WATER DISINFECTION SYSTEMS FOR CUBAN CHURCHES

Gabriel A. Ferrer

This paper describes the need for temporary water disinfection systems in Cuba and the efforts of two United States missionary groups to bring "safe water" to those in need in Cuba. Also described is the technology used for water disinfection systems installed by the two missionary organizations, Living Waters for the World (LWW) and United Servants Abroad (USA), their water treatment capacity, cost and the logistics involved in the transportation and installation of the equipment and the importance of the relationships and roles of the sister Cuban organizations working with LWW and USA in the island.

STATE OF MUNICIPAL WATER IN CUBA

Visitors to Cuba are warned, by many, not to drink the water. It reminds one of the warnings given over the years to foreign travelers visiting Mexico. The author can attest that the warnings are real from his digestive system experience while visiting Cuba.

According to Wikipedia:

> Water supply and sanitation in Cuba is characterized by a high level of access, but limited quality of service. A state owned enterprise is in charge of providing services throughout the country. An exception is a mixed public private company with partial foreign ownership that provides services in part of Havana. In 2015 about 95% of Cubans had access to an improved water source (96% of the urban population, but only 92% of the rural population).[1]

Dr. Manuel Cereijo, a professional engineer associated with Florida International University, has written that:

> The bulk of water and sewer facilities in the Cuban urban areas are over 75 years old. The useful life of water distribution and sewer line is universally accepted at 50 years. This figure is only as reliable as the maintenance provided. Non-maintained lines will fail much more rapidly. The contamination of water leakage and the flow of raw sewage in the streets of urban Cuba is a deadly one. When the pumps are turned off and the pressure in the lines drops to zero and especially in those cases where a negative pressure is created, sewage is introduced into the water system by percolating through the soils surrounding the mains and then being sucked in by negative pressures in the lines.[2]

Compounding the unsanitary water conditions, in Cuba water is not available 24 hours a day as in the United States. Even in Havana water is only available for several hours per day. In many rural areas municipal water may not be available for as many as 12 days at a time. In Santiago de Cuba, water is not available but once every 25 days.

According to a March 2017 report in the AlJazeera news network:

> Cuba is experiencing one of its worst droughts in 100 years. Although the government provides drinking water, the shortages caused by the lack of rain are compounded by an aging and dilapidated infrastructure. More than 50 percent of the available

1. http://en.wikipedia.org/wiki/Water_supply_and_sanitation_in_Cuba

2. Dr. Manuel Cereijo, Water and Sanitation in Cuba: Summary, http://www.amigospais-guaracabuya.org/oagmc279.pdf. See "Conclusions" on page 3.

> water is lost to a leaking drainage system and state water officials must manually change the flow of water in the pipes every day to ensure an equal water divide between houses and neighborhoods.... Even so, some cities in Cuba only have running water once every five days, and only for a few hours at a time. Residents use these hours to fill water tanks and personal reservoirs, usually on roofs. Because the water pressure in the system is so low, Cubans have resorted to using garden hoses and private motors to connect a street-level water supply with their rooftop storage. ... In conditions of extreme drought, such as the one Cuba is currently facing, every city block is permitted to request one government water truck. However, the trucks are too slow to arrive for many Cubans, who pay illegal water vendors to transport water, by horse carriage, from houses that have running water to houses that do not.[3]

The author has been present when water vendors deliver water to some of the churches which he has visited and has heard testimony of Cubans as to how much they pay for water. Water vendors, typically, charge 4 CUC per 500 gallons of water, the equivalent of about $0.008 United States Dollar (USD) per gallon of water.

For comparison, the Cuban residential water tariff is fixed at 1 Cuban Peso (CUP), per cubic meter. The equivalent of $0.00015 USD per gallon of water. Thus, the water sold by vendors costs about 50 times the Cuban municipal water rate. (Note: 1 CUP = $0.04 USD.)

Hotels and embassies are billed at $1.00 USD per cubic meter or $0.0038 USD per gallon, compared to approximately $0.001 USD per gallon in the State of Florida.

HOW CAN WATER BE MADE SECURE TO ALL CUBANS

In general, the existing water distribution systems as well as the drinking water treatment plants in Cuba are in very poor condition. The best way to remedy this situation is a new, island wide, safe water system. However, given the present dire economic conditions in Cuba this is not possible.

Estimates by Dr. Manuel Cereijo[4] and Mr. Josenrique Cueto[5] place the costs of a new safe water system and waste water treatment for Cuba at between $1.5 billion and $5.7 billion USD. According to Dr. Cereijo:

> It is difficult to make an accurate estimate of the capital needed to rebuild the entire Cuban water treatment and distribution system. However, it can be estimated, as an approximation, to be $1.5 billion USD in the first five years, including aqueducts, transmission and distribution systems, water treatment plants and sewer lines.

Dr. Cereijo has proposed a two-phase water distribution system for Cuba: Emergency Tasks (ET) and Permanent Facilities (PF). Emergency tasks shall be considered as the level of work required to provide the minimum essential volume of water consumption and still maintain an acceptable degree of health protection. The ET is a planned transition from the existing situation to the construction of permanent facilities and based on the following assumptions:

- Per capita consumption: 20 gallons per day
- Utilize existing water supply sources
- Citizens to carry water in their own containers from a community tap
- No charges at the community tap
- Supply to be hydrostatic pressure 24 hours per day.[6]

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3. AlJazeera, "Watering down a revolution: Cuba's struggle for water. Cubans face a daily battle for drinking water as the country experiences one of its worst droughts in 100 years. http://www.aljazeera.com/indepth/inpictures/2017/03/watering-revolution-cuba-struggle-water-170309092028542.html.

4. Cereijo, op cit.

5. Josenrique Cueto, "Cuba's Water and Wastewater Infrastructure," FIU Cuban Research Institute, February 12, 2014. https://cri.fiu.edu/research/commissioned-reports/. See presentation slides 11 and 19.

6. Cereijo, op cit.

According to Mr. Cueto,[7] the cost to rebuild the entire Cuban water treatment and distribution system would be $5.7 Billion USD, consisting of two tranches:

- The overall cost of water system improvements would be $3.52 billion USD:
  1. Upgrade of existing potable water pump stations: $1.1 billion USD
  2. Repair of water distribution system: $2.4 billion USD
  3. Sodium Hypochlorite Generation: $0.02 billion USD
- The cost of wastewater infrastructure improvements would be $2.2 billion USD:
  1. Wastewater collection system improvements: $1.2 billion USD
  2. Wastewater treatment plant improvements: $0.55 billion USD
  3. Wastewater pump station improvements: $0.45 billion USD [4]

The work that LWW[8] and USA are doing in Cuba can be considered to be a form of the ET system proposed by Dr. Cereijo. It uses the existing water supply and is available to those in the Cuban population that can reach the present installation locations. However, at this time only 49 water disinfection systems are in place and they only provide water to a very small portion of the Cuban population, estimated to be about 15,000 to 20,000 people per day.

US MISSIONARY ORGANIZATIONS, THEIR RELATIONSHIP WITH CUBAN ORGANIZATIONS, AND THE HELP THAT THEY ARE PROVIDING CUBA

Living Waters for the World (LWW) (livingwatersfortheworld.org) and United Servants Abroad (USA) (unitedservantsabroad.org) believe that all of God's children deserve clean water.

- LWW is responsible for more than 800 water disinfection installations throughout the world. They operate in Africa, South America, Central America, Mexico and the Caribbean.
- USA operates in Africa, South America, Central America, Cuba and the islands of the Bahamas.

Both are Christian organizations that perform evangelical work in addition to water disinfection system installation.

All labor is performed by volunteers and the water disinfection system hardware is donated by private individuals, churches and non-government organizations. See Figures 1 and 2.

LWW is primarily a training and coordination organization. The water disinfection system teams come from missionary church groups and non-profit organizations, such as USA. They provide the manpower, travel budget and materials required for each installation.

Since the U.S. embargo of Cuba is still in place and Cuba is a socialist country, a Cuban "sister organization" is, practically, a requisite for missions to be able to operate in Cuba. USA has partnered with the Council of Cuban Churches (CIC) to install water disinfection systems in Cuba. According to descriptive materials, "the CIC gives unity to the Christian Churches of Cuba and helps unify Cuban churches with other churches around the world."[9] LWW has partnered with the Evangelical Theological Seminary at Matanzas, Cuba.[10]

LWW and USA install safe water systems in many countries. The cultures, economy and educational levels of the people that we meet and with whom we work vary significantly. For example, educational levels of people living in the Amazon jungles of Peru are much lower than those of the people in Cuba.

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7. Cueto, op cit.

8. Author's note: LWW water disinfection systems do not use chlorination. LWW had to stop using chlorination because operators tend to over chlorinate and users distrust the taste of chlorine to the point that they do not use the chlorinated water. Instead LWW water disinfection systems rely on micro filtration and the injection of ozone.

9. Global Ministries, http://www.globalministries.org/lac_partners_concilio_de_iglesias_de_cuba

10. Evangelical Theological Seminary, Matanzas, https://www.presbyterianmission.org/story/december-17-2016/

Figure 1. LWW Volunteer Next to Dry Assembled Standard Ozone System

The Cuban people that we meet in our trips to the island are wonderful individuals. They are educated and have a "can do" attitude, illustrated by the Cuban proverb: "Hay que inventar y resolver", "You have to find a way and get it done." They are hard workers and have a very positive outlook.

They understand the technology of the systems that we install. They do the installation under our supervision. But were we to hand them a sample photo of the water disinfection system they could do the installation without our input.

The reason that missionaries, such as USA, donate the water disinfection systems to the Cubans is because the Cubans, simply, don't have the capital to do it themselves. I've been told by Cubans that "Cuba has a first world educational system and a third world economy."

WATER CONSUMPTION AND PREVENTING DEHYDRATION

According to the World Health Organization (WHO):

> The daily individual requirement for drinking-water implies a minimum that must be safe to consume (by drinking or through food) to prevent the effects of dehydration, whether mild or severe and potentially life threatening. ... How much water a person needs for drinking and food preparation varies considerably, according to diet, climate and the work they do. Yet those with least access to water supply tend to live in warm climates and engage in at least moderately strenuous work. Pregnant women and breastfeeding mothers need more water. ... The minimum amount of water needed for drinking ranges from about 2 liters (1 gallon = 3.8 liters) in temperate climates to about 4.5 liters per day for people in hot climates who have to carry out manual work.... Water is critical for food in many ways: it is used in irrigation, aquaculture and livestock water-

Figure 2. LWW Volunteer Next To Packaged Standard Ozone System

> ing to produce food. The scope of water concerning cooking is restricted to aspects of household use: water as an ingredient of foodstuffs (e.g. rice, pasta, bread), and water as a requirement for food hygiene to ensure that food is safe to eat.... Most people need at least 2 liters of safe water per capita per day for food preparation.[11]

For comparison purposes people in the US consume a per capita average of 90 gallons of water per day. Thus, according to the United States Geological Survey (USGS) in the U.S.:

> Estimates vary, but each person uses about 80-100 gallons of water per day. Are you surprised that the largest use of household water is to flush the toilet, and after that, to take showers and baths? That is why, in these days of water conservation, we are starting to see toilets and showers that use less water than before.[12]

For sizing of water disinfection systems, LWW and USA use a "ground rule" of 1 gallon of safe water per person per day. Note that this is water to be used for drinking, cooking, dental hygiene and baby needs. While it is preferable to use disinfected water for washing hands and bathing, it is not strictly required.

The organizations' water disinfection systems are used in the "batch mode" (v. on demand system mode) and are sized assuming a minimal safe water requirement of one gallon per day per person. Typically, it takes approximately, 2 hours to process 300

11. World Health Organization, http://www.who.int/water_sanitation_health/en/righttowater.pdf. See page 17.

12. United States Geological Survey, Water Science School, Water Questions and Answers. https://water.usgs.gov/edu/qa-home-percapita.html

Figure 3. LWW Volunteer Next to Dry Assembled Standard Ozone System

gallons of raw water to safe water. Or enough safe water for 300 people per day.

The typical safe water storage tanks used in Cuba have a 300 gallon capacity. The safe water tank needs to be emptied, or partially emptied, before another batch of raw water is processed. If a larger safe water storage tank or multiple tanks are available, the processing of raw water can be increased many times over per day. See Figure 3.

THE WATER DISINFECTION TECHNOLOGY USED BY LWW AND USA

Three water disinfection technologies have been developed by LWW. Two technologies use, primarily, micro filtration and one uses micro filtration plus reverse osmosis. The least costly system developed by LWW, called the Ultraviolet (UV) System, uses micro filtration and a UV lamp for radiative disinfection. This system is not used in Cuba because of the relatively high levels of dissolved solids and hardness found in Cuban water, which tend to interfere with UV irradiation. See Figure 4.

The most widely used water disinfection system used by LWW and USA, is the Standard Ozone System (SOS). It is the preferred system for use in Cuba. It uses micro filtration and ozone, a gaseous disinfectant. See Figure 5.

The third water disinfection system used by LWW is the Reverse Osmosis System. This system is not practical for use in Cuba today. It requires resin and salt pellets which are almost unavailable in Cuba. In addition they produce as much as 50% to 70% waste water. Because of the existing water shortages in Cuba this system is not suited for use in Cuba. See Figure 6.

The Standard Ozone System (SOS)

Figure 7 shows a very simplified, "cartoonish," depiction of the SOS. It is intended to show its seven major subsystems: (1) water supply; (2) raw water storage tank; (3) pump; (4) micro-filtration filters; (5) ozone generation/injector unit; (6) ozone/water mixer; and (7) dispensing area.

Figure 8 is a functional block diagram showing how an SOS was connected to the modified infrastructure

Figure 4. Living Waters for the World Ultraviolet System Installation

Figure 5. LWW Standard Ozone System with Arrows Showing Water Flow (First pass: red, Second pass: yellow)

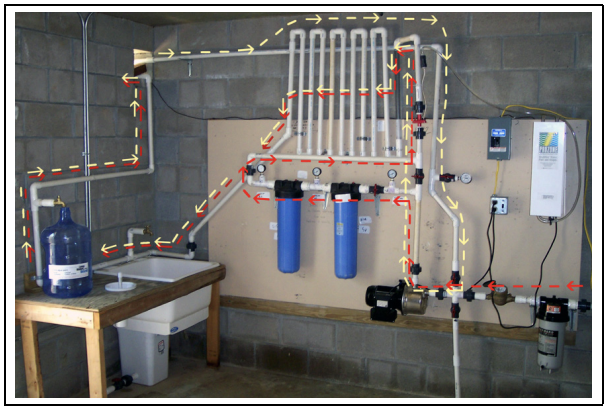


Figure 6. Living Waters for the World Reverse Osmosis System

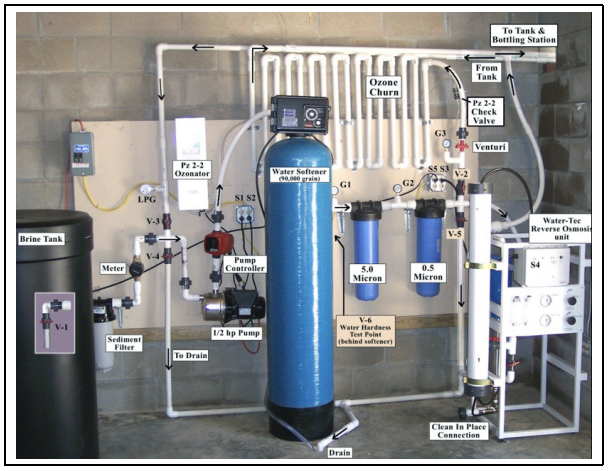
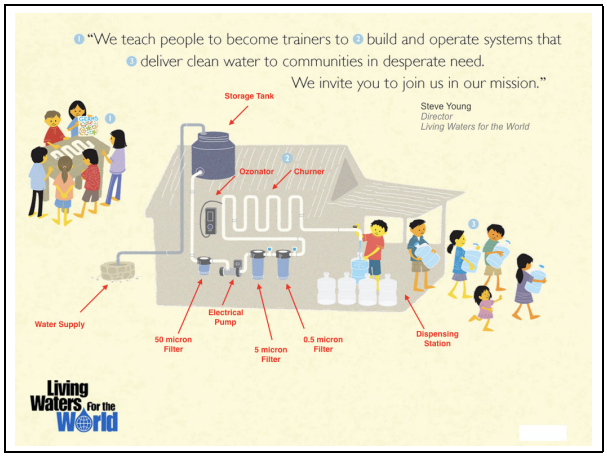


Figure 7. Living Waters for the World Standard Ozone System Illustration



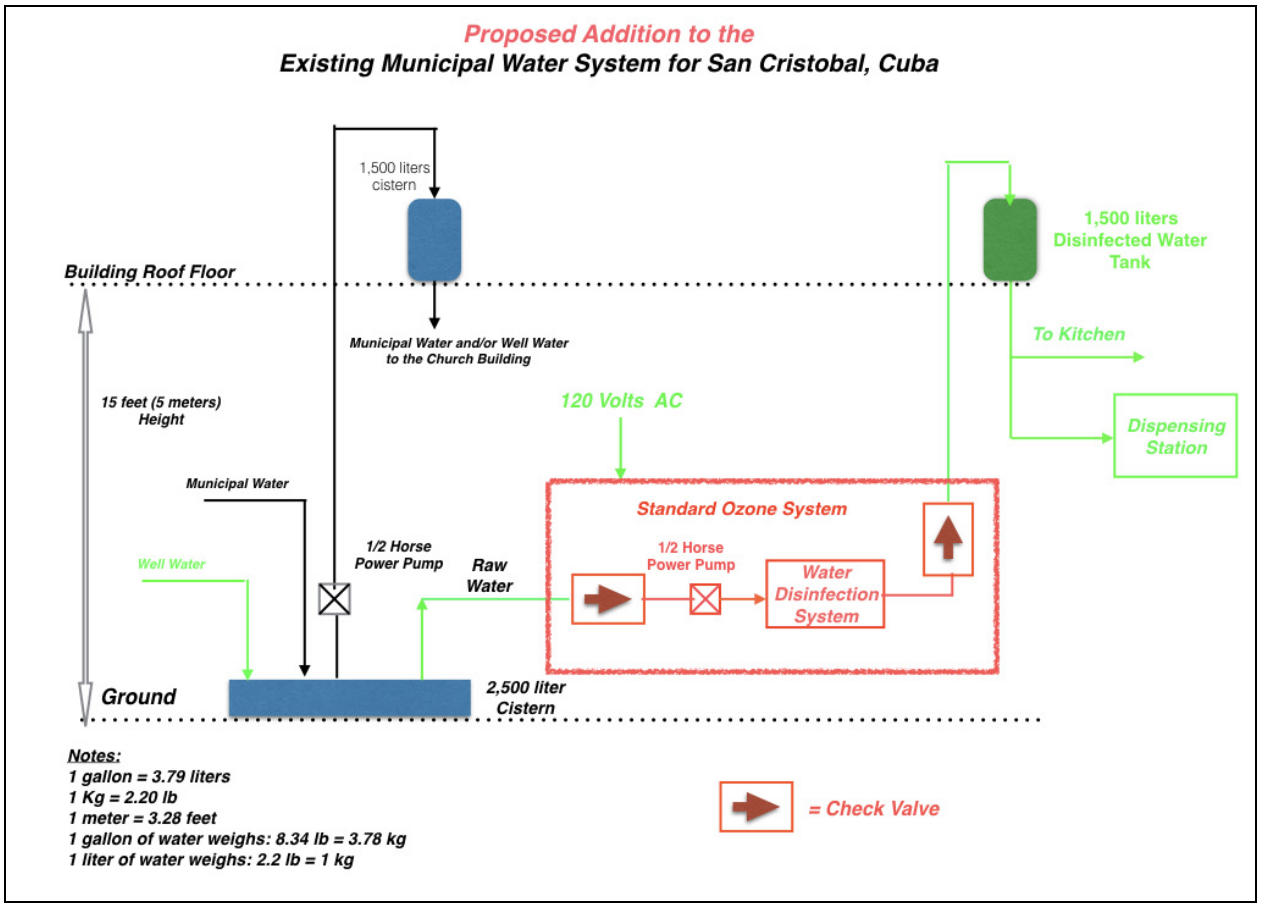
at the "House Church" of the Holy Land in San Cristóbal, Pinar del Río province, about one year ago. It is a typical installation except that in this case the water supply comes from two sources: municipal water and a well located at the back of the church. The existing water system is shown in black and blue.

Before our missionaries arrive to supervise an installation there is infrastructure work that needs to be installed. It is shown in green in Figure 8: a safe water tank of about 300 gallons capacity, plumbing to and from the tank to the SOS (shown in red) and a 20 amp 120 Volts AC service to power our electrical water pump and the Ozonator.

The typical cost of the new infrastructure, including materials and labor is, approximately, $1,500 US Dollars (USD). This work is typically done by members of the church's congregation. If a well and pump is required, it will cost approximately, an additional $2,000. The cost of the SOS hardware is $2,500 and transportation from Miami to Havana costs $500.

The block diagram (Figure 8) shows the well feeding the existing 2,500 liter ground cistern when municipal water is not available. At San Cristóbal, municipal water is often not available for as long as 12 days at a time. The block diagram also shows, in black, an existing 1/2 horsepower electrical pump. Typically, there will be an operational 1/2 horse power electrical water pump at the churches. They are used to pump municipal water, when available, to roof cisterns, as

Figure 8. Overall Functional Block Diagram of San Cristóbal Installation



shown in Figure 8. The municipal water pressure is, typically, not sufficient for water to reach roof top cisterns.

The "raw" water, in Figure 8, is shown being fed to the SOS from the existing ground cistern. In most installations the raw water is fed from a roof cistern which stores municipal water. Direct connection to a municipal water tap is not possible because the water flow available from the municipal water system is insufficient.

Figure 9 shows a detailed block diagram of the SOS. Note that raw water from the cistern flows through a 50 micron (one millionth inch) filter, a 5 micron filter and finally a 0.5 micron filter. This is referred to as "micro-filtration" and is sized to block the cholera bacteria.[13]

After the water is micro-filtrated it flows through a Venturi Aspirator connected to a Prozone company model PZ2-4V Ozone generator unit.[14]The model PZ2-4V generates sufficient Ozone to neutralize the polio virus after two passes.[15]

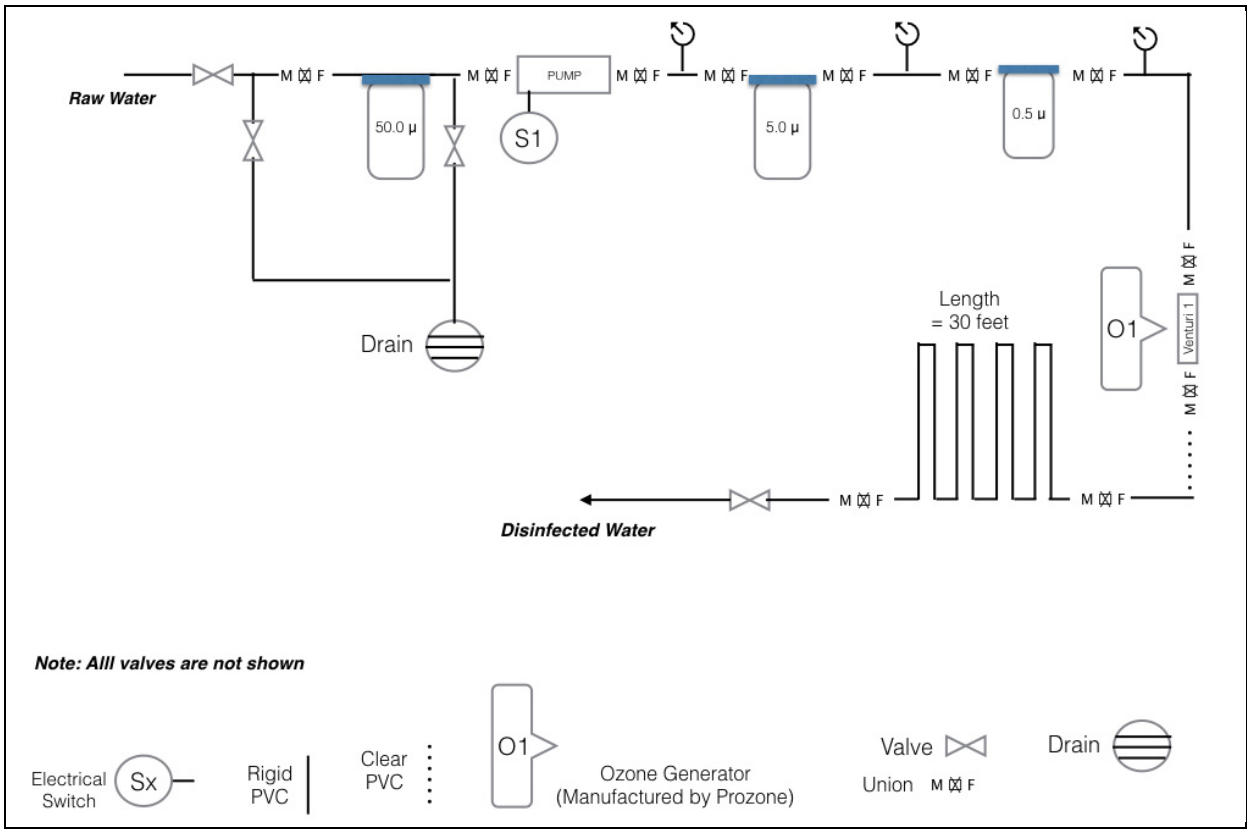
After the ozone is entrained by the Venturi Aspirator, which is connected to the Prozone Ozone generator, the water flows through a 30 feet long "churner" which mixes the water with the Ozone to achieve the

13. Remi van Compernolle and Wil Howie, "Technical summary of filtration, microfiltration and ozone treatment." Living Waters for the World, November 9, 2005. https://www.noexperiencenecessarybook.com/bw9WO/technical-summary-of-filtration-microfiltration-and-ozone-treatment.html.

14. Prozone Systems: Ozone and Advanced Oxidation Systems. http://www.prozoneint.com/industrial/pz2-hybrid-systems/.

15. van Compernolle and Howie, op cit.

Figure 9. Detailed Functional Block Diagram of LWW Standard Ozone System



design contact time. The water then proceeds to the safe water tank.

The water disinfection protocol requires a second pass of the water through the water disinfection system in the "Ozone injection only" configuration. In this configuration the filters are bypassed, since only one pass is required to achieve filtration while two passes are required to achieve the design contact time with the ozone. This system configuration is manually set by the SOS control valves. The process takes about 2 hours to disinfect 300 gallons of water. The existing water disinfection protocol requires that any water that is not dispensed in a 24 hour period be re-ozonated again.

All water disinfection installations in Cuban churches until now are controlled manually. The only exception is the water disinfection system installed at the Church of the New Pines in Holguín. The automatic control for that installation was designed by a member of the church's congregation. The funds for the controller were provided by the church member and the additional valves and flowmeter, required for automation, were donated by USA. It costs, approximately, an additional $1,000.00 to automate an SOS.

Economic Benefits of LWW and USA Installations

Economic studies by LWW show that the cost of boiling water for drinking, cooking and dental hygiene for two people in Cuba cost about $2.00 USD per month. Given that the typical pension for Cubans is $12.00 per month, the $2.00 savings per month realized by using safe water from LWW and USA installations in Cuban churches results in an 8.3% savings per month for a retired couple. In addition, safe water prevents water borne diseases and medical costs to treat those affected.

FUTURE PLANS AND FOLLOW-UP

As of the writing of this paper, USA has 5 Standard Ozone Systems waiting to be installed at Cuban churches. The systems are presently stored at the offices of the CIC in the City of Havana. There is a se-

lection committee staffed with a majority of Cuban nationals who will decide where those systems will be installed. In addition there are 4 SOS stored in a hangar in the city of Port St Lucie, Florida, which are being prepared for shipment to Cuba before the end of 2017. We also have a pledge by a German Non-Government Organization (NGO) for enough funds to procure and install an additional 20 SOS.

We are beginning a project to have water samples analyzed by Cuban laboratories. This is a very important step because bacteriological analysis needs to be completed within 24 hours of when the example is taken. The first phase of this project (14 samples) is funded and we expect to get results in the next few months.

But the most promising part of this water analysis project is the possibility that the University of Miami, Washington State University, United Servants Abroad and the University of Havana may join forces for a study to map the quality of water throughout Cuba.

In addition, a recommended future area of study is to determine the cause of the reported "kidney stone" complaints by Cubans. At all of our installation sites, Cubans have complained of suffering from kidney stones. This may be a result of not drinking enough water as there is a reluctance by many to drink water that may be contaminated.