Effectiveness of CTI Water Chlorinator at controlling bacterial contamination in rural Nicaragua's drinking water

EOS INTERNATIONAL

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Prepared by
Compatible Technology International

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ACKNOWLEDGEMENTS

Over almost two decades, starting with Charlie Taflin, the inventor of the CTI-8 chlorinator, countless individuals and organizations have collaborated to bring safe, chlorinated drinking water to nearly 550 rural communities of Nicaragua. The authors are grateful to all who've contributed to these efforts. In particular, the authors acknowledge the talented and generous support of those who contributed to this survey, including:

Mr. Byron García - MINSA Matagalpa, analyzed three years of data on the incidence of acute diarrheal illnesses and correlated them with the presence or absence of the CTI Water Chlorinator.

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Mr. Sergio Romero (Sr.) of CTI - Nicaragua, who for many years has been leading the water chlorination program for CTI in Nicaragua, and who, in a personal way and starting from and with very little, has led this program to serve so many rural communities.

Mr. Jorge Fernández, who has served as the leader of the Nicaraguan water program as a volunteer of CTI, setting large program goals, and providing the strategic management to reach these goals. Jorge has been instrumental in the sourcing of US funds and has been a great mentor for the program.

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" The amazing thing is that having so much water in our country, there are still thousands of families who do not have safe drinking water. Lake Managua is filled with water, but it is water that cannot be consumed, there are rivers where currents are permanent in summer and winter but they are contaminated, and that water may not be drunk.

We have to talk about the communities that are in the country, our peasant brothers who do not have safe drinking water, some go to the river and bring water, but it is water that is contaminated, they have to boil it to be able to consume it.

However, various projects will reach communities, with the direct participation of our institutions and the non-governmental organizations in which we will work together for community development and they will gradually improve their living and health conditions".

Daniel Ortega Saavedra
President of Nicaragua

Authors

This study was designed by Mr. Jorge Fernández, volunteer of CTI – USA, and Mr. Sergio Noel Romero (Jr.), member of CTI in Nicaragua. The work of gathering information in communities in Matagalpa and Jinotega was carried out by Mr. Romero, who visited each of the 37 communities in the survey, interviewed members of all their CAPS, and managed the taking of water samples in the systems' water tanks for further analysis in MINSA laboratories. Also, Messrs. Romero and Fernández summarized the results in tables 1 and 2 here presented. Water analyses were performed by the MINSA laboratory - Matagalpa.

Additionally, Mr. Byron García, of MINSA Matagalpa, collected 3 years of health statistics on the incidence of acute diarrheal diseases in 33 communities in Matagalpa (18 with chlorinator CTI-8 and 15 without chlorinator), whose inhabitants were referred to MINSA's health centers to receive medical attention when suffering from acute waterborne gastrointestinal diseases. This complementary study, conducted in parallel with the one mentioned in the previous paragraph, was performed during mid-2014.

Compatible Technology International (CTI) is a nonprofit that designs and implements tools in collaboration with small farmers and their communities to improve food and water security in developing countries. CTI's tools empower smallholder farmers with better food production, increased incomes and more sustainable livelihoods.

EOS International (EOS) provides under-served communities with access to low-cost appropriate technologies that generate income, improve health, and preserve the environment. EOS has served as the implementing partner working in collaboration with CTI for the past six years to implement this water chlorinator.

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Abbreviations

- ADD - Acute diarrheal diseases
- MINSA - Ministry of Health of Nicaragua
- CTI - Compatible Technology International – Nonprofit organization headquartered in St. Paul, Minnesota, USA
- EOS - EOS International, nonprofit organization
- SHI - Self-Help International - Waverly, Iowa, USA
- CTI Water Chlorinator (CTI-8) –A Drinking Water Chlorination device designed by Charles Taflin, CTI volunteer, to eliminate bacterial contamination in drinking water systems in rural Nicaragua.
- CAPS – Community Potable Water and Sanitation Committee

I. Introduction

As valuable and essential as safe water is to supporting life, in contrast, unsafe drinking water is among the single greatest threats to the human race—causing over 3 million deaths each year and killing more people globally than all forms of violence, including war. Providing communities with access to clean water reduces deaths and diseases and is proven to spur economic growth, improve food production, and ease the significant burden of healthcare costs.

One of the targets of the Millennium Development Goals (MDGs), established by the United Nations in 2000, was to halve the proportion of people without sustainable access to safe drinking water by the year 2015. The World Health Organization and UNICEF were tasked with monitoring progress towards this goal through a joint initiative called the Joint Monitoring Program for Water Supply and Sanitation (JMP). To establish uniform international standards for measurement, the JMP defined safe water as access to an *improved* water source, which was defined as one that "by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with fecal matter." Examples of improved water sources include piped water, protected wells, and protected springs. In contrast, unimproved water sources include surface water (rivers, ponds), unprotected wells and unprotected springs. [1]

At first glance, there has been significant global progress towards improving access to safe water in the years since the MDGs were established. By the end of 2011, 89% of the world population used an improved drinking-water source, which is 1% above the MDG drinking-water target. This left an estimated 768 million people without improved sources for drinking water, according to the World Health Organization.[2]

Despite this promising news, access to *improved* water sources does not translate to access to *safe* water sources. JMP statistics measuring the prevalence of improved water sources do not account for the quality of water being provided to communities. As a result, water sources considered "improved" by MDG standards can still be contaminated with deadly bacteria, and cause severe waterborne disease and death. This is a significant shortfall, and one that has been acknowledged by the JMP, among others.

Nicaragua is an example of a country of seemingly abundant availability of safe drinking water, with 85% of the country having access to improved water sources, as defined by the JMP. Known as the "land of lakes and volcanoes," Nicaragua has significant freshwater resources. It is the largest country in Central America and home to more than six million people—over 40% of them living below the national poverty line, making Nicaragua the poorest country in Central America by many accounts.[3]

Even in rural communities, where 42% of Nicaragua's population resides, 68% of rural communities have access to improved drinking water sources by JMP standards. According to officials at the Nicaragua Health Ministry (MINSA) officials, Nicaragua has over 5,400 closed water systems in rural communities that collect water from surface sources, like artesian wells high in hills, rivers, creeks, ponds, reservoirs, etc. Typical rural water systems (see appendix II) have a closed point of capture—that is, water comes into a confined space, typically a cement box with coarse filtration and sand inside.

[1] JMP (http://www.wssinfo.org/definitions-methods/)
[2] World Health Organization, UNICEF (http://www.who.int/water_sanitation_health/publications/2013/jmp_report/en/)
[3] World Bank (http://data.worldbank.org/country/nicaragua)

One of the greatest health risks associated with drinking water in Nicaragua and globally is fecal contamination. A 2010 World Health Organization study of water sources in Nicaragua revealed that, "fecal contamination of water sources is a serious problem in Nicaragua, and that water sources in 90% of the municipalities of the country may be contaminated."[4]

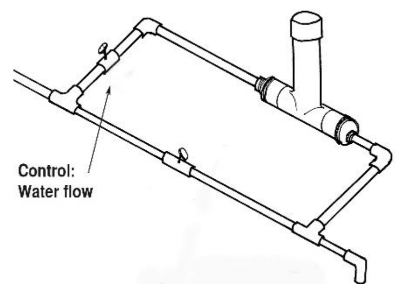
Water Chlorination

Water chlorination is internationally recognized as a safe, low-cost, and highly effective method of treating drinking water. Chlorine has been hailed by the World Health Organization for being an extremely effective method of providing potable water in a village setting, and it's the main method of treating drinking water in Nicaragua, most commonly found in public piped water systems. Chlorine is an optimal water treatment method for several reasons—it's cheap, effective against most types of bacteria and viruses responsible for waterborne diseases, and it continues treating water in its residual form, which prevents recontamination.

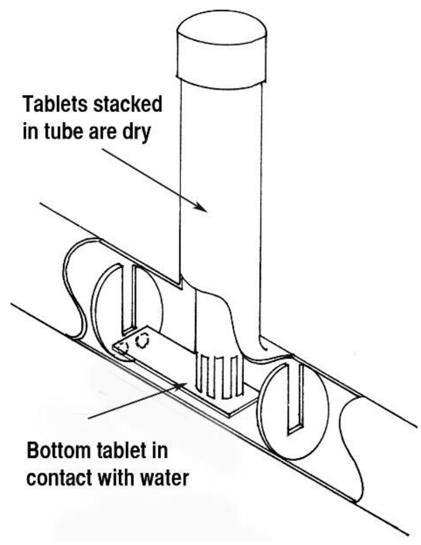
One common type of chlorination technology is an electric dosing pump. This technology, which costs between $900-$1,200 USD, uses an electric pump to release liquid chlorine into community water systems. Another technology, salt water electrolysis ($500-$800), converts salt to chlorine using metal electrodes, often powered by solar panels. Both of these technologies can be prone to failures, as they rely on outside power sources and complex-mechanisms which often require maintenance and repair.

CTI Water Chlorinator (CTI-8)

CTI's Water Chlorinator, also known as the CTI-8, is an inexpensive water chlorination system designed specifically for village conditions and water systems common to Nicaragua and throughout Central America.



The chlorinator was developed by engineers and researchers at Compatible Technology International, a St. Paul-based NGO, and is constructed of readily available PVC piping and chlorine tablets. The Water Chlorinator does not require a power source; rather, it features simple valves that can easily be adjusted to control the water's natural gravity flow through the system, and it utilizes chlorine tablets to deliver a controlled dosage of chlorine to a community's water tank—treating water for up to 1,000 people per unit.



At the publication of this study, the CTI Water Chlorinator is installed in 569 communities throughout 12 of the 17 departments in Nicaragua—providing safe water to more than 301,254 people. In a program led by Compatible Technology International (CTI), Nicaraguan technicians affiliated with CTI and partners EOS International (EOS) and Self-Help International (SHI), train communities to install and maintain water chlorinators in their villages.

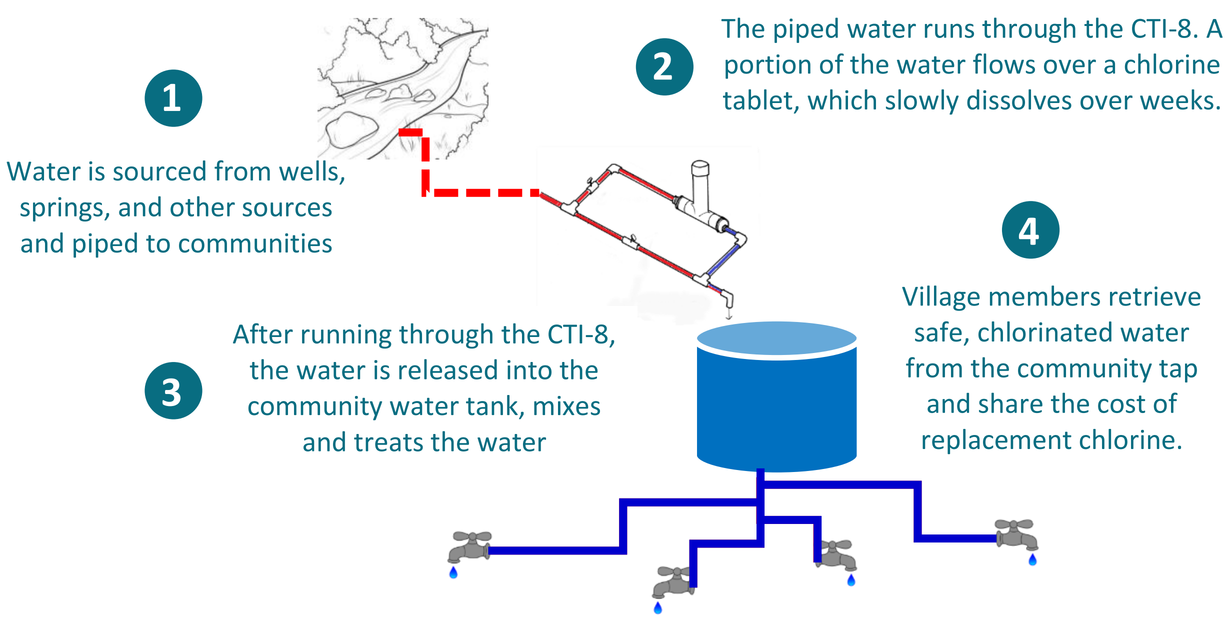
[4] http://www.wssinfo.org/fileadmin/user_upload/resources/RADWQ_Nicaragua.pdf

In each village, formal water committees called CAPS (Comite de Agua Potable y Saniemento or Potable Water and Sanitation Committee) are trained to replenish the chlorine tablets every few weeks and use testing kits to maintain optimal chlorine levels. CAPS committees are common in rural villages and are comprised of volunteers that have committed to oversee the water sources in their communities. CAPS are organized at the community, municipality, departmental, and national levels.

The Nicaraguan Health Ministry (MINSA) provides critical health and sanitation education at installation sites, and keeps a record of the incidence of Acute Diarrheal Disease (ADD). The villages share the cost of purchasing the chlorinator, roughly $200 USD, and continue funding replacement chlorine, which cost each family less than $1-2 USD per year (see Appendix III for more on installation in rural communities).

To keep a constant supply of chlorine tablets within short distance from local villages, CTI has established more than 20 regional chlorine banks that store small inventories of tablets for sale to local villages. These banks keep records indicating which communities are replacing their chlorine, so staff is alerted when villages fail to maintain their systems.

CTI Water Chlorinator (CTI-8) Installation



The Study

Despite the clear need for water treatment in rural Nicaragua, and a strong support system in the rural sector with organized CAPS and Health Ministry offices, access to water treatment technologies in Nicaragua is limited, and many that have been introduced have proven ineffective as a result of failures in the technology, inappropriate local maintenance, or both.

This study was undertaken to:

1) Examine the effectiveness of the CTI-8 chlorinator at controlling bacterial contamination in rural drinking water systems in Nicaragua

2) Measure the impact of chlorinator installations on public health, in relation to incidences of acute diarrheal disease

3) Profile rural villages in regard to the status of their water sources, community engagement in water and sanitation, and operational status of the CTI-8 in communities where it's been adopted.

To answer the research questions, data was collected and analyzed among communities in Nicaragua with a CTI-8 installed and those without water chlorination technologies. Village water samples were tested for bacterial contamination, incidences of Acute Diarrheal Disease (ADD) were analyzed, and data on the status of community water systems—including the maintenance of chlorination units and community engagement in water and sanitation—was recorded to capture a comprehensive picture of the impact of the CTI-8 chlorinator on rural health.

Though the data is preliminary, it shows that the CTI-8 Water Chlorinator is markedly effective at eliminating bacterial contamination in community water sources.

- The chlorinator eliminated all traces of the bacteria contamination where present.

- Communities without a water chlorination system exhibited more than twice the rate (154% higher) of ADD than in those with a chlorinator present.

- The CTI-8 installations have an exceptional sustainability rate, with 95% of chlorinators in good operating condition

That said, **reducing waterborne disease cannot be achieved by any one technology alone.** Community leadership is critical, and all technological interventions must be accompanied by a comprehensive approach that includes measures to prevent contamination prior to reaching the community water tank and after the water is collected at the tap.

II. Methods

This study was conducted during March - June 2014 in 37 rural communities located within the departments of Matagalpa and Jinotega, and in villages with a typical, closed, gravity-fed community water system. Research was led by Mr. Sergio Noel Romero Jr., who has had previous experience in rural water systems and the installation and operation of the CTI-8.

Surveys and water analyses were made following a uniform process using questionnaires prepared in advance and tested via a pilot test and also following the procedures for sampling water followed by the MINSA laboratories.

This research was based on data from three complementary sources:

1) **Water samples were collected and analyzed for bacterial contamination** in 31 villages—21 communities <u>with</u> a CTI-8 installed and 10 <u>without</u> a CTI-8 or any other water treatment system. Six additional communities were included in the study; however because the village leaders with access to the water storage tanks were at their workplaces during the surprise visits, no water samples

were collected in these communities. The sampling was conducted without giving communities advance notice to avoid influencing the operational status of the units.

In each water system (either with or without CTI-8), two water samples were collected by Mr. Romero Jr. and analyzed by MINSA. The first sample was taken prior to the water's entry in the water tank to identify those communities with bacterial contamination in their original water sources. In communities with a water chlorinator installed, a second sample was collected as the water was leaving the tank at the community tap, to measure the effectiveness of the chlorinator at eliminating bacterial contamination.

With full coordination with Mr. Daniel Morales Director of the Laboratory of Hygiene and Epidemiology Matagalpa SILAIS, the team performed water samples using equipment and PathoScreen reagents that verify the presence and absence of bacteria results obtained. This test identifies the presence of Enterobacteriaceae (The Enterobacteriaceae are a large family of Gram-negative bacteria that includes, along with many harmless symbionts, many of the more familiar pathogens, such as Salmonella, Escherichia coli, Yersinia pestis, Klebsiella and Shigella)The samples of water were analyzed following the protocol of testing defined by the Nicaraguan Ministry of Health. The key results of this part of the study are presented in Table 1 on page 11.

2) CAPS leaders were surveyed to collect **data on the status of local water systems and community participation in health and sanitation development.** Mr. Romero Jr. administered questionnaires in person to CAPs leaders in 37 villages (26 with CTI-8s installed and 11 with no chlorination technology) regarding:

- Number and gender of CAPS members
- Organizations and professionals present in the community
- Community drinking water supply and systems, including primary sources and water tanks
- Waste management and hygiene conditions
- Status of chlorination technology in community and interest in accessing technology

The goal was to understand the nature of community involvement as the basis for adoption. It was vital and productive for the survey administrators to meet the communities in the field. Researchers—who accompanied survey administrators on all visits and provided diagnostic information— observed strong community participation. During visits, the authors noted the engagement of many different community leaders, including CAPS members (many of whom are women), leaders of local churches, women's networks, and young people, all of whom are providing their time and effort for the welfare of their community. The summarized results of these surveys are presented in Tables 2.1 through 2.9, starting on page 18.

3) **Incidences of acute diarrheal diseases (ADD)** among communities with a CTI-8 and those without water chlorination technologies were compared by Mr. Byron García from MINSA's office in Matagalpa. Three years of medical data were analyzed from patient visits at health centers in 33 communities—in 18 villages with a CTI-8 and 15 villages with no chlorination technology. MINSA regularly uses such medical reports to monitor incidences of acute diarrheal diseases (ADD) and to provide community assistance. The data provide a long-term complement to the more instantaneous picture obtained in points 1) and 2) above. Key results in this part of the study are presented in Tables 3.1 through 3.3, starting on page 23.

III. Findings

Bacterial analysis of water samples

Bacterial analysis of 31 community water sources was conducted to determine the effectiveness of the CTI-8 at eliminating harmful bacterial contamination. In each community, two water samples were taken for analysis by a MINSA technician. An initial sample was collected at the pipe just prior to the water's entry to the community water tank, and if that system had a CTI-8 Water Chlorinator, before the water was treated. The second sample was taken at the tap, as water was leaving the tank, and if those systems had a CTI-8, after the water had received a dose of chlorine.

Just one village of the 21 visited with a CTI-8 installed lacked chlorine tablets at the time of the sampling. This indicates that the CTI-8 is maintained in good operating condition by the vast majority of communities that use it.

Of the twenty villages tested with functioning water chlorinators, dangerous bacterial contamination was discovered in the piped water (before chlorination treatment) reaching three villages. Although a 15% contamination rate is an alarming figure, putting thousands of lives at risk, it should be noted that this study was not designed to indicate the overall frequency of bacterial contamination in rural water sources, as numerous variables influence the presence of bacteria at any given time, including weather, season, location, day, and type of initial water source.

As was to be expected through the action of chlorine, all water samples leaving the tanks with the CTI-8 installed tested negative for bacteria. These results indicate that **the CTI-8 controls bacterial contamination without exception and over time.** TABLE 1 shows the results of laboratory tests, as reported by MINSA.

Water samples were also collected in 10 communities without the CTI-8 installed, seven (70%) of which had bacterial contamination prior to reaching the tank as well as at the community tap, representing a health risk to the health of the population.

Communities that did not have a water chlorinator installed had a significantly higher likelihood of contaminated drinking water entering their water tank than those that did have a CTI-8 (70% in communities without a CTI-8, against 15% in those with CTI-8). Program staff has observed that villages that install water chlorination systems are, in general, more actively engaged in maintaining hygienic water systems, all the way from the water source to the tank, which may explain the correlation.

As a whole, a significant number of the community water sources tested had the fortune of receiving water in safe drinking condition *at the time of the sample* (21 of 31 sampled populations, or 67%). But only those populations with CTI-8 had ***the assurance of drinking safe water***. This is significant, considering that water contamination conditions change quickly as a result of weather conditions, human actions, and other external factors. Where today there is no presence of bacterial contamination, tomorrow may show the opposite.

Table 1 – Results from bacterial water analyses in communities with and without CTI-8

		Does system have a CTI-8 installed?		Did the CTI-8 have chlorine tablets?		With CTI-8 Chlorinator				Without CTI-8 Chlorinator			
						Pre CTI-8		Post CTI-8		Pre CTI-8		Post CTI-8	
						(Bacterial presence)				(Bacterial presence)			
	Community Name	**Yes**	**No**	**Yes**	**No**	**Pos.**	**Neg.**	**Pos.**	**Neg.**	**Pos.**	**Neg.**	**Pos.**	**Neg.**
1	La Granja	X		X			X		X				
2	Lomas de Guadalupe	X		X		X			X				
3	Waswali Central	X		X			X		X				
4	Paz y Reconciliación	X		X			X		X				
5	Paiwas Sector 1	X		X			X		X				
6	Paiwas sector 2	X		X			X		X				
7	Samulali	X		X			X		X				
8	Mercedes # 2	X		X			X		X				
9	Hato el Chilamate	X		X			X		X				
10	Hacienda Sta Emilia	X		X		X			X				
11	Sisle	X		X			X		X				
12	Sasle	X		X			X		X				
13	Venecia	X		X			X		X				
14	El Pelon	X		X		X			X				
15	El Mojon	X		X			X		X				
16	San Gregorio	X		X			X		X				
17	Jiguina	X		X			X		X				
18	Mancotal Arriba	X		X			X		X				
19	La Esmeralda	X		X			X		X				
20	La Fundadora	X		X			X		X				
21	Pueblo Nuevo	X			X		X		X				
22	Tepeyac***	X											
23	La Grecia***	X											
24	La Amancia***	X											
25	Yaule #2***	X											
26	La Concordia***	X											
27	Mercedes # 1		X								X		X
28	El Libano		X							X		X	
29	Valle Los Herrera		X								X		X
30	El Sarsal		X							X		X	
31	Los Limones		X							X		X	
32	La Florida		X							X		X	
33	Las Tejas #2		X							X		X	
34	El Barro #1		X							X		X	
35	Lipolulo		X								X		X
36	La Suana		X							X		X	
37	El Limixto***		X										
	TOTAL	**26**	**11**	**20**	**1**	**3**	**18**	**0**	**21**	**7**	**3**	**7**	**3**
	Communities visited	**37**		**21**						**10**			

***Water samples could not be taken in these communities due to lack of access to the water tank.

Community Surveys on Health and Water Quality

Interviews were conducted in 37 villages to collect information on the communities, the water supply to households, and on general health. With respect to water supply, the survey covered points relating to catchment sources, water tanks, and water pipes. In water systems with the CTI-8 installed, additional questions were asked on its state of maintenance. Where there was no water treatment, villagers were asked questions about the attitude of the community towards installing a CTI-8.

Key findings:

Although there are a good percentage of homes that have water at all hours of the day (67%), on average, nearly one-third of households receive water only partially during the day. 20% of households have water only a few hours a day. Lack of water, even for a few hours can increase the use of contaminated containers to store water, indirectly increasing the risk of ADD. Inside the home, villagers use a number of different containers to store water for use during the day. These containers are not generally cleaned or sanitized between uses and could constitute a source of contamination.

With regard to water catchments, most are artesian wells, with water flowing out from the ground in remote areas protected by a cement box or encasements. Only a minority of the catchments are underground wells, indicating that the water capture, unless well protected, could be a weak and exposed point in most Nicaraguan rural water systems, especially when some of the villagers have their homes near the water source, where human waste can contaminate the source. According to many communities, a significant risk of contamination comes from the use of pesticides.

All the communities interviewed had a storage tank, which are generally seen as sufficient to supply the consumption needs of the population. This would not be the case in communities where water service is for only a few hours of the day, though. In general, there are common practices for the cleaning of tanks, but 16% of tanks are washed every three months or more infrequently, thus providing opportunities for the intrusion of organic materials and other pollutants between clean ups.

Networks of pipes carrying water are usually made of iron or PVC. Although the study did not measure the frequency with which pipes are damaged and thus open to contamination, the authors can report from previous experiences that these breaks can be a significant cause of contamination, and should be attended to immediately.

Health conditions in the communities confirm the existence of areas of risk, such as fecal matter left in the open outdoors, the intrusion of rainwater in latrines with consequent spills on surfaces, the poor disposal of household waste, and the pervasive presence of insects and animals that are vectors for diseases, combine to frequently punish villagers, in particular children. These are all crucial factors for the more general elimination of acute diarrheal diseases. The chlorination of water is a critical step, but other measures will be needed for a more complete success.

Communities with CTI-8 systems show chlorinators have been working for a considerable time, with 80% of them in service for at least two years. This speaks positively of the durability of the CTI-8 and the value with which it is perceived by the communities, and in particular, the CAPS. More importantly, 100% of the CAPS declared that before the presence of the CTI-8, the frequency of acute diarrheal diseases was higher and that it decreased once the chlorination of water was started. Those communities without CTI-8 also have a very positive attitude towards installing a CTI-8 in the near future. Communities with a stronger presence of voluntary organizations and professionals seem more likely to install a CTI-8, indicating the importance of community support from outside organizations.

Table 2.7: Waste management and hygiene conditions

		With CTI-8 Installed		Without CTI-8 Installed		TOTALS	
		#	%	#	%	#	%
Fecal matter in the open air?	Yes	23	88%	11	100%	34	92%
	No	3	12%	0	0%	3	8%
Do the latrines overflow from winter rainfalls?	Yes	19	73%	6	46%	25	64%
	No	7	27%	7	54%	14	36%
Observed insect/vermin infestations:	Flies	26	100%	11	100%	37	100%
	Mosquitos	26	100%	9	82%	35	95%
	Bed bugs	17	65%	4	36%	21	57%
	Mice	26	100%	11	100%	37	100%
	Rats	26	100%	11	100%	37	100%
How many activities are there to educate the community?	Many	26	100%	Did not ask communities without a CTI-8			
	Few	0	0%				
	None	0	0%				
Is the community interested in environmental education materials?	Yes	26	100%				
	No	0	0%				
Where are grey and black waters discharged?	Septic tanks	Did not ask communities with CTI-8		0	0%		
	In the courtyard			8	73%		
	In streams			3	27%		
How is garbage disposed?	Burned			6	55%		
	Buried			4	36%		
	In the wind			11	100%		

Table 2.8: Status of CTI-8

Data collected in 26 communities with a CTI-8 installed

		#	%
How old is the CTI-8?	Less than 6 months	2	8%
	7 months to 1 year	5	19%
	2 to 5 years	13	50%
	6 to 9 years	3	12%
	More than 10 years	3	12%
Is the CTI-8 in good working condition?	Yes	26	100%
	No	0	0%
Is the CTI-8 well-protected?	Yes	20	77%
	No	6	23%
What is the frequency of chlorine tablet refilling?	Every 3 days	1	4%
	Weekly	12	46%
	Every 10 days	1	4%
	11 to 15 days	10	38%
	15 to 25 days	2	8%
Has the community accepted chlorine treatment?	Yes	26	100%
	No	0	0%
Did you experience higher ADD incidence prior to CTI-8?	Yes	26	100%
	No	0	0%
Have you seen a reduction on ADD incidence post-CTI-8 installation?	Yes	26	100%
	No	0	0%
Would you recommend installing the CTI-8 to other communities?	Yes	26	100%
	No	0	0%

Incidence of Acute Diarrheal Diseases in Communities

To determine how the installation of water chlorination systems impact public heath, Mr. Byron García at MINSA's office in Matagalpa collected and analyzed three years' of medical data from patient visits at health centers in 33 communities—in 18 villages with a CTI-8 and 15 villages with no chlorination technology. Table 3.3 presents the average ADD rate (cases per thousand people) in 15 villages with no chlorinator and 18 villages with a CTI-8 between 2011 and 2013. See Appendix I, table 3.1 and 3.2, for ADD data for each community by year.

There is a widespread pattern of fluctuation in the rate of the ADD incidence from year to year, which can be attributed mainly to variable climatic conditions, floods, contagion, etc. These conditions seem to impact all communities across the board on a given year, whether or not they have the chlorinator CTI-8 installed.

Table 3.3: Average ADD rate in Villages*

Based on patients visiting MINSA health centers in 15 villages with no chlorinator and 18 villages with CTI-8

	2011	2012	2013	2011-2014 Average
ADD Rate in Communities with No CTI-8 Chlorinator	153.9	126.2	130.1	136.7
ADD Rate in Communities with CTI-8	59.6	39.6	62.1	53.8
Reduction of reported cases with CTI-8 chlorinator	**61%**	**69%**	**52%**	**61%**

*Average ADD rate per thousand people

Communities that have the chlorinator show a markedly lower ADD incidence rate to that of the communities without CTI-8. The rates in each year are significantly lower, around 40% of the observed rates where there are no CTI-8's. On average for the three years, the incidence rate is 54 inhabitants per thousand against 136 affected inhabitants where there is no water chlorination. **Chlorination of drinking water through the CTI-8 determines a marked improvement of the conditions of public health in these communities.**

IV. Discussion

The results of this study revealed **valid** and **conclusive** data regarding the treatment of drinking water through the CTI-8 chlorinator and prevention of incidences of acute diarrheal diseases (ADD) in rural Nicaragua. These findings may also apply to other countries or regions of the world where the quality of water, the level of organization of their communities, and their water systems are similar.

The study shows that chlorination of rural water sources through the CTI-8 significantly reduces bacterial contamination and incidences of ADD. All water systems with the CTI-8 installed and operating correctly provided water free of bacteria, even when the water entering the system from the source was contaminated. This data indicates that free chlorine is totally effective at eliminating the presence of harmful bacteria, reinforcing the status of water chlorination as a global standard for water treatment. Additionally, comparison of the three-year incidence of ADD in rural villages indicates that communities without a water chlorination system exhibited more than twice the rate of ADD (154% higher), than in those with a chlorinator present (136 cases per thousand inhabitants against 54 cases per thousand where there is chlorination).

Installation of the CTI-8 Chlorinator provides sustainable access to safe drinking water. The overwhelming majority of communities have maintained their chlorinators over time, as evidenced by the fact that 95% of the 21 of the installed CTI-8 units inspected during surprise visits to communities were stocked with chlorine and in good operating condition. In this regard, the CTI-8 program, which maintains regional “chlorine banks” with an inventory of tablets available for local purchase is providing sufficient access to chlorine replacements. This is in contrast to what program staff have observed in chlorinator systems requiring liquid chlorine, which is much more difficult to transport and restock in chlorination units. Notably, the majority of villages surveyed (80%) had been operating the chlorinators for at least two years, indicating long-term adoption of the technology. In addition, the sustainability achieved through the CTI-8 chlorinator and program support is significantly higher than the global average, which studies indicate range between just 60-70% sustainability.[5]

Reducing waterborne disease cannot be achieved by water treatment technologies alone. Communities can still suffer from ADD even when their water sources are free from contamination, indicating that hygiene and sanitation education are critical. In this regard, the activity of the Health Ministry and CAPS at the local level is essential. Enhancing the level of public education on sewage and toilet contamination, the frequent washing of hands, and the protection of drinking water in each transfer from the source is critical. However, the chlorination of water is an excellent step forward to the day in which rural residents of Nicaragua will be able to drink their water without fear of bacterial contamination leading to diarrheal diseases.

In villages with a CTI-8 in operation there is a stronger presence of volunteer civil service organizations, community health leaders, and NGOs, which together raise the level of community education and support on issues of water and public health. Along with them, stronger assistance by agencies of the program, MINSA support and the participation of CAPS, collectively represent a higher level of sanitation education and community sensitivity than those communities that do not have a CTI-8. As a result, communities with more active participation from these groups, tend to experience less bacterial contamination in their water sources.

The study findings demonstrate that a significant reduction on the incidence of acute diarrheal disease would be observed if the nearly 5,400 Nicaraguan rural water systems had a CTI-8 chlorinator in operation. This would not only bring a concrete relief to rural residents of Nicaragua, but also free up a considerable amount of human and material resources for other aspects of Nicaraguan public health.

Recommendations

Installations of the CTI-8 should be expanded to cover all rural water systems in Nicaragua. At the date of this study’s publication, there were more than 560 CTI-8s in operation, reaching about 10% of rural water sources, and providing access to safe water to more than 300,000 people. Installations are being led by Compatible Technology International (CTI) and its NGO partners, with support from CAPS members and Health Ministry officials (see Appendix IV: CTI-8 Program in Nicaragua). Key to accelerating the dissemination of the CTI-8:

- **Extend the efforts of governmental organizations in support of the CTI-8 program nationwide.** Organizations, such as MINSA Matagalpa and MINSA Jinotega, are of fundamental importance in the fight for public health and against acute diarrheal diseases. Much of the progress made to

[5] http://rural-water-supply.net/en/resources/details/419

date in this program must be credited to the support from MINSA Matagalpa and Jinotega personnel. To achieve success at the national level, it is necessary that other regional bodies of the MINSA join the effort.

- **Motivate all the CAPS in Nicaragua to incorporate the chlorinator CTI-8 in their water systems.** These community organizations already have legal recognition, and can capitalize on the efforts of volunteer citizens, as they are in charge of the water systems and, at the national level, have a central leadership group. CAPS provide for the maintenance of water systems and are invaluable in protecting the health of rural residents. To bring the program to an expanded national level, it is necessary to gain the support of all CAPS in Nicaragua.

- **Inspire other Non-governmental organizations** (NGOs), interested and willing to actively participate in the CTI-8 program, to join CTI and its partners to make the purification of water in all of Nicaragua's rural populations a reality. Any organization interested in the program is welcome to communicate with and direct inquiries to the contacts provided at the end of this report to launch a similar effort in the local area where they are already present.

- **Motivate any other organization or individual** interested in the sanitation of drinking water to extend the use of the CTI-8, both in Nicaragua and in any other country or region of the world.

V. Appendix

Appendix I: Data

Table 1 – Results from bacterial water analyses in communities with and without CTI-8

		Does system have a CTI-8 installed?		Did the CTI-8 have chlorine tablets?		With CTI-8 Chlorinator				Without CTI-8 Chlorinator			
						Pre CTI-8		Post CTI-8		Pre CTI-8		Post CTI-8	
						(Bacterial presence)				(Bacterial presence)			
	Community Name	**Yes**	**No**	**Yes**	**No**	**Pos.**	**Neg.**	**Pos.**	**Neg.**	**Pos.**	**Neg.**	**Pos.**	**Neg.**
1	La Granja	X		X			X		X				
2	Lomas de Guadalupe	X		X		X			X				
3	Waswali Central	X		X			X		X				
4	Paz y Reconciliación	X		X			X		X				
5	Paiwas Sector 1	X		X			X		X				
6	Paiwas sector 2	X		X			X		X				
7	Samulali	X		X			X		X				
8	Mercedes # 2	X		X			X		X				
9	Hato el Chilamate	X		X			X		X				
10	Hacienda Sta Emilia	X		X		X			X				
11	Sisle	X		X			X		X				
12	Sasle	X		X			X		X				
13	Venecia	X		X			X		X				
14	El Pelon	X		X		X			X				
15	El Mojon	X		X			X		X				
16	San Gregorio	X		X			X		X				
17	Jiguina	X		X			X		X				
18	Mancotal Arriba	X		X			X		X				
19	La Esmeralda	X		X			X		X				
20	La Fundadora	X		X			X		X				
21	Pueblo Nuevo	X			X		X		X				
22	Tepeyac***	X											
23	La Grecia***	X											
24	La Amancia***	X											
25	Yaule #2***	X											
26	La Concordia***	X											
27	Mercedes # 1		X								X		X
28	El Libano		X							X		X	
29	Valle Los Herrera		X								X		X
30	El Sarsal		X							X		X	
31	Los Limones		X							X		X	
32	La Florida		X							X		X	
33	Las Tejas #2		X							X		X	
34	El Barro #1		X							X		X	
35	Lipolulo		X								X		X
36	La Suana		X							X		X	
37	El Limixto***		X										
	TOTAL	**26**	**11**	**20**	**1**	**3**	**18**	**0**	**21**	**7**	**3**	**7**	**3**
	Communities visited	**37**		**21**						**10**			

***Water samples could not be taken in these communities due to lack of access to the water tank.

Results from survey questionnaires administered to CAPS in 37 communities in Matagalpa and Jinotega

Table 2.1: Number of CAPS members

	With CTI-8 Installed		Without CTI-8 Installed		TOTALS	
	#	Average #	#	Average #	#	Average #
Number of CAPS interviewed	**26**		**11**		**37**	
Men	112	4.3	55.0	5.0	167	4.5
Women	67	2.6	32.0	2.9	99	2.7
Total	179	6.9	87.0	7.9	266	7.2

Table 2.2: Organizations and professionals present in the community

	With CTI-8 Installed		Without CTI-8 Installed		TOTALS	
	#	%	#	%	#	%
Churches	24	92%	9	82%	33	89%
Government Cabinets	20	77%	7	64%	27	73%
Women's Org.	13	50%	7	64%	20	54%
Cooperatives	19	73%	3	27%	22	59.5%
Youth Org.	16	61.5%	8	73%	24	65%
Professors	26	100%	10	91%	36	97%
Col. Volunteers	13	50%	7	64%	20	54%
Midwives	23	88.5%	7	64%	30	81%
Brigades	22	85%	2	18%	24	65%

Table 2.3: Community drinking water supply & systems

		With CTI-8 Installed		Without CTI-8 Installed		TOTALS	
		#	%	#	%	#	%
How does the water service supply your home?	Homes with a water service supply	3686	36%	1241	55%	4927	39%
	Households with personal water faucets	2944	29%	588	26%	3532	28%
	Households with communal water faucets	2944	29%	342	15%	3286	26%
	Households without water service	746	7%	87	4%	833	7%
	Total estimated homes	**10320**	100%	**2258**	100%	**12578**	100%
If your home has a water service, what is the length of service?	All day	16	62%	8	80%	24	67%
	Half the day	4	15%	1	10%	5	14%
	Less than 5 hours a day	5	19%	1	10%	6	17%
	3 times a week	1	4%	0	0%	1	3%
Where is water stored in the home?	Water pitchers	25	96%	11	100%	36	97%
	Gallon jugs	22	85%	11	100%	33	89%
	Barrels	25	96%	11	100%	36	97%
	Well	17	65%	8	73%	25	68%
	Buckets	20	77%	11	100%	31	84%
	Large jugs	17	65%	9	82%	26	70%
Are the means of water storage protected?	Yes	16	48%	11	100%	27	61%
	No	17	52%	0	0%	17	39%

Table 2.4: Water catchment sources

		With CTI-8 Installed		W/o CTI-8 Installed		TOTALS	
		#	%	#	%	#	%
Type of water source	River	0	0%	0	0%	0	0%
	Stream/creek	7	28%	0	0%	7	19%
	Natural groundwater source	15	60%	11	100%	26	72%
	Dug well	3	12%	0	0%	3	8%
Distance from the community to the catchment source	From 0 to 3 km	11	42%	6	55%	17	46%
	From 3 to 6 km	12	46%	5	45%	17	46%
	6 km and over	3	12%	0	0%	3	8%
Is the source easily accessible by unwelcome people or animals?	Yes	9	38%	5	45%	14	40%
	No	15	63%	6	55%	21	60%
Is the water catchment source fenced in?	Yes	20	83%	7	64%	27	77%
	No	4	17%	4	36%	8	23%
What types of contamination risks are there to the catchment source?	Toilet for people and animals	2	7%	5	45%	7	18%
	Coffee production waste	7	26%	0	0%	7	18%
	Livestock waste	2	7%	1	9%	3	8%
	Homes in the zone above where the water is captured	4	15%	0	0%	4	11%
	Use of pesticides	12	44%	5	45%	17	45%
What types of water filters are present at the catchment source?	Slow filter	0	0%	0	0%	0	0%
	Fast filter	0	0%	0	0%	0	0%
	Course filter	21	81%	9	82%	30	81%
	None	5	19%	2	18%	7	19%
	Dynamic filter	0	0%	0	0%	0	0%
Are there signs posted at the source to prevent unlawful entry?	Yes	3	13%	1	9%	4	11%
	No	21	88%	10	91%	31	89%
Are these areas protected and/or reforested?	Yes	26	100%	10	91%	36	97%
	No	0	0%	1	9%	1	3%
Is the water source the property of the community?	Yes	22	88%	8	73%	30	83%
	No	3	12%	3	27%	6	17%

Table 2.5: Pipeline system

		With CTI-8 Installed		Without CTI-8		TOTALS	
		#	%	#	%	#	%
How is the pipeline system constructed?	The entire water system is made of PVC	2	8%	2	18%	4	11%
	The water system has PVC and steel pipes	24	92%	6	55%	30	81%
	The water system has PVC, steel pipes, & plastic hose	0	0%	3	27%	3	8%
	Water system with plastic hose	0	0%	0	0%	0	0%
	There are no pipes	0	0%	0	0%	0	0%
Are there risks to the system?	River passes	15	54%	4	21%	19	40%
	Stream passes	0	0%	1	5%	1	2%
	Saltwater leakage	5	18%	6	32%	11	23%
	People and animals	8	29%	8	42%	16	34%
How are repairs done:	PVC accessory	22	30%	5	18%	27	27%
	Glue PVC	22	30%	10	36%	32	32%
	Temporary rubber patch	12	16%	4	14%	16	16%
	Melt tube to join tubes	17	23%	9	32%	26	26%

Table 2.6: Water storage tank

		With CTI-8 Installed		Without CTI-8 Installed		TOTALS	
		#	%	#	%	#	%
Is there a water tank?	Yes	26	100%	11	100%	37	100%
	No	0	0%	0	0%	0	0%
Age of water tank	New	1	4%	1	9%	2	5%
	1 to 4 years	8	32%	2	20%	10	29%
	5 to 10 years	4	11%	7	41%	11	21%
	10 to 20 years	5	14%	0	0%	5	11%
	More than 20 years	8	24%	1	8%	9	20%
Distance from the community to the tank	From 0 to 3 km	18	69%	9	82%	27	73%
	From 3 to 6 km	5	19%	1	9%	6	16%
	More than 6 km	3	12%	1	9%	4	11%
Tank capacity	Good supply to community	26	100%	11	100%	37	100%
	Regular/at times insufficient	0	0%	0	0%	0	0%
	Without sufficient capacity	0	0%	0	0%	0	0%
Does the tank show cracks and/or overflow outlets?	Yes	5	19%	2	18%	7	19%
	No	21	81%	9	82%	30	81%
Has the tank been repaired?	Yes	13	50%	4	36%	17	46%
	No	13	50%	7	64%	20	54%
How often is the tank cleaned?	Monthly	20	77%	7	64%	27	73%
	Every 2 months	2	8%	2	18%	4	11%
	4 times a year	0	0%	2	18%	2	5%
	2 times a year	4	15%	0	0%	4	11%
	It is not cleaned	0	0%	0	0%	0	0%
Is the tank painted inside?	Yes	4	15%	0	0%	4	11%
	No	22	85%	11	100%	33	89%
Is the tank painted outside?	Yes	23	88%	6	55%	29	78%
	No	3	12%	5	45%	8	22%
Can rainwater come inside the tank?	Yes	2	8%	3	27%	5	14%
	No	24	92%	8	73%	32	86%
Are there human intrusions in the tank?	Yes	4	15%	5	50%	9	28%
	No	22	85%	6	55%	28	76%
Is the tank area fenced in?	Yes	22	85%	7	64%	29	78%
	No	4	15%	4	36%	8	22%
Are there risks at the tank area?	Flood Zone	4	16%	1	9%	5	14%
	Near the river	0	0%	0	0%	0	0%
	Near the ravine/stream	1	4%	0	0%	1	3%
	Saltwater leakage	0	0%	0	0%	0	0%
	There are no risks	21	84%	10	91%	31	86%

Table 2.7: Public Health-Waste management and hygiene conditions

		With CTI-8 Installed		Without CTI-8 Installed		TOTALS	
		#	%	#	%	#	%
Does fecal matter exist out in the open?	Yes	23	88%	11	100%	34	92%
	No	3	12%	0	0%	3	8%
Do the latrines overflow from winter rainfalls?	Yes	19	73%	6	46%	25	64%
	No	7	27%	7	54%	14	36%
Observed insect/vermin infestations:	Flies	26	100%	11	100%	37	100%
	Mosquitos	26	100%	9	82%	35	95%
	Bed bugs	17	65%	4	36%	21	57%
	Mice	26	100%	11	100%	37	100%
	Rats	26	100%	11	100%	37	100%
How many activities are there to educate the community?	Many	26	100%	Did not ask communities w/o a CTI-8			
	Few	0	0%				
	None	0	0%				
Is the community interested in environmental education?	Yes	26	100%				
	No	0	0%				
Where are grey and black waters discharged?	Septic tanks	Did not ask communities with CTI-8		0	0%		
	In the courtyard			8	73%		
	In streams			3	27%		
How is garbage disposed?	Burned			6	55%		
	Buried			4	36%		
	In the wind			11	100%		

Table 2.8: Status of CTI-8

Data collected in 26 communities with a CTI-8 installed

		Totals #	Totals %
How old is the CTI-8?	Less than 6 months	2	8%
	7 months to 1 year	5	19%
	2 to 5 years	13	50%
	6 to 9 years	3	12%
	More than 10 years	3	12%
Is the CTI-8 in good working condition?	Yes	26	100%
	No	0	0%
Is the CTI-8 well-protected?	Yes	20	77%
	No	6	23%
What is the frequency of chlorine tablet refilling?	Every 3 days	1	4%
	Weekly	12	46%
	Every 10 days	1	4%
	11 to 15 days	10	38%
	15 to 25 days	2	8%
Has the community accepted the use of chlorine as a water treatment?	Yes	26	100%
	No	0	0%
Did you experience higher ADD incidence prior to CTI-8?	Yes	26	100%
	No	0	0%
Have you seen a reduction on ADD incidence post-CTI-8 installation?	Yes	26	100%
	No	0	0%
Would you recommend installing the CTI-8 to other communities?	Yes	26	100%
	No	0	0%

Table 2.9: Interest in installing Water Chlorinator

Data collected in 11 communities with no water chlorination technology

		Totals #	Totals %
Does the community believe installing a CTI-8 would be important for community health?	Yes	11	100%
	No	0	0%
Is the community in agreement to install a CTI-8 to disinfect water?	Yes	11	100%
	No	0	0%
Is the community okay with training to control epidemics?	Yes	11	100%
	No	0	0%
What types of institutions visit your community?	City Hall	0	0%
	Ministry of Health	9	82%
	Ministry of Education	7	64%
	Women's network	4	36%
	Political Organizations	4	36%
	Technicians of the Ministry of Forestry	3	27%
	Ministry of Environment	3	27%
	Ministry of Agriculture	1	9%
	Non-Government Organization	4	36%

Table 3.1: Three-Year Comparison of ADD Incidence Rates in communities without the CTI-8

Based on patients visiting MINSA health centers

No	Communities without CTI-8 Water Chlorinator	2011			2012			2013			
		ADD Cases	Village Pop.	ADD Rate*	ADD Cases	Village Pop	ADD Rate*	ADD Cases	Village Pop	ADD Rate*	
1	Quebrada Honda	212	1960	**108.2**	184	2020	**91.1**	202	2160	**93.5**	
2	Las Escaleras	181	2040	**88.7**	97	2140	**45.3**	169	2340	**72.2**	
3	Jucuapa Abajo	112	420	**266.7**	184	450	**408.9**	198	480	**412.5**	
4	La Corneta	59	545	**108.3**	71	580	**122.4**	123	600	**205.0**	
5	Nuevo Amanacer	149	1595	**93.4**	148	1740	**85.1**	132	1800	**73.3**	
6	Laguna Seca	83	1770	**46.9**	76	1805	**42.1**	43	1841	**23.4**	
7	Tejerina	126	675	**186.7**	91	705	**129.1**	83	720	**115.3**	
8	Apante Grande	63	165	**381.8**	75	175	**428.6**	72	185	**389.2**	
9	Jamaica	113	210	**538.1**	79	220	**359.1**	84	240	**350.0**	
10	Aguas Frias	98	210	**466.7**	88	220	**400.0**	82	240	**341.7**	
11	Las Lajas	92	175	**525.7**	86	186	**462.4**	74	200	**370.0**	
12	Las Tejas Numero 1	89	730	**121.9**	76	750	**101.3**	102	780	**130.8**	
13	Cacao Sur	120	215	**558.1**	68	220	**309.1**	73	240	**304.2**	
14	Limixto	98	155	**632.3**	85	165	**515.2**	79	180	**438.9**	**3 YR**
15	San Jose	117	260	**450.0**	63	280	**225.0**	85	300	**283.3**	**Avg.**
	TOTAL	**1712**	**11125**	**153.9**	**1471**	**11656**	**126.2**	**1601**	**12306**	**130.1**	**136.7**

*Rate per thousand people

Table 3.2: Three-Year Comparison of ADD Incidence Rates in communities with the CTI-8

Based on patients visiting MINSA health centers

No	Communities with a CTI-8 Water Chlorinator	2011			2012			2013			
		ADD Cases	Village Pop.	ADD Rate*	ADD Cases	Village Pop	ADD Rate*	ADD Cases	Village Pop	ADD Rate*	
1	Molino Norte	75	630	**119.0**	47	642	**73.2**	28	642	**43.6**	
2	La Flor	12	159	**75.5**	2	162	**12.3**	9	162	**55.6**	
3	Palcila	138	353	**390.9**	78	360	**216.7**	67	360	**186.1**	
4	Matazano	26	189	**137.6**	14	192	**72.9**	60	192	**312.5**	
5	Chilamate Ojo deAgua	9	424	**21.2**	4	432	**9.3**	12	432	**27.8**	
6	Jucuapa Centro	35	383	**91.4**	35	390	**89.7**	56	390	**143.6**	
7	Aranjuez	28	565	**49.6**	8	576	**13.9**	33	576	**57.3**	
8	Las Banquitas	38	706	**53.8**	30	720	**41.7**	41	720	**56.9**	
9	El Guineo	23	494	**46.6**	30	504	**59.5**	21	504	**41.7**	
10	La Granja	25	200	**125.0**	21	204	**102.9**	32	204	**156.9**	
11	Jucuapa Occidental	8	424	**18.9**	2	432	**4.6**	14	432	**32.4**	
12	Malespin	8	294	**27.2**	5	300	**16.7**	4	300	**13.3**	
13	La Grecia	5	565	**8.8**	3	576	**5.2**	8	576	**13.9**	
14	La Amancia	5	824	**6.1**	1	840	**1.2**	6	840	**7.1**	
15	Tepeyac	31	1041	**29.8**	38	1068	**35.6**	45	1068	**42.1**	
16	Primavera	21	618	**34.0**	12	630	**19.0**	22	630	**34.9**	
17	Nuestra Tierra	11	530	**20.8**	4	540	**7.4**	52	540	**96.3**	**3 YR**
18	Paz y Reconciliacion	45	706	**63.7**	34	720	**47.2**	68	734	**92.6**	**Avg.**
	TOTAL	**543**	**9105**	**59.6**	**368**	**9288**	**39.6**	**578**	**9302**	**62.1**	**53.8**

*Rate per thousand people

Table 3.3: Average ADD rate in Villages*

Based on patients visiting MINSA health centers in 15 villages with no chlorinator and 18 villages with CTI-8

	2011	**2012**	**2013**	**2011-2014 Average**
ADD Rate in Communities with No Chlorinator	153.9	126.2	130.1	136.7
ADD Rate in Communities with CTI-8	59.6	39.6	62.1	53.8
Reduction of reported cases in communities with CTI-8 water chlorinator	**61%**	**69%**	**52%**	**61%**

*Average ADD rate per thousand people

Appendix II: Rural Nicaragua Water Systems

Typical Nicaraguan rural water systems have the following common features:

Water Source
- An open water source, where the water catchment at the source is remote and isolated from contaminating factors, such as those created by the presence of animals, human dwellings, or other sources of contamination.
    - The point of capture is usually closed, where the water comes into a confined space, typically a cement box with coarse filtration and sand inside.
- A closed water system, consisting of a sealed well and pump. The water filters through the ground, making its way to the water table where the pump elevates the water to the elevated tank. Generally a water filter is not needed for this type of water source as the ground serves as the filter.

Main Pipe
- The water is transported by PVC or metal pipes from the water source to the elevated tank with flow rates between 7 and 70 liters per minute. Water pipes may be pressurized with a pump or may flow by gravity if the water source is at a higher elevation than the tank. The turbidity of the water should be less than 10 units entering the storage tank.

Storage Tank
- The pipeline discharges water into a cement storage tank built on a hill or in a metal or plastic elevated tank. The tank is closed with an access cover to prevent pollution from air or from human and animal interference.
- The tank is emptied and cleaned regularly, e.g. once a month. Before placing the tank back in service, the ideal step is to give it a "chlorine shock" to be discharged through the pipe coming down from the tank to homes, contributing to the cleaning of the pipelines.

Distribution System
- From the tank, drinking water is distributed by PVC or metal pipes that run to individual households or to public water supply points and are controlled with simple water valves. The water pressure is created by the elevation of the tank.

Appendix III: The CTI-8 Water Chlorinator

The CTI-8 is a low-cost and easy-to-manufacture water chlorinator constructed with PVC materials available in most local markets. It was designed to be installed in small gravity-fed aqueducts and those supplied by electric pumping. The equipment is usually located on the pipe supplying the water storage tanks. The CTI-8 delivers a controlled dose of chlorine from solid chlorine tablets, sufficient to inactivate most of the pathogens that are present in community drinking waters.

The CTI-8 is designed to remove microbial contamination. It has no effect against physical pollution (for example, plant debris) or chemicals such as arsenic, pesticides, etc.

<u>Materials:</u>
- PVC pipes, "T" joints, and covers
- Glue for PVC pipe
- On/off PVC valves

Chlorine Supply:

Communities must have access to the proper chlorine approved for human consumption, and comprised of the proper chemical makeup (calcium hypochlorite and trichloroisocyanuric acid). In Nicaragua, CTI and partners have established several regional chlorine banks, which hold an inventory of chlorine tablets, so communities always have access to replacement chlorine.

Community Involvement:

It is vital that a well-trained CAPS (potable water committee), or similar organized body take ownership of maintaining the systems and engaging other community members. They take responsibility for regular monitoring of water and the chlorinator system, which entails:

- Measure the level of chlorine in the water 3 to 4 times a week initially and at least once a week once system is in normal operation. The chlorine measurement is made in the storage tank and at another point in the water distribution system
- Maintain a community fund to buy chlorine tablets, carry out maintenance, repairs, and monitoring

Cost:

- Initial approximate cost of materials, construction and installation: US $200
- Average cost of chlorine tablets: US$3 - US$ 10 per month, depending on population served

The installation of the chlorinator and its subsequent maintenance

- The chlorinator is easily installed, usually on top of the water tank at a point prior to the entrance of water into the tank, connecting a part or the total of the volume of water to the chlorinator.
- Inside the chlorinator, water runs and comes into contact with the chlorine tablets, dosing the water with a minuscule amount of chlorine, enough to be carried into the tank where the active chlorine eliminates bacteria. Once out of the tank, treated water is free of harmful bacteria.
- Prior and during the installation, the community representatives (CAPS leaders) are trained in assembly, installation, maintenance and repair of the chlorinator. Without moving parts, the chlorinator operates generally for years with no breaks or repairs needed.
- The CAPS staff is trained to in the use of a simple chlorine color-meter, which allows periodic control that ensures the chlorine level is appropriate to eliminate bacteria.
- At the time of installation, staff associated with the organizations in the program provide instructions for several hours on a number of public health and hygiene issues to raise the attention of the community to these issues.

Appendix IV: CTI-8 program in Nicaragua

Since 2008, nonprofit Compatible Technology International (CTI) has led efforts to help communities in rural Nicaragua access safe and affordable clean water through the installation of the CTI-8 Water Chlorinator. Promotion and installation of the CTI-8 is managed by staff at CTI and its NGO partners, who travel by bus, motorcycle, and foot to reach remote rural villages where they help locals assemble the chlorinator and attach it to their community water tanks.

Currently, CTI directly oversees installations in Northern Nicaragua. In other regions of the country, installations are primarily driven by NGOs EOS International in the West and Self-Help International (SHI) in the South. The key project partners and their staff in Nicaragua include:

Compatible Technology International (CTI), based in Saint Paul, Minnesota, USA, with offices in Matagalpa, Nicaragua, covering the Northern center of the country, with the following members in its team:

- Sergio Romero Sr., who began the CTI-8 program in Nicaragua nearly a decade ago and has taken it to its current level, assisted by
- Sergio Noel Romero Jr., who had responsibility for fielding this research and manages the chlorine banks, and
- Marlon Castro who is responsible for CTI-8 installations and the various aspects of the training and assistance to the CAPS

EOS International (EOS), based in Iowa, USA, with offices in San Isidro, Nicaragua, covering the Northwest of the country, with the following members in its water treatment team:

- Mr. Alvaro Rodriguez Davila, Director of EOS – Nicaragua, and
- Milton Rocha, directly responsible for coordinating the drinking water program

Self-Help International (SHI), based in Waverly, Iowa, USA and with offices in San Carlos, Nicaragua, covering the South of the country on the border, with the following members in its team:

- Jorge Luis Campos, Director of SHI, Nicaragua, and
- Orlando Montiel, directly responsible for the drinking water program

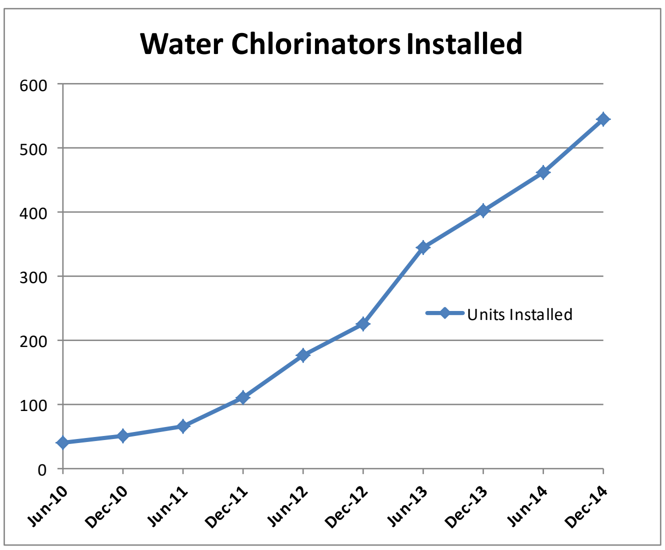
In each community installing CTI's Water Chlorinator, local CAPS leaders are trained to assemble their chlorinator, install it in their water system, and calibrate the system so it releases the correct amount of chlorine which can easily be measured using simple chlorine testing kits. Program staff also advises communities on improved sanitation and hygiene practices, with support from health Ministry officials, who provide health and sanitation education and monitor the general health and risk of waterborne disease among rural communities.

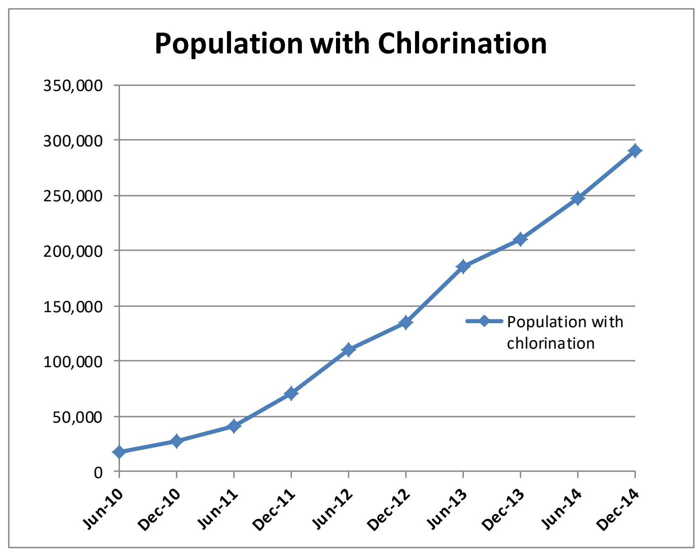
The CAPS purchase the Water Chlorinators on behalf of their villages and from each family in the village to fund the replacement chlorine tablets every few months, so the communities aren't dependent on outside funding to maintain their sources of safe water. To keep a constant supply of chlorine tablets within short distance from local villages, especially important during the rainy season when roads may become impassable and flooding contaminates all water sources; CTI has created over 20 regional chlorine banks that hold small inventories of tablets. This ensures that chlorination systems remain in operation at all times, protecting the villagers from bouts of bacterial diseases.

The ongoing maintenance of installed units is completely sustainable, without reliance on donor support. Outside support is only used for the growth of new unit installations. More than 300,000 people in more than 560 villages have sustainable sources of safe water through this program, and the program is currently reaching an additional 60,000 people every 12 months. Expansion of the program can be accelerated by growing the number of NGOs associated with the program, to achieve a more extensive geographic coverage that can eventually reach all of rural Nicaragua and allow rural Nicaraguans to have the capacity of chlorinating drinking water. Any organization that is interested in participating should contact: cti@compatibletechnology.org.

CTI-8 Installations in Nicaragua
2010-2015

	Jun-10	Dec-10	Jun-11	Dec-11	Jun-12	Dec-12	Jun-13	Dec-13	Jun-14	Dec-14
Number of units installed	39	50	66	109	176	225	345	402	462	545
Total population served with chlorinated water	17850	27486	41262	70115	110547	135421	184944	210541	247503	290000





Questions regarding this report or any aspect of rural water in Nicaragua, please feel free to contact the following by email:

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