and four times per week and 22 percent collect water every day. This data suggests that most households are storing their water for at least two days, thus increasing the likelihood of re-contaminating the treated drinking water.

Willingness to Pay

Residents demonstrate a high willingness to pay for treated water. Approximately 95 percent of users are satisfied with the cost of water. **Fifty-five percent responded that the cost of water is acceptable and 40 percent responded that the cost of water is cheap.** When asked if the monthly payments for water are sufficient to cover the costs of gasoline and chemicals, 64 percent responded that the payment is sufficient to cover the cost and 32 percent responded that the payment is not sufficient to cover costs. Respondents seemed less confident in their responses when addressing the replacement of parts. **When asked if the monthly payments for water are sufficient to cover the costs of parts for repair, 66 percent responded that they are not sufficient while only 33 percent responded that the monthly payment is sufficient**. Consistent with the belief that the amount they are paying is not adequate to cover repair expenses; most respondents expressed a willingness to pay a higher monthly fee. **Approximately 64 percent of users would be willing to pay between S/. 1 and S/.5 more for water each month, while 20 percent would be willing to pay between S/.6 and S/.10 more for water per month.** These amounts are in addition to what users already pay. Three respondents, 2 percent, said they could not afford to pay any more, and 20 declined to answer or responded that they did not know. When asked if each household would be willing to contribute a one-time payment of S/. 60 for a new pump, were the existing pump to break, residents appeared hesitant. Thirty-nine percent of users would be willing to pay a one-time payment of S/. 60 for a new pump and 53 percent of users would not be willing to pay. Whether hesitance to contribute a large one-time fee is due to ability or willingness is not known, but smaller monthly payments present a more attractive option for residents. Table 3 summarizes the survey findings.

Table 3 Household survey responses to questions of water payment and preferences of payment

Are sufficient funds collected for:			**Are users willing to pay:**		
	Yes	**No**		**Yes**	**No**
Chemicals & Gas	64%	32%	**An increased monthly fee**	88%	2%
Repairs & Expensive Parts	33%	66%	**A one-time fee of S/. 60 for a new pump**	39%	53%

Community Cohesion

Community cohesion in CONAPAC communities appears to be particularly high. **Twenty-four percent of survey participants from communities with a WTP constructed by CONAPAC responded that the WTP plant belonged to CONAPAC, while 63 percent said that the WTP belonged to the community.** The survey data indicates a sense of ownership and community identity, both of which can indicate community cohesion. In addition, the vast majority of respondents, 92 percent, responded that they either always or almost always attend their monthly community meeting. The majority of exceptions were the elderly.

Another indicator of strong community organization and cohesion is the ability to cope with challenges. In the communities visited, the challenges are high and low water levels. **Overall, the WTPs in 12 of 16 communities, 75 percent, were not functional at some point during the last year.** Approximately 61 percent of residents responded that their community had the capacity to repair their WTP when needed while 32 percent responded that their community did not have the capacity.

In communities where the WTP is currently functioning, 90 percent of respondents stated that the WTP is always or almost always discussed at monthly community meetings. In communities that do not have functioning WTPs, only 76 percent of respondents stated that the WTP is always or almost always discussed at monthly community meetings. Respondents who replied that the WTP is not ever discussed at community meetings tend to live in communities with currently non-functioning WTPs, Lago Yurac Yacu and Urco Mirano, or where only a few households located close to the WTP are users as is the case in Santa Teresa.

When users from functioning and nonfunctioning WTPs were asked who they would talk to about issues with water, such as cloudiness or bad taste and odor, respondents from communities with functioning WTPs responded as follows: 43 percent would speak with an operator; 30 percent would speak with the water committee; and 12 percent would speak with the community during the monthly meeting. For residents of communities without functioning WTPs, 30 percent of respondents would speak with the water committee, 26 percent would talk to the community leader, 15 percent would talk to the operator, and 15 percent would speak with the community during the monthly meeting. It is of note that the community leader appears to be more important in communities that do not have functioning WTPs, while only 2 percent of respondents would approach a community leader in areas where WTPs are functioning. Whether or not the WTP was functioning had an effect on respondents' belief that whomever they chose to speak with about water issues would change something. Belief that action would be taken to repair WTPs was 85 percent and 79 percent for functioning and non-functioning WTPs, respectively. Despite the decrease

in communities with non-functioning WTPs, there remains a high belief that communities can repair their WTPs through communication with community leaders.

Distance

Interestingly, **85 percent of the 148 respondents surveyed who live less than a 15-minute walk from the WTP reported being 'consistent users' of the WTPs. The number of 'consistent users' decreased to 41 percent for respondents who live at a walking distance from the WTP that is greater than 15 minutes.** This data correlates with 60 percent of respondents who are non-users of the WTPs that cite distance as their primary reason for not collecting water. Researchers observed that obstacles such as streams and hilly terrain are detractors to water collection. In communities where terrain is not flat and dry and distance between households and the WTP is great, POU water treatment may be an alternative with higher uptake among users.

Education

Anecdotally, researchers noted during interviews that many respondents believe that the quality of education has improved in recent years. Younger survey respondents seemed to have an enhanced knowledge regarding the importance of clean drinking water. Many elderly residents mentioned that they had attended school, but that their education did not compare to the education that the younger generation is receiving today. **Figure 5** demonstrates the trend between age and education in the communities surveyed that have a relationship with CONAPAC. In general, the younger a respondent, the more years of school they have attended. It was also noticed that education was a priority for many parents, who mentioned education as a potential reason for leaving their community in the future.

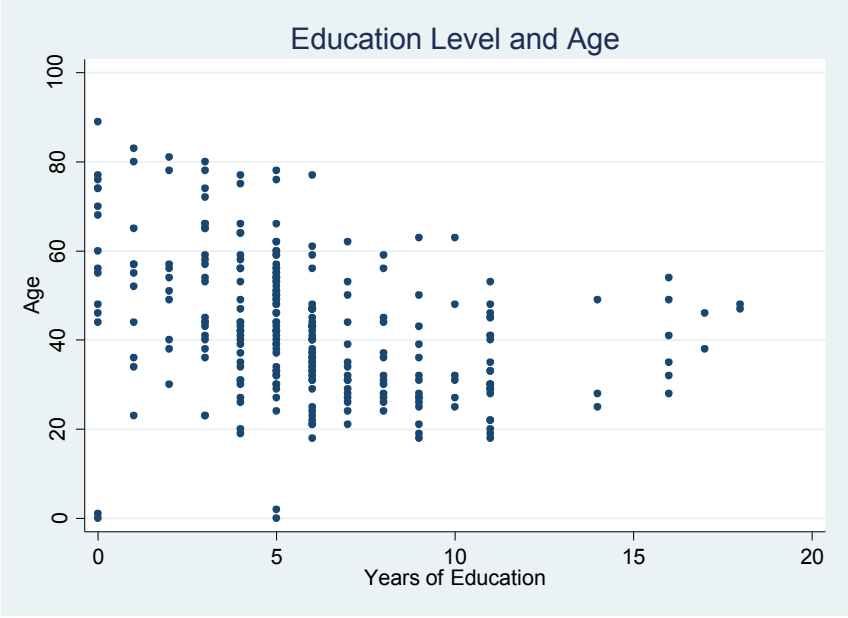

Figure 5 Correlation of age and level of education among interview respondents

Operator Interview Results

A summary of each operator interview conducted in the 17 communities visited that partner with CONAPAC is provided in Appendix C and an overview of the status of the WTPs is provided in the following sections.

Table 4 - Number of households in communities visited, as reported by operators and CONAPAC, and percent of community that is collecting water from the CONAPAC WTP

Community	Operator Interview No Households	CONAPAC No Household	Percent Change in No Households	Percent of community using WTP
Santa Victoria	18	39	-54	83
Lago Yurac Yacu	52	49	6	29
Llachapa	49	56	-13	37
Isla Tamanco	42	55	-24	57
San Juan de Floresta	24	25	-4	83
Puinauhua	47	37	27	64
Auca Cocha	20	17	18	65
Centro Unido	30	35	-14	93
Canada	25	23	9	100
Irlanda	36	34	6	86
Ramon Castilla	28	48	-42	50
Yanamono II	40	31	29	50
Palmeras II	52	35	49	29
Suni Caño	20	25	-20	90
San Luis	40	52	-23	88
Iquique	50	48	4	52
Santa Teresa	73	10	>100	5

Population

The total number of households in each community was provided to the research team by CONAPAC. This data was used to determine the minimum number of households within a community to visit in order to collect a representative sample of the community. The operator interview provided data on the number of households in the community and these numbers were found to vary from those numbers provided by CONAPAC. **Table 4 - Number of households in communities visited, as reported by operators and CONAPAC, and percent of community that is collecting water from the CONAPAC WTP**provides both the household numbers provided by CONAPAC and the operators as well as the percent difference between the two. **There is a large difference between the community size reported by an operator and that reported by CONAPAC.** Only two communities were found to remain relatively stable in size, San Juan de Floresta and Canada. Both of these communities are located on the Napo River and are further away from Iquitos. The variation in community household number data between operators and CONAPAC is evidence of fluctuation in community size due to factors such as river flooding, location of crops, ties to family, and proximity to markets in Iquitos. Community size also varies annually, during high and low river seasons. These

factors must be considered when deciding which water treatment option is appropriate in a particular community.

Community use

Operators were asked how many households are in the community and how many households collect water from the WTP. **Table 4** shows the operator reported percentage of each community that is collecting water from each CONAPAC WTP. It should be noted that the use reported by the operator may not always be representative of the actual use within a community. This was the case in the community of Canada, where the operators stated that all households collect water from the WTP meanwhile household interviews revealed this was not the case.

Year-Round Treatment

Of the 17 CONAPAC WTP operators interviewed, six reported that they cannot treat water year-round, and are offline for an average of three to six months. These communities that report not treating water year-round, Santa Victoria, Lago Yurac Yacu, Auca Cocha, Canada, Suni Caño, and Santa Teresa, are located in various locations along the rivers and have neighboring communities that experience the same high and low river flow conditions and are able to treat water year-round. It is expected that the actual number of communities that do not treat water year-round is higher than the number reported due to satisficing during the operator interviews. It is worth noting that **both the flooding of the WTPs during the high water season and the lack of pipes to pump water during the dry season are factors that contribute to the WTPs not functioning year-round.** The factors contributing to the success or failure of a WTP functioning year-round appear to be linked to community dynamics and the organization of the WTP management structure but are not well understood.

WTP Management Structure

All of the communities visited, except for Irlanda and Iquique, have a water committee to oversee the WTP and most have women represented in their committee as either a secretary or speaker. Both Irlanda and Iquique have experienced difficulty in their WTP management; see community summaries for more detail. WTP operators tend to hold a position within the water committee, usually president or vice president, although some communities have elected to have the position of operator separate from the water committee positions. The number of water committee members varies from three to seven members, including operators and usually two speakers. Most operators are male, although Puinahua and Iquique have female operators. However, both situations arose due to a lack of male interest in becoming an operator. Ten of the communities visited have not established a formal method of paying WTP operators. Some informal payment methods include allowing operators to collect drinking water free of charge or receiving help from the community in tending to the operators farmland. Of the ten communities that do not formally pay the WTP

operators, it is not uncommon that these operators do not wish to be paid. However, in other instances they do want to be paid but the community is not willing. The payment structure in the communities that do pay operators varies. Some communities pay a set amount to the operator per month, 15 to 40 soles; other operators receive one sol per household that collects water from the WTP. Water treatment continues to be rotated in communities, but now rotates between designated operators instead of households. The number of operators in a community varies from one to four. All of these factors appear to contribute to the long-term operation of these community WTPs although it is difficult to discern which sole factor is responsible for creating a resilient WTP that can treat water year-round. Two WTPs were not functioning during the time of visit, Lago Yurac Yacu and Suni Caño.

Operator Training

Of the 17 communities visited, operators from all but Santa Victoria attended the two-day operator training provided by CONAPAC in the beginning of 2013. Each community was invited to send two operators for training and all communities sent two operators, except for Centro Unido and Canada, which only sent one operator for training. It is worth noting that neither of the operators from these two communities that attended the CONAPAC operator training passed the examination in order to receive their official certification.

Table 5 Operator interview score and operator training data from each community visited

Community	Operator Score	Attended OT?	Passed OT Exam?	Operator Age
Santa Victoria	2	N	n/a	23
Lago Yurac Yacu	2	Y	1 Y, 1 N	45-55
Llachapa	2	Y	Y	34, 47
Isla Tamanco	1	1 Y, 1 N	1 Y, 1 N	43, 42
San Juan de Floresta	3	Y	Y	58, 39
Puinauhua	2	Y	Y	43
Auca Cocha	2.5	Y	Y	40
Centro Unido	1	N	n/a	40
Canada	1.5	Y	N	58
Irlanda	3	Y	Y	29
Ramon Castilla	2	Y	N	30
Yanamono II	3	Y	Y	22
Palmeras II	1	N	n/a	37
Suni Caño	1	Y	N	36
San Luis	3	Y	Y	27
Iquique	2.5	Y	Y	35
Santa Teresa	0.5	N	n/a	63

Table 5 provides the interviewed operator's score, whether they attended CONAPAC operator training, whether they passed the examination and received their certificate, and age. **Of the 17 out of 32 CONAPAC WTP operators interviewed, 24 percent scored**

a 3, suggesting excellent operator understanding, 41 percent scored a 2, suggesting an improved operator understanding, and 35 percent scored less than a 2, suggesting insufficient operator understanding. Recall that the WTPs visited were selected as a representative sample of all 32 CONAPAC WTPs, thus ideally the results of the operator interview should be able to scale. Therefore, suggesting that approximately 8, 13, and 11 WTP operators have an understanding of excellent, improved, and insufficient, respectively.

Highest scoring communities

The communities of San Juan de Floresta, Irlanda, Yanamono II and San Luis demonstrated the highest level of understanding of the water treatment process, passing the CONAPAC operator training, and receiving a score of 3 during the follow up operator interview. Both Irlanda and Yanamono II have operators that are young, 22 and 29, respectively. Anecdotally it was found that younger operators have a higher level of understanding of the water treatment process although no direct correlation was found between operator education level, age, and level of understanding.

In the case of San Juan de Floresta, the reason for the excellent understanding of the water treatment process is due to the two operators of this community, inquisitive engineers at heart, who have taken an interest in water treatment. In the case of Irlanda, the young operator of the WTP has taken a business approach to providing water for his community and is therefore interested in ensuring that the water he provides is of good quality. This reasoning and age explains his excellent understanding of water treatment. In the case of Yanamono II, the operator is highly educated, young, and the son of the WTP treasurer. These factors emphasize the importance of the operator's position in his community. The three unique factors of these communities have led to an operator with great understanding of the water treatment process. In the case of San Luis, support from a senior water treatment operator with excellent operator understanding is the most likely reason for the excellent understanding of younger operators. Each of these four communities, San Luis, San Juan de Floresta, Irlanda, and Yanamono II are harnessing **unique factors that encourage proper water treatment; mentorship, leadership, business, and age/education**.

Correlations

It was found that **the score an operator received when taking the CONAPAC operator training examination does not always correlate with the score received during the follow up operator interview**. This is largely evident in the community of Isla Tamanco, in which an operator received a score of 17, out of 20, on the operator training exam and a score of 1 during the operator interview. In contrast to this, the operators that received a score of 3 during the follow up interview all passed the CONAPAC operator training exam, but received varying scores on the exam. The

operator in San Luis received an exam score of 12, the minimum score to pass the examination, and received a score of 3 during the follow up interview, demonstrating excellent understanding of the water treatment process. The variation in correlation between the operator training exam score and follow up interview score suggest that the examination score is not a sufficient indicator of operator understanding and highlights the importance of the follow up interview.

Training Material

There was large variation in which aspect of the water treatment process operators struggled with. The summary notes and raw data files can be referenced when looking for the specific factors an operator in a community struggled with. Overall, operators that did not score a 3 during the follow up interview are lacking an understanding of the material outlined in the rubric of Table 2. **When asked if there were topics on which operators would like more instruction, eight operators replied yes and mentioned topics such as how to improve sedimentation, how to use the pH test kit, proper chemical doses, and most commonly, how to backwash and repair filters.**

Long-term Operation

Based on conversations and observations during visits with operators, **WTPs in these communities do not appear able to function long term without the continued monitoring and evaluation and support of CONAPAC. This was found in communities with strong leadership and qualified operators as well as those without. Reasons for the lack of sustainability appear to be due to, in large part, a lack of savings for future repairs and a lack of knowledge of how to repair the WTP filters**. When asked during the follow up interview if the monthly revenue received from water users is enough to purchase replacement tubes when needed, 41 percent responded never, 29 percent responded sometimes, and 12 percent responded always. Out of the 11 operators explicitly asked if their community has a savings plans, five responded yes and were able to quantify the amount, with a savings span from as little as 20 soles to as high as 400 soles, and three operators responded yes but were unable to quantify the amount. Three operators stated that there are no savings. These results suggest that operators are aware of the need to have savings, but not all communities are able to save.

Water Quality Results

Household recontamination

A total of 68 households had their water sampled for *E. coli* and 46 households had their water sampled for free and total chlorine, regardless of their water source. Of these water samples, 49 percent were positive for *E. coli*. **37 samples were from households that collected water from a CONAPAC WTP and of these samples 30 percent were positive for *E. coli*.** Table 5 presents the percentage of the total samples

collected that tested positive for *E. coli* in each community with a CONAPAC WTP. Table 5 only considers samples collected from households that collect water from a CONAPAC WTP. It is interesting to note that four of the eight communities visited had no households with water samples found positive for *E. coli*, although it is not understood why this distinction occurs. A total of 38 samples were collected from households that collected water directly from the source, a river or creek, and all samples except for one tested positive for *E. coli*. Based on the *E. coli* data, the water collected from a CONAPAC WTP is more likely to contain fewer microbial pathogens when compared to raw water used for consumption. **All WTPs sampled tested negative for *E. coli* meanwhile 30 percent of household water samples tested positive for *E. coli* suggesting that recontamination is occurring and that behavior change is the limiting factor in achieving consumption of safe drinking water and the full benefit of the investments made into the water treatment process and operator training program.**

Table 6 Percent of household water samples that tested positive for *E. coli*, based on community

Community	Percent of samples positive for *E. coli*
Canada	90
Centro Unido	50
Irlanda	20
Isla Tamanco	0
Llachapa	0
Puinahua	0
Ramon Castilla	70
San Juan de Floresta	0

Free and total chlorine was measured in 42 households with water collected from a CONAPAC WTP. A total of three samples had a measureable free chlorine concentration, which was found to be due to the water sampled being collected within three hours prior to the sampling. The water treatment process of a CONAPAC WTP consists of a carbon filter that is designed to remove carbon due to the cultural distaste for chlorine. **The presence of a chlorine residual in the three household water samples that tested positive, are indicative of a spent carbon filter, bypassed carbon filter, or overdosing of chlorine, all of which are issues that are need to be addressed in order to properly treat water.** While the WTP design aims to remove chlorine, the presence of a chlorine residual in collected water provides a continuing barrier to recontamination due to improper handling and storage of collected water.

Water Treatment Plant

WTP water quality data are shown in Table 7 with elevated results shown in red text. **All WTPs tested negative for *E. coli* at the final collection tap, sample site 5, except for the community of Suni Caño.** The difficulties observed in Suni Caño community are

discussed in the community summary in Appendix C and appear to be due to improper water treatment. It is not possible to determine whether increased turbidity results or the presence of chlorine at sample site 5 are due to operator treatment error or faulty filters. A measurable free chlorine concentration at the final collection tap, sample site 5, does not correspond to good or bad water treatment, due to the carbon filter located before the final tap in order to remove chlorine. Rather, the presence of chlorine at the final tap is indicative of a faulty carbon filter or a bypassed carbon filter. While the presence of chlorine at the final collection tap acts to continually disinfect water, users dislike the taste of chlorine. Based on field observations of filter performance, turbidity values at the collection tap should be below 1 NTU, as is found in a majority of the WTPs. The highest turbidity values were measured in the communities of Puinahua, Auca Cocha, and Canada. The explanations for these findings are case specific and are discussed in the community summaries. For example the community of Auca Cocha collects water from a spring fed source, which has different water quality parameters, and thus the operators need training on how to treat their specific water, which requires different chemical additions than those operators that treat water from the Amazon and Napo Rivers.

Table 7 Water quality results from all WTPs visited

Community	*E. coli* (MPN/100 mL)		Turbidity (NTU)		Total Chlorine (mg/L)		Free Chlorine (mg/L)	
Sample Site:	2	5	2	5	2	5	2	5
Santa Victoria	-	-	-	-	-	-	-	-
Lago Yurac Yacu	-	-	-	-	-	-	-	-
Llachapa	0	0	13.6	0.66	4	3	4	1
Isla Tamanco	0	0	1.47	0.62	0	0	0	0
San Juan de Floresta	0	0	1.37	0.34	4-10	0	4-10	0
Puinauhua	0	0	8.32	2.16	-	-	-	-
Auca Cocha	0	0	9.32	1.67	2-4	0	2-4	0
Centro Unido	0	0	3.63	0.6	4-10	2	4-10	2
Canada	0	0	5.71	2.51	0	0	0	0
Irlanda	0	0	3.13	0.32	4	0	4	0
Ramon Castilla	0	0	3.19	0.31	0.5	0	0	0
Yanamono II	0	0	0.74	0.28	2	2	1	2
Palmeras II	4.7	0	8.23	0.94	0.5	0	0	0
Suni Caño	-	1.5	1.3	1.47	-	-	-	-
San Luis	0	0	1.11	0.58	4	2	4	2
Iquique	0	0	2.98	2.9	2	1	1	0.5
Santa Teresa	9.6	0	4.35	1.32	0	0	0	0

Community WTP versus POU

The strong sense of community that is present in some of the communities visited allows for the centralized WTP model to function well. When evaluating the best water treatment option in the rural communities that CONAPAC works with, centralized

WTP's appear to be a feasible option in dense communities where households are centrally located meanwhile a POU option appears to be more feasible in communities that are dispersed and households are distant from a community center. A caveat is that communities that are denser may continue to experience times throughout the year, up to half of the year, without access to water from a centralized WTP. During this time period there is either the need for an alternative treatment option at the household or the WTP should be managed in a way that allows for water to be treated throughout the year without interruption. A large investment has already been made by donors to construct WTPs and train operators on how to treat water and maintain the WTP. Economically in communities with CONAPAC WTPs, it appears to be more beneficial to invest in ensuring that WTPs remain operational year-round rather than to provide an alternative POU treatment option that requires the creation of a new supply chain, training of all households, promotion of behavior change, and most likely ongoing maintenance. If achieving a fully functional WTP year-round is not an option, a POU option may be necessary during the time period a WTP is offline.

The addition of a POU treatment option to a community with a CONAPAC WTP may result in a drop off of use of the WTP, especially due to the attractiveness to users of not having to haul water from the WTP to the household. A decrease in the number of WTP users will decrease the amount of revenue earned, which is required to maintain the WTP over time. The economy of scale of a large user base allows operators to have the revenue needed to make larger purchases such as pipes, valves, and pump.

The water quality results show that users that collect from a CONAPAC WTP have high rates of recontamination and the POU water quality results show that there are high levels of contamination, which is largely due to the water being stored in a bucket for a period of days. The water that is treated with the Sawyer filter, the current POU pilot study, is stored due to the very low flow rates of the filter. Were the filter flow rate more rapid, users could truly treat their water at the point of use, thus eliminating the need for storage and the increased risk of recontamination. Essentially both treatment options considered, a centralized WTP and a low flow-rate filter, are weakened due to the lack of a secondary barrier to microbial contamination, i.e. there is no residual disinfectant, such as chlorine. Encouraging users of both systems to add chlorine to their household storage buckets would result in decreased risk of contamination. The POU report discusses this in more detail.

Non-CONAPAC Water Treatment Programs

Rotary International

Three communities with WTPs constructed by RI were visited: Urco Miraño, Yanamono I, and Palmeras I, and each of the WTPs had a design not found in the other WTPs visited.

The Urco Miraño WTP appeared to have been out of use for many years and no consistent narrative emerged regarding when the WTP had been constructed or for how long it had functioned. The WTP was a collaboration between RI and Water Missions International. Two 1000-liter tanks receive the influent water and the design incorporates three filters followed by alum and chlorine addition. The design appeared to be too advanced to be managed by the community, parts could not be replaced locally, and the instruction manual inside the WTP was in English.

The Yanamono I and Palmeras II WTPs were functional at the time of the visit. The Yanamono I WTP operator attended the CONAPAC operator training, even though the RI WTP design is different from the CONAPAC WTP design. The operator for the RI WTP in Palmeras II works closely with the operator of the CONAPAC WTP located in the same community, who attended the operator training. The operator of the RI WTP in Yanamono I appeared to have a good understanding of the WTP, however, water is only treated and available for collection every fifteen days, often leaving the community without water. Interestingly, the operator in Yanamono I raised the final collection tap during flood season to keep the WTP online, suggesting a bit of ingenuity. In the case of Palmeras II, the operator seems to lack basic understanding of water treatment processes.

Municipal Systems

Three communities with WPTs constructed by the municipal government were visited; San Antonio de Marupa, San Alejandro, and Sapo Playa. For various reasons, none of the three WTPs are working, nor did any of them function for a substantial period of time. Community members had little if any part in the construction or maintenance of these WTPs, such as volunteering to help with construction or by contributing financially, as is required by CONAPAC in order for a community to receive a WTP. Furthermore, no training of the importance of clean water occurred in these communities nor did the government work with the community to establish a sufficient governance structure. In the instance of Sapo Playa, it appears that the WTP only required gasoline to function, but the community was divided in who should pay and how much and no operator had yet been trained. Anecdotally, there did not appear to be an incentive to bring the WTP online. The WTP in San Antonio de Marupa has not functioned since its construction.

CONAPAC model versus other models

Relative to the municipal and RI WTPs visited by the research team, CONPAC WTPs appear to be more sustainable, based on the fact that they are in operation for a longer period of time than the other WTPs. CONAPAC's model of requiring community buy-in and cooperation and their continued active presence in each community to support the community in managing their WTP is a large reason for the continued use and operation of the WTPs. Training and support of a governance structure has also

been a key to CONAPAC's success, consistent with the best practices in the rural water sector. CONAPAC's design of the WTP also allows for local replacement of parts, something that has plagued one of the RI WTP in Urco Miraño.

Recommendations

Operator Training

Based on observations in the field of operator turnover and a lack of understanding of material by certified operators, an annual operator training is recommended. A one-time operator training program does not appear to guarantee that operators are able to properly treat water.

A component of the operator training program that needs to be emphasized is the designation of an official operator and their responsibility to not only properly treat water but also to train future operators. There appears to continue to be multiple operators in communities, and finger pointing in regards to responsibility for water treatment. Aside from technical aspects of treating water, the need for operator compensation, be it pecuniary or not, and increasing the cost of water in order to create a savings fund are needed to ensure the long-term operation of the WTPs. Operators of a WTP that is constructed of wood are concerned about how to raise funds to rebuild the WTP with a concrete superstructure. The operator training should work specifically with operators of these communities to address this issue and aid in creating a solution.

Proper back washing of filters and proper valve configuration during water treatment and backwash should be emphasized during the operator training. The filter design appears to continually cause problems, such as leaking of filter media and the failure of the carbon filter to remove chlorine, even when backwashing is done correctly. Operators should be encouraged to contact CONAPAC by phone in the event that filter problems continue, only after the operator has exhausted all known repair options, backwashing and repair of broken valves. At this point CONAPAC can discuss with operators next steps, such as a visit by CONAPAC staff to the community to ensure that the filter is indeed in need of replacement, how the funds will be raised to pay for the replacement, and the date of the filter replacement.

Year-round provision of drinking water must be emphasized during operator training. Special attention should be given during training to the difficulties in treating water during high and low water level periods. These difficulties include purchasing pipe, connecting pipe, and increasing the level of the collection tap.

Education Initiative

Recontamination of water collected from the WTP appears to be a limiting factor to providing safe potable drinking water. In order to tackle this obstacle, CONAPAC is encouraged to push education of safe water storage and handling. Behavior change requires repeated messages and CONAPAC's ongoing relationship with the communities allows for a successful campaign. McKenzie-Mohr (2013) presents many avenues of promoting behavior change. Survey results show that there are many users that consume drinking water from a CONAPAC WTP and another source, such as a river. These 'inconsistent users' are not receiving the benefit of paying a monthly fee to consume treated water. Promotion of 'consistent use', of consuming drinking water only from a CONAPAC WTP, and education on why this is important will allow for more users to receive the benefit of paying for water that is treated.

Monitoring

The three years of monitoring and evaluation of CONPAC WTPs conducted by CU Boulder has resulted in improvements to the program on an annual basis. The first year of monitoring resulted in the adoption of color-coded valves to aid operators in proper valve configuration during water treatment and backwashing. The second year of monitoring resulted in the development of an operator training curriculum that resulted in the training and certification of 35 operators. The results of the third year are presented in this report. It is strongly encouraged that CONAPAC continue the annual monitoring and evaluation of their efforts in order to make the most beneficial impact in the most efficient way. A monitoring program the encompasses qualitative data collection, such as household surveys and operator interviews, coupled with quantitative data collection such as household and WTP water quality sampling, will provide CONAPAC with the robust data needed to continue to make informed decisions on how to best manage their water program.

CU Student Experience

Lia Brune

The opportunity to participate in applied water treatment research with a local in-country partner has proven to be a priceless once in a lifetime experience. From this experience I have grown my personal ability to conduct independent research as well as my professional ability to guide a team of researchers in the field. With these skills I seek to continue to work in the field of water treatment and look forward to more collaborative research studies that can contribute to furthering the field of water treatment processes in developing communities.

Ahn Lee

Working with CONAPAC was a priceless experience. The organization gave me a new appreciation for NGOs that have a committed and consistent presence in the

communities they serve. Their data-driven monitoring program should prove invaluable to the sustainability of their work and serve as a model for other NGOs in the region. As a researcher trained to be critical of certain development initiatives, CONAPAC struck me as a gem, with a vision for not only appropriate solutions in the present but also long-term self-sufficiency. As I finish my degree I look forward to returning to this kind of field work, working with communities to assess their needs and desires and evaluating ongoing efforts to meet such goals.

Elizabeth Travis

Participating in this research project has been a rewarding and enlightening experience. Having learned about the value of monitoring and evaluation in enhancing the sustainability of development projects, it was particularly interesting to see how this can be achieved firsthand. I am particularly pleased that I got to work with a local NGO that is actively involved in the communities they work with. I have learned invaluable things about the challenges and benefits of research conducted in the field.