Rural Water System Disinfection Pilot Project for Carabuela, Ecuador

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Abstract

Sustaining clean water supplies are vital to human health and well-being. It is for this reason that the UN included water supply infrastructure in their Millennium Goals for 2015. Water disinfection using chlorine experiences only a low level of acceptance in the rural sector of developing countries. Greater levels of understanding are needed to identify and resolve these problem issues. This pilot study was implemented to advance a better understanding of these issues.

This paper discusses the implementation and results of the Carabuela community water system chorine disinfection pilot project. The water system uses two automated diaphragm dosing pumps to provide measured amounts of liquid sodium hypochlorite to the water supply. The seven communities of Carabuela built and manage the water system supplying more than 500 homes. The water system receives water from a number of protected springs.

Vozandes Community Development designed the water system renovations and continues to provide limited follow-up support to Carabuela. Each home has either an outside water spigot or a house connection to the community water supply.

Ecuadorian government now requires rural communities to disinfect their water supply with chlorine. In spite of this, rural Ecuadorian communities rarely disinfect their water supply due to numerous cultural and technical factors. This pilot project was conducted to determine if these factors could be overcome by using automated chlorine dosing pumps to minimize and precisely control the chlorine levels while also providing reliable disinfection of the water. A serious incidence of water supply contamination with domestic wastewater in a neighboring community provided significant impetus to this pilot project.

The pilot study scope includes monitoring the public acceptance of the chlorine levels, and willingness to maintain the disinfection equipment. In addition the chlorine levels and occurrence of coliform in the water distribution system were periodically monitored. The pilot study was successful in dosing chlorine to disinfect the protected spring water used by the community for a number of months at levels low enough to minimize the taste and odor for public acceptance but adequate to eliminate coliform.

Background

The seven communities of Carabuela built and manage the water system which receives water from a number of springs and supplies water to about 500 homes. Vozandes Community Development designed the water system renovations and continues to provide limited follow-up support to Carabuela. Each home has either an outside water spigot or a house connection to the community water supply.

Carabuela is located on the Pan American Highway north of Otavalo, the capital city of Imbabura Province. Renovations of the water system began in 2008, and were completed by the community in 2010. Vozandes Community Development provided the design and construction supervision.

During the course of building the Carabuela water system, in April 2009, the neighboring community of Peguche water system, which furnishes water to about 800 homes, was contaminated by sewage for a brief period of time causing numerous cases of intestinal infection. At least 50 people were hospitalized and the unofficial estimates of sickness range as high as 1200.

Sewage apparently entered the Peguche water system through breather pipes open to the environment and ground level access hatch openings to the spring. Both Peguche and Carabuela are peri-urban communities relatively close to Otavalo, the provincial capital. In each of these communities, the springs are relatively close to homes and thus have a certain level of contamination risk. Carabuela minimized these risks during the most recent renovations and rebuilding of their water system. This was done by covering all spring collectors with earth and sealing off all access points to their springs. None the less, the additional measure of chlorine disinfect was recommended to Carabuela to provide a higher level of defense. Ecuadorian government health authorities have also requested that Carabuela disinfect their water supply using chlorine.

Rural Ecuadorian communities rarely disinfect their water supply due to a number of cultural and technical factors. The litmus test for acceptable drinking water by rural Ecuadorians is taste. Chlorinated water with a chemical taste is routinely rejected or avoided by the rural population with the result that either the chlorine disinfection is not sustained or people turn to the use of less secure water sources for domestic consumption.

It is our observation that the following factors contribute to the fact that chlorine disinfection is rarely implemented by rural Ecuadorian communities;

- Absence of adequate water purity or treatment to minimize chlorination by-products and the taste and odors which the byproducts impart.
- Lack of accurate water test equipment to measure chlorine residual level.
- Lack of accurate consistent chlorine dosing methods and equipment to precisely add the correct amount of chlorine continuously and reliably.
- The additional cost of chlorine and chlorination equipment.
- Lack of perceived health benefits.

Pilot Project Design

This pilot project was conducted to determine if these factors could be overcome by using automated chlorine dosing pumps to minimize and precisely control the chlorine levels while also providing reliable disinfection of the water. The serious incidence of water supply contamination in the neighboring community of Peguche provided added impetus to this pilot project.

The pilot study scope includes limited monitoring the public acceptance of the chlorine levels, and willingness to maintain the disinfection equipment. In addition the chlorine levels and occurrence of coliform in the water distribution system were monitored. A key element in the project design is the use of protected springs as the water supply. This assures that the water is relatively free of organic material to minimize taste and odor issues.

Equipment Information

The Carabuela water system uses two automated *BlueWhite Chem-Feed* diaphragm dosing pumps to provide measured amounts of liquid chlorine to the water supply. One dosing pump, is located in the pump house which pumps 252 m^3/day or 76% of the community water demand. The dosing pump feeds 1% active chlorine (1% hypochlorite) via flexible plastic tubing to the suction foot valve of the Grundfos 20 HP vertical turbine water pump. A relay in the pump panel simultaneously activates the diaphragm dosing pump when the 20 HP pump is operating. Using this approach, the chlorine is thoroughly mixed with the pumped water and has an average contact time of about 19 hours in the pipe and upper storage reservoir before reaching any users.

A second dosing pump provides chlorine to the gravity flow segment of the water system. This portion of the water system supplies an estimated 80 m^3/day or 24% of the total. This second pump is operated by a digital time clock which can activate the pump for variable time periods up to six times per day. Presently, six pumping periods of 12 minutes each are used to dose the receiving reservoir with 1% chlorine solution. The times of dosing are designed to correspond with times of peak use so that the resulting chlorine residual is relatively constant as the water leaves the reservoir and enters the distribution system.

The average contact time for the gravity portion of the system is about 22 hours. A dividing wall in the 75 m^3 tank prevents short-circuiting between the inflow to the tank and its outlet to the distribution system. Excess water received from the springs, overflows at a collector tank rather than at the reservoir so that only the water consumed is chlorinated. This approach saves the cost of chlorinating that additional water not used by the community.

In both locations, chlorine dosing is maintained at 1.2 mg/L with a resulting chlorine residual of 0.3 mg/L. The community measures the chlorine residual using Hach Model 66 and Model 80 chlorine measurement kits. The use of dosing pumps maintains the chorine residual at a constant level with very little variation.

Figure no. 1 – Picture of chlorine dosing unit for gravity flow

Figure no. 2 – Picture of chlorine dosing unit to supply pumped flow

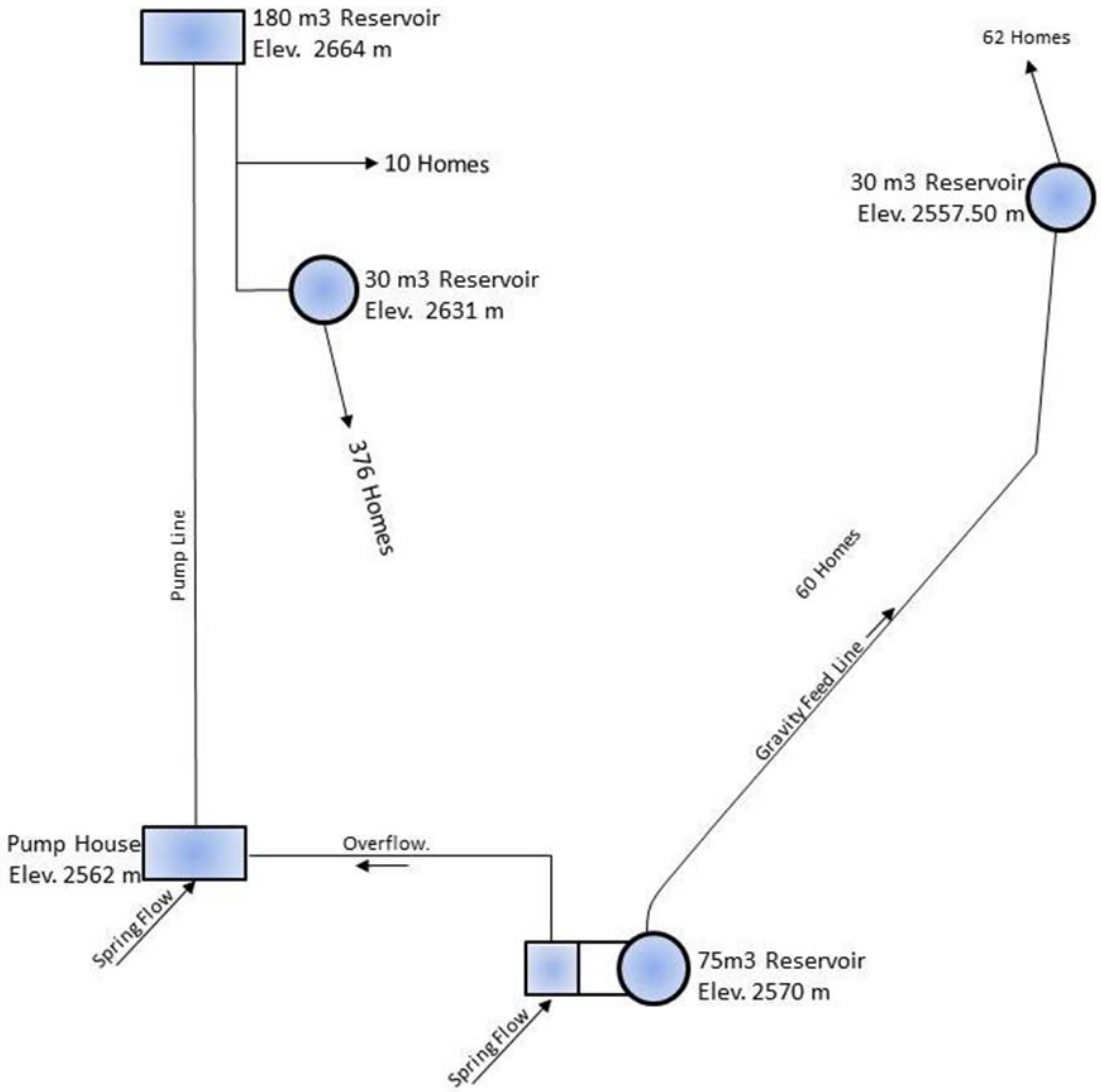
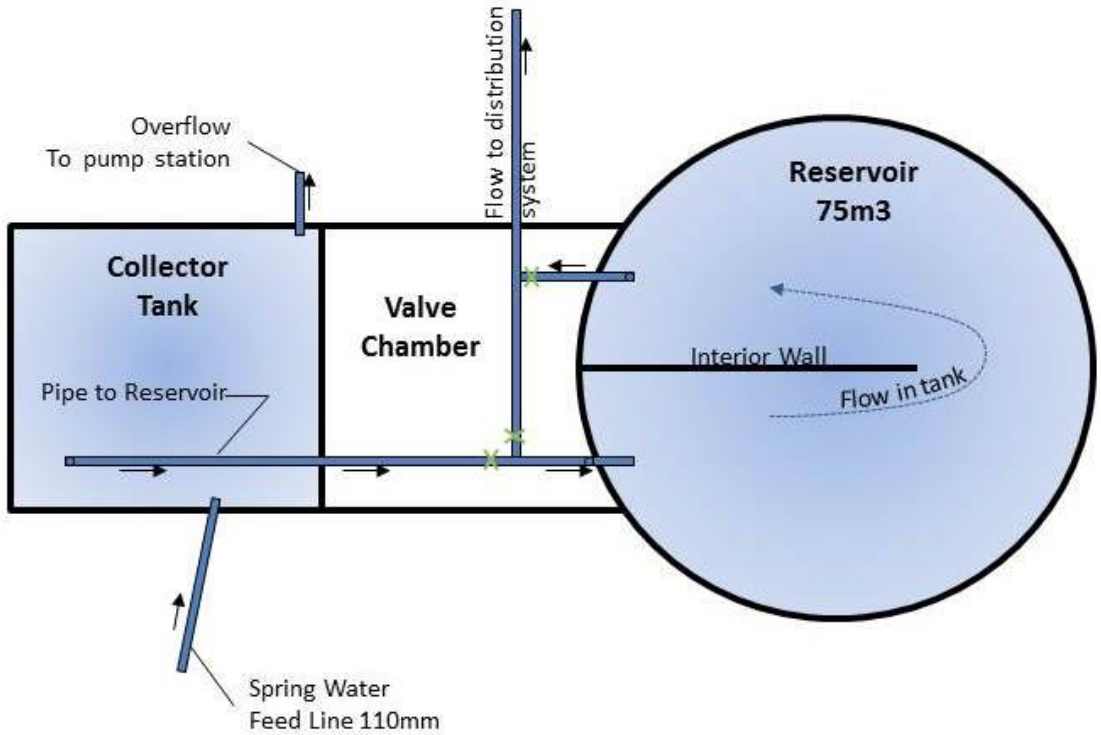


Figure no. 3

Figure no. 4
Detail of plastic chlorine feed tube passing through the mechanical seal in the pump station floor. The plastic tube extends down to the foot valve.

Figure no. 1 is a picture of the gravity installation located in a small building over the cistern adjacent to the 75 m3 gravity reservoir. Figure no. 2 shows the diaphragm pump for the pump house installation. A water meter is located above the each of the plastic HDPE chlorine solution tanks to aid in measuring the amount of water required to dilute the sodium hypochlorite solution to 1%. Figure no. 3 shows a schematic of the Carabuela water system. A key feature of the chlorine dosing at the pump house and the gravity reservoir is that only water actually entering the water system is chlorinated. Excess spring water not used by the community overflows at the pump station.

Figure no. 5
Carabuela Water System
Gravity Flow Chlorine Contact Tank Schematic



Comparison of Chlorine Costs

Currently, 10% liquid sodium hypochlorite is diluted to produce the 1% chlorine solution stored in the 530 liter tank under each of the dosing pumps. Liquid chlorine is supplied in refillable 250 liter plastic drums by a chemical supplier in Quito and delivered to the community. The water system uses about 4 liters per day of 10% liquid sodium hypochlorite. The cost of chlorination is \$0.004 per m3 or approximately 2% of the operating budget for the water system. Customers pay \$0.20/m^3 for water.

A cost comparison of the various means of chlorine disinfection is shown in Table no. 1. The comparison indicates that granular calcium hypochlorite would be about 34% more expensive than liquid chlorine and there is some concern that granular material could cause maintenance issues for the chlorine diaphragm pumps. Normal laundry bleach (5% sodium hypochlorite) in gallons or half gallons at wholesale cost would range about 4 to 6 times more expensive than the 10% sodium hypochlorite in 250 liter drums. During limited periods of time, the community has used regular 5% laundry bleach.

A pilot project implementing on-site generation of chlorine produced by electrolysis is being considered as a possible next step in this project. Electrolysis has the advantages of lower costs, reduced risks of chemical storage, and the ease of delivering only salt. This additional part of the pilot project would need to define the issues of maintenance and controlling the chlorine dose for this type of equipment.

Table no. 1 – Cost Comparison of Chlorine Supply Options

Chlorine Supply	Cost	Monthly Consumption	Monthly Cost	Cost per cubic meter
Granular Calcium Hypochlorite 65% Chlorine	$3.12/Kg.	18.69 Kg.	$58.42	$0.006
10% Liquid Sodium Hypochlorite	$0.36/liter	121.5 liters	$43.74	$0.004
Laundry Bleach 5% Liquid Sodium Hypochlorite	$0.84/liter	243.0 liters	$203.87	$0.020

Public Acceptance

Chlorination disinfection plans were discussed in the health & hygiene classes given during the project construction and follow-up as well as during the public community meetings during construction of the water system.

The public reaction to chlorine disinfection has been limited and can best be characterized by skepticism. During the initial startup, when chlorine residual concentrations went above 0.7 mg/L, concern was expressed and chlorination was discontinued for a period of about 2 months. When chlorination was reinitiated to a residual level of 0.3 mg/L, only limited taste was noticeable to the public. Careful control of chlorine dosing and chlorine residual seem to limit the taste and odor issue leading to improved public confidence. The community has operated the disinfection at this level for five months without complaints or public concern.

Coliform testing using Colilert water test kits are performed twice per week in four locations with simultaneous measurement of the residual chlorine. To date, all coliform tests have been negative when the chlorine residual is 0.3 mg/L or greater.

Cultural and Community Development Aspects

The Otavalan Quichua people of Imbabura Province where Carabuela is located, are perhaps the most entrepreneurial and advanced tribe of Ecuador. The Otavalo tribe was the last tribe to be dominated by the Incas in the pre-colonial period. Traditionally, the people produce woven goods as well as farm. Some limited production improvements of woven goods in recent decades enable them to export their goods worldwide as well as selling to tourists. The business experience, exposure to other cultures, and forward thinking of these people; better position them to take important steps of development.

A significant number of Otavalan people live overseas and facilitate the sale of artisan goods produced in that province. The people of Carabuela estimate that annually they sell and ship about 2 million dollars' worth of sweaters, hats, scarves, and other woven goods.

The strategy of community development focuses on communities most ready for positive change rather than necessarily the neediest communities. The community of Carabuela was selected because of their motivation to improve their water supply, sanitation and hygiene; and their desire to reduce health risks. The desired outcome is that Carabuela be a leader in the sense that other communities will observe how to improve their water system as well as the health benefits of doing so.

Problem Issues

One of the most difficult implementation issues of the disinfection pilot project was locating chlorine dosing equipment providers in Ecuador both knowledgeable about their equipment and its limitations; and willing to install and service equipment in remote rural locations. The equipment provider selected proved inadequate on both of these counts. In the end, some simplification was made to the installation and technical people on our own staff were used to solve the installation issues. This learning cycle both humbled and enabled us to better teach the community leaders in running the disinfection equipment.

Originally the water system design for the gravity flow portion of the Carabuela water system employed a *Blue-White* paddle wheel flow meter to pulse the chlorine dosing pump and dose chlorine solution proportional to the water demand. Unfortunately, the equipment provider did not call our attention to the fact that the design flow was outside of the flow-velocity range of the flow meter. The limited head losses allowable in this part of the water system limited the possible solutions. This problem was finally resolved by installing a time clock to operate the chlorine pump. The variations in chlorine residual are being monitored in this part of the water system to determine if the time clock is an adequate solution. Up to this time, the daily water use for this segment of the water system appears to be consistent enough so that the chlorine residual stays within the desired range.

The initial chlorine dosing pump installation in the main pump station failed a short time after being placed into operation, due to the wear of the plastic main

driving gear. A new steel gear was ordered from the US, but valuable time was lost with the water disinfection out of operation. This experience points to the need to employ equipment and parts more readily available in Ecuador; and to the need for backup units. These are issues which need to be worked out in the future iterations of the pilot project.

Conclusions

The results of this pilot project show that sustaining chlorination disinfection can be achieved by rural Ecuadorian communities by taking into account the following factors;

- Limiting chlorine levels to 0.3 mg/L adequately reduces the taste and odor issues of chlorination for long-term public acceptance.
- Chlorine dosing of 0.3 mg/L is adequate to eliminate coliform in clean protected spring water in this particular situation.
- Using protected spring water sources providing a high quality water supply which reduces disinfection needs and therefore reduces potential disinfection by-products.
- Use of diaphragm dosing pumps which meter the chlorine dose rate either by flow or time to maintain a stable chlorine residual level is effective.
- Chlorine residual testing equipment providing accuracy to the nearest 0.1 mg/L combine with regular testing is necessary to successfully implement chlorine disinfection.
- Use of 10% sodium hypochlorite provided in 250 liter plastic drums provides the most economical method of chlorinating for a community of 500 homes in this area of Imbabura Province.
- Defining a low cost method of supplying chlorine for disinfection is important for long-term sustainability.
- Providing adequate training for water system staff in the operation & troubleshooting of chlorination equipment and testing for chlorine residual is essential.

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water to their community formed an essential ingredient of the successful outcome. Above all we are grateful for the providential sustaining hand of the Almighty.