User Field Guide for MINSA's In-Line Chlorinator

Developed by: Benjamin Yoakum *"Erachi"* a U.S. Peace Corps Volunteer

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This guide is not a completed work. Please, if you think revisions, additions or subtractions are necessary make them and disseminate them. If you make revisions please send the revised field guide to benyoakum@gmail.com. Please note who made the revisions and when these revisions were made! Please make sure updates are also made to the identical guide written in Spanish. Please keep MINSA technicians updated!

The most up to date field guide can be found at: http://usfmi.weebly.com/technical-briefs.html

1. Background Information on MINSA's In-Line Chlorinator:

MINSA's in-line chlorinator is an instrument that adds chlorine to rural gravity fed water supply systems (an aqueduct). The term "in-line" designates that the chlorinator is connected directly to the polyvinyl chloride (PVC) pipe that is transporting water from the catchment source to the storage/distribution tank. The chlorinator is attached 2-5 meters before the storage tank to the influent PVC pipe. The in-line chlorinator, shown in Figure 1, is made entirely of PVC.

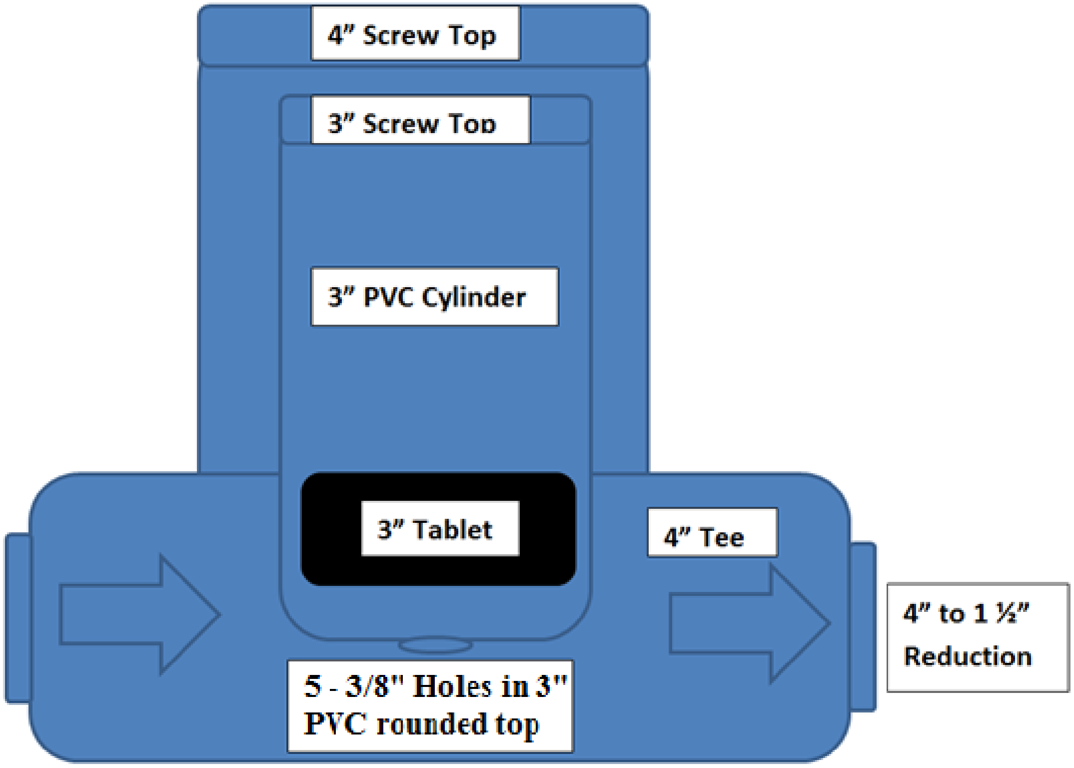
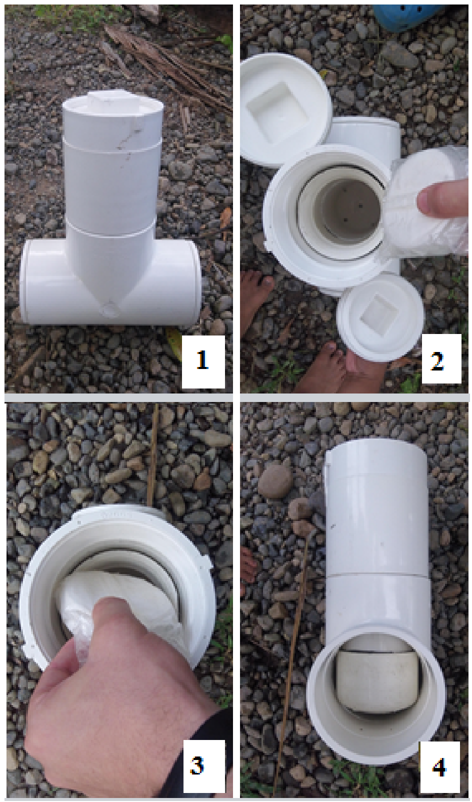


Figure 1: Diagram of MINSA's In-Line PVC Chlorinator (Orner, 2011)

The chlorinator is made of a 4-inch Tee that has a small segment of 4-inch PVC on the upper Tee which is then closed off by a 4-inch screw top. A 3-inch cylinder (made from 3-inch PVC pipe) is inserted into the 4-inch Tee being accessed by the screw top. This cylinder consists of a 3-inch rounded top that faces down and a 3-inch screw top that faces up toward the 4-inch screw top. Five holes that are approximately 3/8 inch in diameter are drilled into the bottom 3-inch rounded top. This entire 3-inch cylinder is glued into place inside the 4-inch Tee. A chlorine tablet(s) is added by removing both screw tops and placing the chlorine tablet(s) into the 3-inch cylinder and then closing the screw tops. This chlorinator can be attached to different size pipes by reducing the two ends of the 4-inch Tee to the size of the influent pipe. For example in Figure 1 the influent and effluent PVC pipes are stated to be 1.5 inches. Figure 2 shows an unconnected in-line chlorinator and Table 1 provides details of the chlorine tablets used in MINSA's in-line chlorinator.



1) Front view
2) Top view showing where the chlorine tablets would be inserted (Note: holes in bottom)
3) Top view showing chlorine tablet being inserted into chlorinator
4) Side view showing the 3 inch cylinder sitting all the way down in the 4 inch Tee

Figure 2: Photo Description of MINSA's In-Line Chlorinator

Table 1: Chlorine Tablet Product Specifications

Manufacturer	Productos Quimicos IBIS
Chemical Name	Calcium Hypochlorite
Weight of Tablet	200 grams
Shape of Tablet	Cylindrical "puck"
Diameter of Tablet	3 inches
Color of Tablet	white grayish
Chemical Formula	$Ca(OCl)_2$
Effective Chlorine	70% minimum

MINSA sells their In-Line chlorinators in San Felix, Chiriqui, pre-made with the aforementioned design to communities for $25. If you would like to purchase one of the chlorinators pre-made contact Fredy or Virgilio at:

Fredy: fredy.camarena@yahoo.es 6800-4455
Virgilio: virgilio0674@gmail.com 6782-4525

It is strongly recommended that you purchase your chlorinator directly from MINSA as they have more experience constructing them and will most likely be cheaper for your community as 3” and 4” pipes are expensive to purchase.

2. How to Install Your In-Line Chlorinator:
There are a few items you will need before attempting to install your in-line chlorinator:

1) Hacksaw – for cutting pipe
2) PVC Glue – a small bottle should be adequate
3) PVC shutoff valve – this needs to be the same size of the pipe where you are putting in the chlorinator
4) 2 reductions from 2” to the size of pipe where you are putting in the chlorinator
5) Teflon tape or a rubber 3” gasket (to seal the screw tops)
6) A MINSA In-Line Chlorinator

When installing the chlorinator you want select a location that is close to the storage tank but also on level ground. You can put the chlorinator further up the line (closer to your source and farther from the storage tank) but you need to consider the future additional work added to the operator to walk farther from the tank every week when adding a new chlorine tablet(s).

Once you have decided on a location for the chlorinator you need to turn off the water upstream of where you are planning to install the chlorinator. When the water is off cut the pipe and glue in the new shutoff valve first and then the chlorinator second (closer to the tank). There should be a few feet separating the shutoff valve from the chlorinator. This allows the user to easily replace the valve or the chlorinator without needing to replace both if only one breaks. See figure 3 for a visual description of this installation.

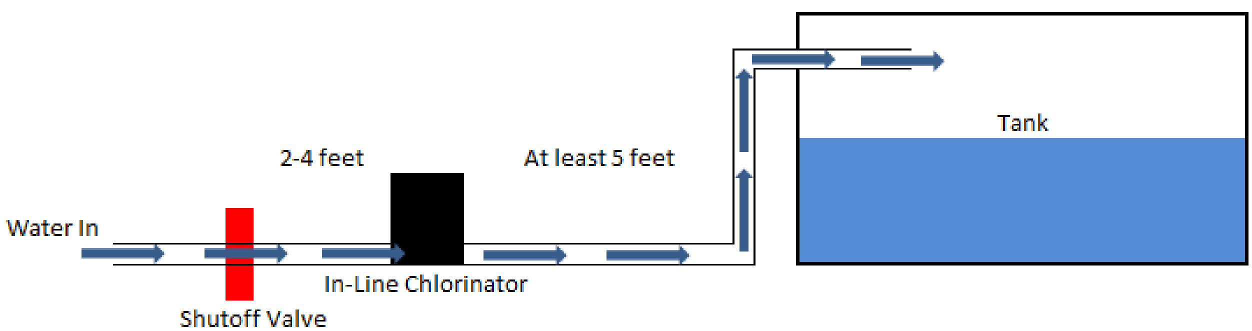


Figure 3: Location of Shutoff Valve, Chlorinator and Tank

The chlorinator if purchased from MINSA in San Felix comes with 2 reductions from 4” to 2” but users may need another 2 reductions from 2” to the size of the pipe that is located at the installation site. For example if the pipe where you are installing the chlorinator is 1½” then you will need to buy and glue in the two 2” to 1½” reductions to the pre-made chlorinator. The user also needs to apply Teflon tape or rubber gaskets to each of the screw tops. Without applying this water will leak out of the top of the chlorinator through the screw tops. The gaskets are a better option if your water committee has the money and can find them in a hardware store. If you cannot afford or cannot find the gaskets Teflon tape will work fine but you will need to reapply the tape once every 3-6 months as the tape will naturally start coming off after repeated use. Also it may be necessary to physically support the chlorinator so that it does not fall over or tilt from side to side. This can be done by using sticks, rocks or even partially burying the chlorinator so only the top Tee portion is visible.

The installation method listed above will work for most systems however if you are capturing water from a stream source and a significant amount of debris is entering your storage tank your chlorinator may clog often. If this is the case you should set up your system differently to account for the possibility of your chlorinator clogging. Please see the discussion of this topic in Section 5.3.

3. Normal Operating Procedure – Adding New Tablet(s) to the Chlorinator

Now that your chlorinator is installed you are ready to start chlorinating. To chlorinate effectively you need to add new chlorine tablet(s) to the chlorinator once a week. Therefore, the aqueduct operator or committee managing the aqueduct needs to schedule a set day and time to add the new chlorine tablet(s). It is important that the tablet(s) are added on the same day and time every week. For example you may choose 6am every Monday to add a new tablet(s). When the operator is at the chlorinator he needs to follow the following procedure to add new tablet(s):

1) Shut off the water coming to the chlorinator using the shutoff valve next to the chlorinator
2) Remove both screw tops
3) Remove any excess chlorine tablets that may be left in the chlorinator
4) Insert the new chlorine tablet(s)
5) Close both screw tops (add additional Teflon tape if necessary)
6) Reopen the shutoff valve

Chlorine Tablets:

Chlorine tablets can be obtained from your local MINSA technician. Currently the tablets are free of charge in the Comarca Ngöbe-Bugle and in other Provinces they are being sold for $2 per tablet. The tablets should be handled with care so they do not break. It is also recommended to use a piece of plastic or paper when handling the tablets. This is because the chlorine tablet if in direct contact to skin can cause a mild itchy/burning sensation and will leave an odor on your hands. When they are not being used store the extra tablets in a sealed, dry, 5 gallon bucket.

4. Determining the Right Amount of Chlorine Tablets for Your System

Determining the correct amount of chlorine tablets to use for your system is important. Using too little chlorine allows for poor disinfection and the possibility for the water in your aqueduct to remain contaminated. Using too much chlorine can leave an unwanted taste and odor in your water and in extreme cases can have negative health effects. The process of determining the right amount of chlorine tablets is somewhat complicated and should be done with your local MINSA technician. The process of determining how many chlorine tablets you should use in your system is described in this field guide. If you are interested in how this process was derived or are interested in the chemistry of this process refer to the references listed at the end of this guide.

4.1 The Ct Method

Chlorine can kill water-borne pathogens (disease causing microorganisms). The effectiveness of chlorine to kill these pathogens is based on two factors – the concentration of the chlorine in the water and the amount of time this concentration is in contact with the water before the water is consumed. The concentration of the chlorine is typically measured in mg/L as chlorine (Cl_2) and the time the chlorine is in contact with the water, the contact time, is measured in minutes (min). We are interested in the product of these two values as that number tells us if a given pathogen can be killed based on previous studies. The product of these two values is called the Ct value and the equation for this value is provided below:

$$Ct = C \times t$$

Where:

C is the "Free Chlorine Concentration" in units of $\left(\frac{mg}{L} Cl_2\right)$

t is the "Total Contact Time" in units of (min)

"Ct" has units of $\left(min \frac{mg}{L} Cl_2\right)$

Equation 1- Ct

Table 2 presents the necessary Ct values to kill common water-borne pathogens found in rural Panamanian aqueduct systems.

Table 2: Literature Ct Requirements for Pathogen Destruction

Pathogen	Ct Requirement (min-mg/L Cl_2)	Temperature (C^o)	pH
Salmonella typhi	1	20-25	7
Hepatitis A	0.41	25	8
Giardia lamblia	15	25	7
E. coli	0.25	23	7
E. Histolytica	35	27-30	7
Vibrio cholerae	0.5	20	7
Rotavirus	0.05	4	7

(Adapted from CDC, 2013)

The largest value listed above is 35 min-mg/L therefore a slightly more conservative value of 40 min-mg/L will be our target value. To be clear, we want have a contact time and a chlorine concentration what gives us a Ct value that is ≥ 40 min-mg/L at all times during a week of chlorinating. This will result in us effectively killing any waterborne pathogens found in our water systems.

Now that we have a target Ct value we need to first calculate the time chlorine will stay in contact with water in our system before it is consumed. This “contact time” will be different for every system because it depends on: the flowrate of water in a system, the size of your community’s storage tank, the distance the first house receiving water is from the storage tank and the pipe sizes in the distribution system.

4.2 Determining Chlorine Contact Time

Chlorine contact time is calculated by determining the amount of time chlorine is in contact with water in your system before being consumed. This time starts when water passes through the in-line chlorinator and ends when leaving the first faucet at the first house in your system. Water therefore is in contact with chlorine first for a period of time in your community’s storage tank and then for a period of time in the PVC pipes leading to the first house before being used. Therefore we need to first calculate the amount of time water is stored in your storage tank before being used and second calculate the time water is in the your systems pipes before being used. In most rural aqueducts the piping from the storage tank to the first house is short and as a result the time water resides in this tubing is less than a few minutes. As a result it is often only necessary to calculate the time water is in your storage tank. As a general rule if the distance from the storage tank to the first house is < 250 meters the time water will be in these pipes will be small and you only need to calculate the time water will be stored in your storage tank. First we will calculate the contact time for your storage tank and then we will calculate contact time in your pipes before the first house in your system.

4.2.1 Contact Time in Your Storage Tank

Contact time in your storage tank is a based on: the daily minimum volume of water in the storage tank, the daily maximum flow out of your storage tank, and a “baffling factor”. These values are important as they will give you the shortest chlorine contact time during daily operation. We want to use the shortest contact time when calculating our Ct values so that we can know the Ct value is sufficient to kill the waterborne pathogens in our water system at all times during the day/week.

The volume of a storage tank can be calculated by entering the inside of the tank when the tank is being cleaned and measuring the length, width and height of the tank. Make sure to measure the height of the tank only up to where the overflow pipe is located and not to the roof of the tank as water will never reach that height. If your water tank is always overflowing with water from the overflow pipe than use the length, width and height values and calculate the tank volume using the following equation.

$$\text{Tank Volume (gal)} = \text{Length (ft)} \times \text{Width (ft)} \times \text{Height (ft)} \times 7.48 \left(\frac{\text{gal}}{\text{ft}^3}\right)$$

Equation 2 – Tank Volume

However, if during the peak hours of water use the water level in the storage tank lowers (this can be seen visually by no water leaving the overflow pipe) then it is necessary to recalculate the volume of water in the storage tank. This is because when the water level lowers in the tank the volume of water in the tank also lowers and this will lower the chlorine contact time. Therefore if this is the case for your system you need to measure the lowest point that the water level in the tank reaches during peak hours and use this new smaller height value in the equation above when calculating the volume of the tank. See the following figure (Figure 4) for clarity.

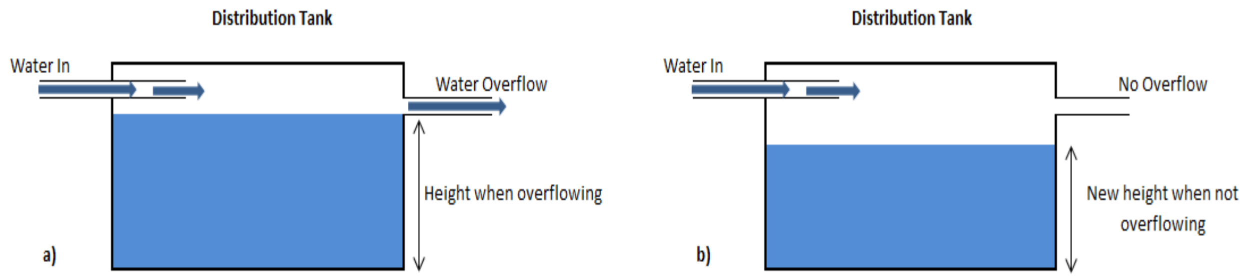


Figure 4: Height of Water When: a) Water is overflowing b) Water is not overflowing

Next we need to calculate the maximum flow rate of water out of the tank on a normal day of use. This maximum flow rate will normally coincide with the minimum water level in the distribution tank. To calculate the maximum flow rate measure the water level in the tank every 30 minutes during the time period you expect users to use the most water. Typically this is in the morning when everyone is cooking breakfast, bathing and getting ready for the day or in the mid to late afternoon. After you have measured the water level a couple of times, identify the value that has the largest change in the level of water over a given 30 minute time interval. A representation of this change in water level can be seen in Figure 5:

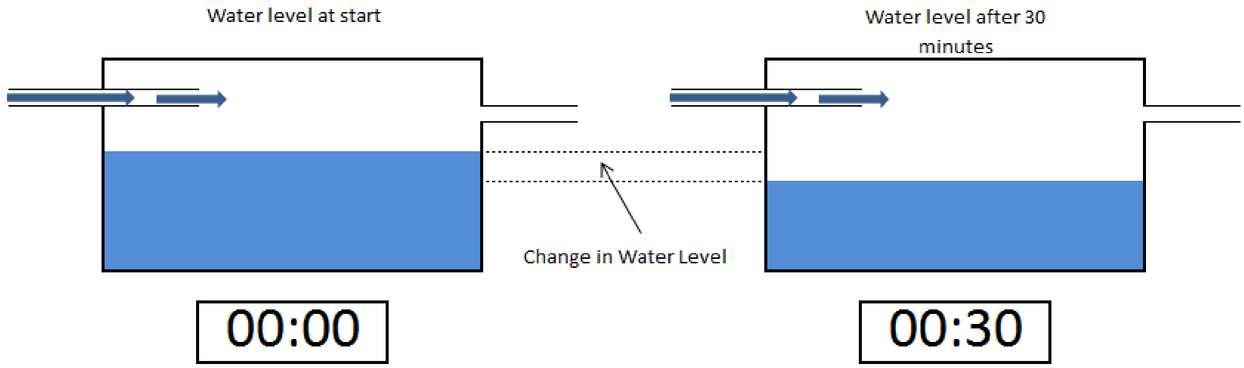


Figure 5: Change in water level over a given 30 minute interval

For example in Figure 5 at time 00:00 the water height might be 5 feet and 30 minutes later at time 00:30 the height of water in the tank might be 4.5 feet. The change in the height of water would therefore be: 5 feet - 4.5 feet = 0.5 feet. This value will be referred to as the "change in water level" in Equation 3.

Use the length and width values you previously calculated for the total tank volume along with the "change in water level" value to calculate the maximum flow rate by using the following formula:

$$\text{Max Flow Rate}\left(\frac{\text{gal}}{\text{min}}\right) =$$

$$\frac{\text{Length(ft)} \times \text{Width(ft)} \times \text{Change in water level(ft)} \times 7.48\ \text{gal/ft}^3}{30\ \text{minutes}} + \text{Flow into storage tank}\left(\frac{\text{gal}}{\text{min}}\right)$$

Equation 3 – Max Flow Rate

In the above formula the "flow into the storage tank" is the flow of the water from the source entering the tank through the influent pipe (the pipe that is bringing water to your storage tank). This can easily be calculated with a 5 gallon bucket and a stop watch. Simply measure the time it takes to fill the 5 gallon bucket with your stop watch and use that time value in the following formula to calculate the flow into the your tank:

$$\text{Flow into storage tank}\left(\frac{\text{gal}}{\text{min}}\right) = \left(\frac{\text{5 gallons}}{\text{time elapsed (sec)}}\right) \times 60\left(\frac{\text{sec}}{\text{min}}\right)$$

Equation 4 – Flow into Storage Tank

However, if your distribution tank is always overflowing (this can be visually seen as there is always water flowing out of the overflow pipe) simply use the "Flow into storage tank" value for you max flowrate.

Now it is time to calculate the chlorine contact time *in your storage tank*. To calculate this value use the "max flowrate" and "tank volume" values you have already calculated in the following formula:

$$\text{Contact time in storage tank (min)} = \frac{\text{Tank Volume (gal)}}{\text{Max Flowrate}\left(\frac{gal}{\text{min}}\right)} \times 0.3$$

Equation 5 – Contact Time in Storage Tank

The value 0.3 in Equation 5 is the tank's "baffling factor." This value accounts for the chlorinated water entering the tank not mixing completely with all the water already in the tank before leaving the tank. As a result of this imperfect mixing the chlorinated water stays in the tank for only an estimated 30% of the calculated time hence the value 0.3. This value is a conservative value for a baffling factor for a standard cubical tank.

Now that we have calculated the chlorine contact time for your storage tank it is time to calculate the chlorine contact time for your piped distribution system.

4.2.2 Contact Time in Your Piped Distribution System

The contact time in *the piped distribution system* is the time water is in contact with chlorine starting from when the water leaves the storage tank until it reaches the faucet of the first house in the distribution system. This is calculated by first determining the total volume of water stored in the pipes starting from the storage tank and ending at the first house. Then this value this value is divided by the maximum flow rate.

In the following equation pipe length was measured with a tape measure and the inside pipe diameter was determined from labeling on the pipe. The total volume of water in a pipe was determined as:

$$\text{Volume in Pipe (gal)} = \text{Length of Pipe (ft)} \times \pi \times \left(\frac{\text{Pipe Diameter (in)}}{2}\right)^2 \times \left(\frac{7.48\left(\frac{gallons}{ft^3}\right)}{144\left(\frac{in^2}{ft^2}\right)}\right)$$

Equation 6 – Volume of Water in a Pipe

You may need to use this equation several times if you have several different diameter pipes between the storage tank and the first house. Once you have the volume of water in each different pipe calculated you need to add all of these volumes together to get the total volume in the piped system (Equation 7).

$$\text{Total Volume in Piped System (gal)} = \text{Volume in Pipe of Diameter}_1 + \text{Volume in Pipe of Diameter}_2 + \text{Volume in Pipe of Diameter}_3 \ldots$$

Equation 7 – Total Volume in Piped System

The contact time in the piped system is then calculated by dividing the value obtained from Equation 7 (Total Volume in Piped System) by the value obtained from Equation 3 (Max Flowrate) as shown in the following equation:

$$\text{Contact time in Pipes (min)} = \frac{\text{Total Volume in Piped System (gal)}}{\text{Influent Flowrate } \left(\frac{\text{gal}}{\text{min}}\right)}$$

Equation 8 – Contact Time in Pipes

4.2.3 Total Contact Time

Now we can calculate the total chlorine contact time of your system. This is done by adding the value you obtained from Equation 5 (Contact time in Storage Tank) and Equation 8 (Contact Time in Pipes) as shown in Equation 9:

$$\text{Total Contact Time (min)} = \text{Contact time in Tank (min)} + \text{Contact time in Pipes (min)}$$

Equation 9 – Total Contact Time

Remember if the distance between your storage tank and the first house in your distribution system is short then the “Contact Time in Pipes” value you calculate will be very small. Therefore if this distance is small (< 250 meters) you do not need to calculate the “Contact Time in Pipes” value.

4.3 Determining Chlorine Concentration

We now need to know the chlorine concentration in the water. Specifically we need to know the free chlorine concentration in water. The flowchart in figure 6 presented below will help explain what the term free chlorine represents:

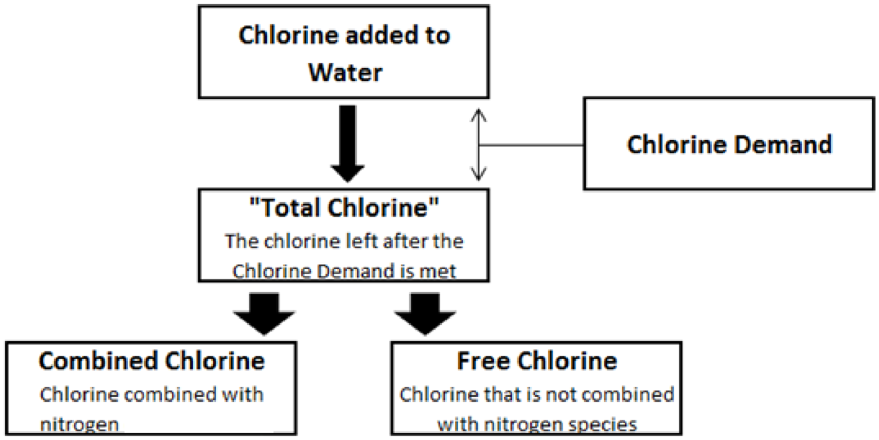


Figure 6: Chlorine Residuals Created when Chlorine is Added to Water

When chlorine is added to water some of the chlorine is used up killing off bacteria and other organisms in the water. The amount of chlorine needed in this process is called the chlorine demand. The concentration of chlorine left in the water after this process is finished is called the "Total Chlorine" concentration. "Total Chlorine" is the sum of two different species of chlorine: "Combined Chlorine" and "Free Chlorine". "Combined Chlorine" is the chlorine that is *combined* with nitrogen (a type of chemical) compounds in the water. This type of chlorine is not as good at disinfecting water as the other type of chlorine, "Free Chlorine." The other type of chlorine in water is "Free Chlorine" which is the chlorine in your water that is not combined with nitrogen compounds. This "Free Chlorine" has a great ability to disinfect water and therefore the presence of this type of chlorine determines if water is sufficiently chlorinated. When we measure chlorine we are interested only in the concentration of "Free Chlorine" that is in water.

Currently MINSA in the Comarca Ngöbe-Bugle is using a color wheels made by HACH to determine the free chlorine concentration in rural aqueducts in the region. The HACH testing manual for this color wheel can be found on the last page of this document. This manual explains how to take a sample and measure the free chlorine concentration of a sample of water.

Side note on using other instruments to measure "free chlorine" concentration: The use of digital colorimeters is also an effective way of measuring chlorine concentrations but the use of this instrument will not be discussed here as the instrument is expensive and is currently not used in the region. Kits specifically manufactured to measured chlorine in pools (this is often stated on the kits box) should be avoided as they often only measure "total chlorine" concentrations and are often not accurate.

Three values are important to remember when taking free chlorine measurements:

1) *Maximum Total Chlorine Concentration at any Location*: The World Health Organization (WHO) states that the maximum residual disinfectant level (MRDL) or the maximum level the concentration of "Total Chlorine" should reach is 5 mg/L Cl_2. This is because people regularly drinking water with chlorine residual values higher than 5 mg/L Cl_2 may develop health problems. However in this guide we are only sampling "Free Chlorine" concentrations. Therefore a good rule of thumb is to limit the level of free chlorine to a

maximum of 3 mg/L Cl_2. By doing this you can be fairly sure the total chlorine residual will be less than 5 mg/L Cl_2. Samples to determine if you are exceeding the *Maximum Total Chlorine Concentration at any Location* should be taken from the influent pipe into the distribution tank. This water will have this highest chlorine concentration in the entire system.

2) *Minimum Free Chlorine Concentration*: The minimum free chlorine concentration recommended is 0.2 mg/L Cl_2 at the last house receiving water in your distribution system. The last house is chosen to test for this value as it has the greatest chance of having the lowest free chlorine concentration value due to the chlorine being used up while sitting in the system. It is important to have some chlorine in all locations in your system so that if for example from a pipe is broken there will be some chlorine available to disinfect the water at that location. Again samples to determine the *Minimum Free Chlorine Residual* should be taken from the faucet of the last house in the system.

3) *Free Chlorine Concentration to Meet the Required Ct Value*: Finally you need a free chlorine concentration value that is large enough to give you a Ct value that is sufficient to disinfect the water in your system. Samples to determine the *Free Chlorine Concentration to Meet the Required Ct Value* should be taken from the cleanout valve of the distribution tank. By sampling water from the clean out valve you have the best estimate of the concentration of "Free Chlorine" leaving your storage tank. However, it is advised that you leave the exit valve open for 3 minutes before taking a sample so that dirt does not enter your sample. This calculation is presented in the next section (4.4).

4.4 Calculating Your Ct Value

We can now determine the Ct value for your system at a given time. You should already have the following two values: Total Contact Time (value from Equation 9) and "Free Chlorine" Concentration (measured as described in Section 4.3). To calculate the Ct value for your system multiply these two values together to get the final Ct value:

$$\text{Ct Value} = \text{Total Contact Time} \times \text{Free Chlorine Concentration}$$

which is

$$Ct\left(\frac{\text{mg-min}}{\text{L}} Cl_2\right) = C\left(\frac{\text{mg}}{\text{L}} Cl_2\right) \times t\ (\text{min})$$

Equation 1 - Ct

4.5 Deciding if there are Enough Chlorine Tablets in the Chlorinator

As mentioned before we want our Ct value to be at or above 40 mg-min/L at all times during the week. If your calculated value is greater than or equal to 40 mg-min/L congratulations you are effectively chlorinating your water system (Note: This is assuming your *Maximum Total Chlorine Concentration at any Location* is an acceptable level). If your Ct value is below 40 mg-min/L you need to increase the amount of tablets you are using each week. This should increase your chlorine concentration which will then increase your calculated Ct value. It is recommended that you increase the amount of chlorine added by ½ a tablet per trial until you reach your target 40 mg-min/L Cl_2 Ct value. Therefore if you were using 2 tablets and found your Ct value was less than 40 min-mg/L in the next trial/week you would use 2 and ½ tablets. If again with 2 and

½ tablets your Ct value was below 40 mg-min/L you would again increase the amount of chlorine by ½ tablet and use 3 tablets for the next trial/week.

In another example if you used 2 chlorine tablets in your chlorinator and found that your Ct value was > 40.0 min-mg/L but your *Maximum Total Chlorine Concentration at any Location* was thought to be above 5 mg/L (due to you finding a "Free Chlorine" concentration of > 3 mg/L) you would need to reduce the amount of chlorine in your chlorinator by ½ of a tablet to 1 and ½ chlorine tablets and retest your system. This process is presented visually in Figure 7:

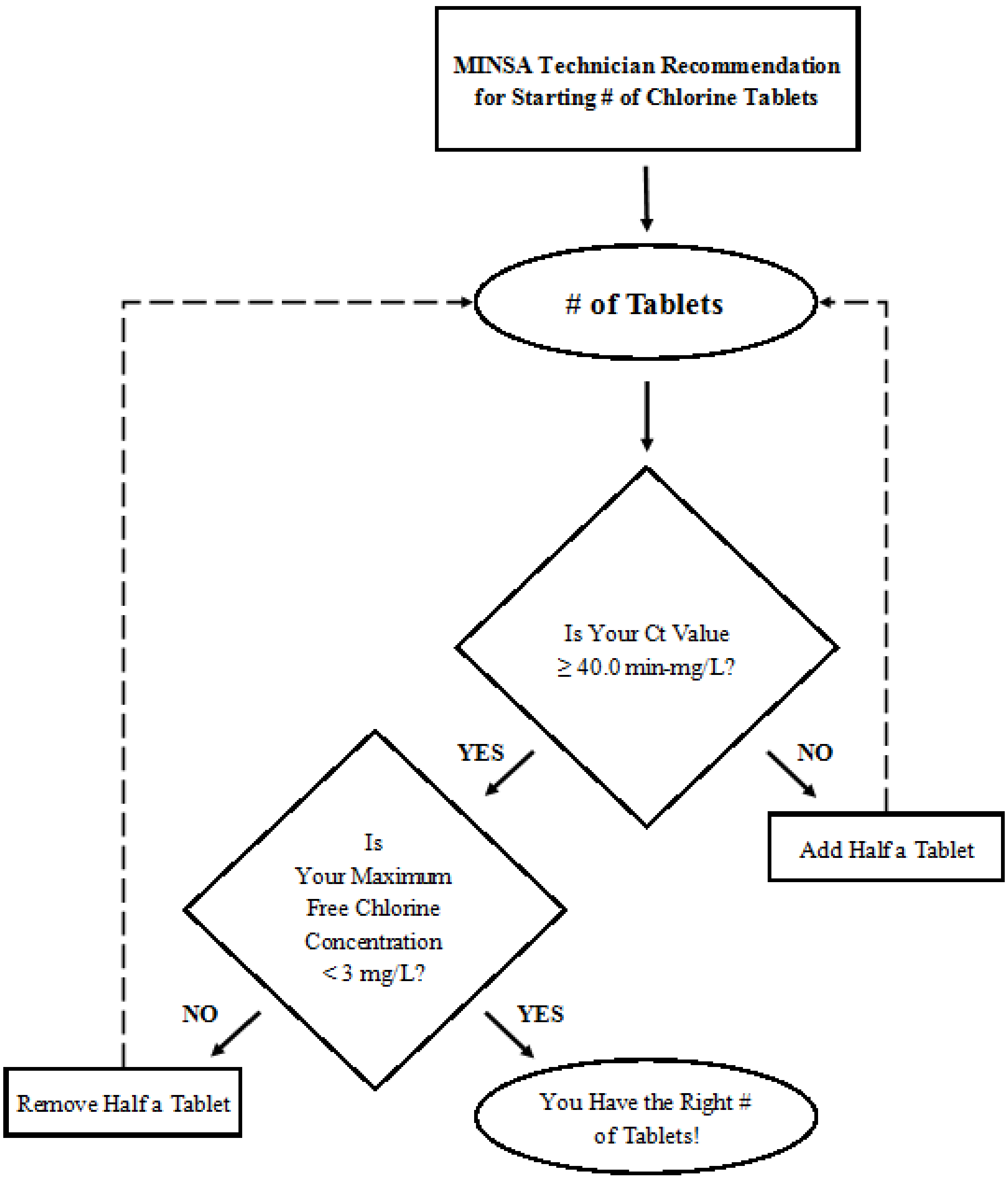


Figure 7: Flowchart - How to Determine a Correct # of Tablets for Your Chlorinator

As Figure 7 describes your community should ask your local MINSA technician for a recommended number of chlorine tablets to start chlorinating your system. If no MINSA technician is available it is recommended you start with 1 chlorine tablet. You would then need to calculate your chlorine contact time and measure free chlorine in your system over one week. You should be measuring free chlorine at 3 locations throughout the week: The pipe that is delivering water to the storage tank (influent pipe), the cleanout pipe to your storage tank and at the last house in your systems distribution system. The days that are most important to sample are Day 1 (2 hours after you have inserted the chlorine tablets), Day 2 (24 hours after you have inserted the chlorine tablets), Day 6 and Day 7.

5. Recommended Education Program for Communities Using the Chlorinator

Educating a community on why a chlorination program may be beneficial to them, how they can effectively chlorinate and where they can look for help if they are having difficulties is a key to a successful long term chlorination program. The following materials form the basis of a seminar that should be presented to communities before a chlorination program is started. It is recommended that if possible a MINSA technician present this material to a community as they are the organization communities should go to for help in the future and will be a permanent organization in Panama for the foreseeable future.

5.1 Transmission Pathways of Sickness

The first topic in any seminar should be a brief overview of the transmission pathways of sicknesses or stated simply as “how and why people get sick.” This topic first presents why ingesting excrement will cause a person to be sick and then describes how human or animal excrement can be transmitted in various ways into a person’s body thereby causing them to be sick. A few examples of how excrement can enter a person’s body (transmission pathways) are:

1. Excrement is left on someone’s hand after anal cleansing and then their hand enters their mouth at a later time (when eating or drinking)
2. An animal defecates in a stream and then downstream someone uses that same water for their drinking water source
3. Food is not covered and mosquitos carry nearby excrement onto food thereby contaminating food and later a person eats this food
4. A mother cleans her baby that has defecated and then cooks dinner contaminating the families food

These are just some of many potential scenarios. Different scenarios should be used in different community situations. The key to this topic is to talk about how communities can prevent each scenario so that they do not get sick. This should lead to sanitation practices and in the case of example 2 above lead communities to talk about water source protection and treatment. For example 2 above one way to prevent people getting sick is to chlorinate the water before people drink it. This topic will then lead into the second topic which describes basic general knowledge of chlorination.

Peace Corps Panama has an excellent manual entitled “Vías de transmisión de las enfermedades” translated to *transmission pathways of sicknesses* that describes how this topic can be presented. If you are interested in reading or using this manual (available only in Spanish) please contact: eh@pa.peacecorps.gov. Many similar guides are available online or in print.

5.2 General Knowledge of Chlorination

Now that a community knows why they get sick from ingesting excrement (possibly described as "bad microbes") and how they can prevent this in a certain scenario (through chlorination) some general knowledge of chlorination is necessary. However, describing the chemistry of water chlorination is not advisable in most communities in the Comarca Ngöbe-Bugle.

A presentation should be made describing what type of things chlorine can kill or remove from water and what it cannot kill or remove. For example chlorine can kill/remove the following things in water: algae, viruses and some microbes/bacteria/pathogens/parasites. Chlorination cannot remove dirt or debris from water systems. It is important for community members to understand that chlorination does not remove dirt/debris/sediment/turbidity from their water. This is important both so that when community members see sediment in their water they know that this does not mean chlorination is not working and also so that the community does not have incorrect expectations of what a MINSA chlorinator will do in their community.

A community also needs to understand what two factors determine whether chlorine will be able to kill microbes in their aqueduct's distribution system. These two factors are the concentration of chlorine in their water and the amount of time that their water is in contact with this concentration of chlorine (contact time). An analogy often used to describe this concept is cooking chicken. When you cook chicken you need to apply a certain amount of heat for a certain amount of time to cook the chicken. Heat here is like concentration and the time the heat is applied to the chicken is like the contact time. If you have a hotter pot the chicken will cook faster and you need the heat to be applied for a shorter time but if the pot is not very hot you will need a much longer time to cook the chicken. This is also a good time to fully describe what "contact time" and "concentration" mean. Concentration of chlorine can be described with an analogy of sugar in water. The more sugar you put in a glass of water the sweeter it is – the cup has a higher concentration of sugar.

A discussion of the smell and taste of chlorine should be discussed with the community. Notably that some taste or a faint smell of chlorine does not mean that water is unsafe to drink. Community members should know that the *only* way to determine if their water has too much or too little chlorine in it is to measure the chlorine concentration with a color wheel or digital colorimeter.

A short discussion should also be presented to the community that discusses how a large amount of dirt or debris in water can prevent effective chlorination. This should lead into a discussion of the importance of continual tank maintenance/cleaning, water source protection and the possibility of constructing a filter or settling tank if there is a significant turbidity problem.

5.3 Knowledge Specific to MINSA's In-Line Chlorinator

There are some important topics that need to be presented to a community that are specific to MINSA's in-line chlorinator.

The first is discussing with a community the importance of installing the chlorinator before their storage tank. This allows the storage tank to provide a large chlorine contact time which is important for effective chlorination.

The second topic that is important to discuss with a community is the iterative method to determine the correct amount of chlorine tablets needed in a unique community system. During this time the first four sections of this manual are described. It is important that the community or at least members of the water community understand the iterative process of identifying an appropriate chlorination regimen that is shown visually in Figure 7. It should be stressed to the community that new chlorine tablets need to be replaced once a week at the same time on the same day each week.

Another important topic is to discuss how community members can obtain more chlorine tablets. Community members should know the name and contact number of the technician in their area. If you do not know who is the local MINSA technician in your area (in Panama) contact Fredy or Virgilio (contact information is provided in Section 1). Communities should understand that this technician is the person they should contact if they are having problems with their chlorinator. Communities should also know that this is where and with whom they can purchase a new chlorinator if needed.

Finally a discussion on how a community can clean their chlorinator and how often they can clean their chlorinator needs to be discussed. If a community has very little dirt entering their system (as with many spring capture systems) they may never need to clean their chlorinator. However, if a system has a large amount of dirt entering their system (as with many stream catchment systems) they need to clean their chlorinator once a month and additionally after each large storm event. This is done by configuring the chlorinator in different way as described in the configuration below:

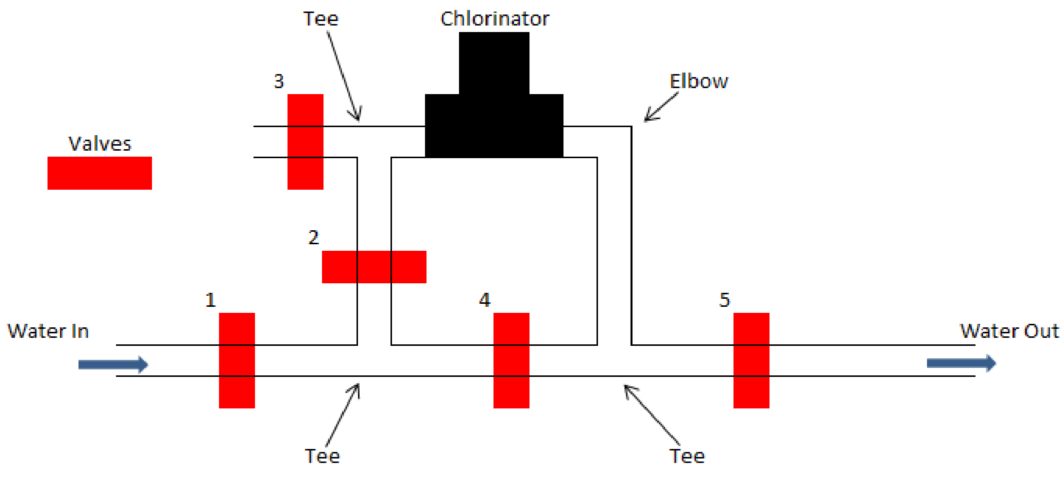


Figure 8: Basic Configuration of Chlorinator for Systems with Turbidity Problems

Note that this configuration requires three PVC Tees, one 90^{o} elbow and 5 valves. When the system is in normal operating conditions the configuration would look like the below figure:

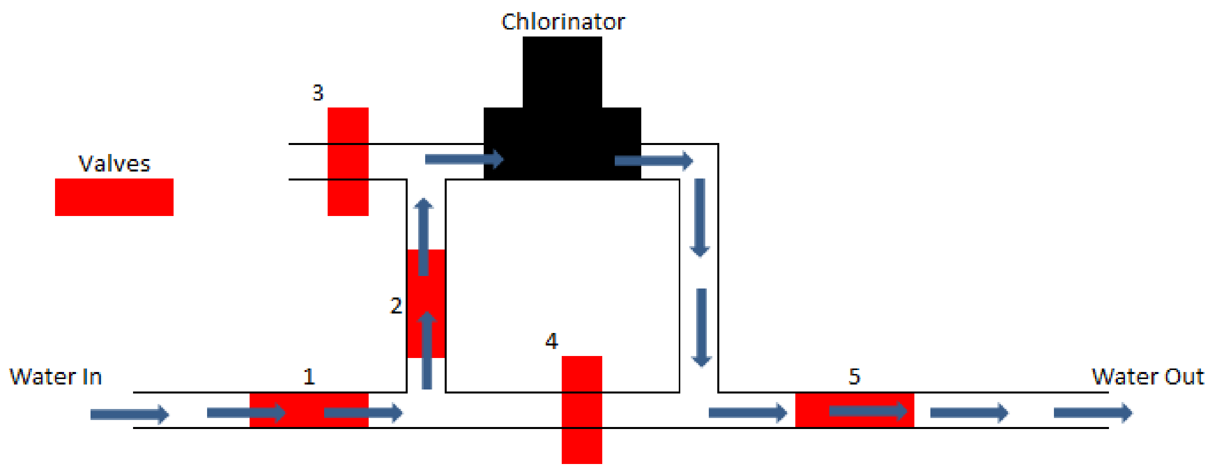


Figure 9: Configuration of Valves when Chlorinator is Being Used

And when the operator needs to clean out the chlorinator the system would be configured as in the figure below:

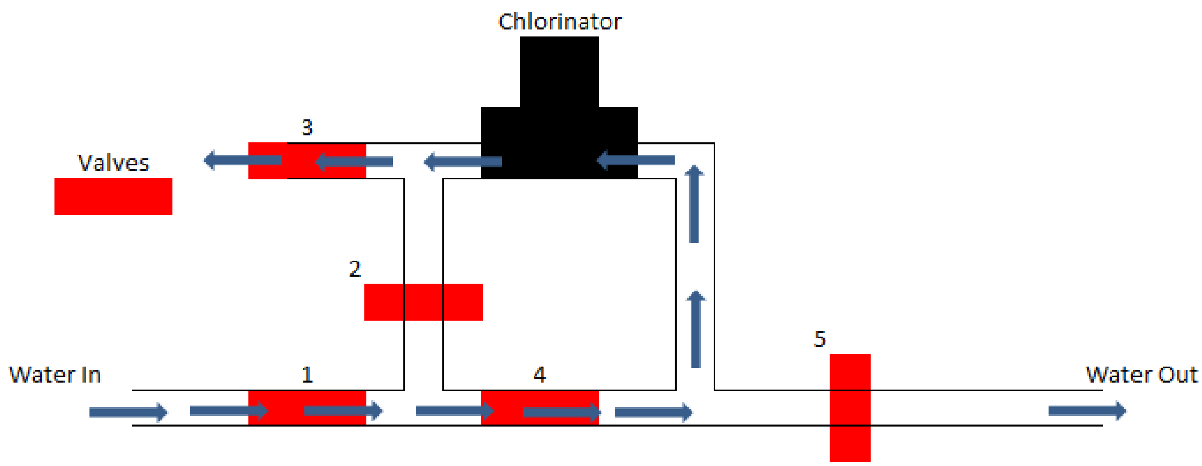


Figure 10: Configuration of Chlorinator when Cleaning/Backwashing the System

6. Common Problems and Solutions Associated with MINSA's In-Line Chlorinator

The following are problems that may arise with the MINSA in-line chlorinator. These problems however will not affect all communities and are therefore left out of the recommended education program that is to be presented to each community (Section 5). If you are having a problem that is not discussed below please contact your local MINSA technician.

Pressure Problems Affecting MINSA's In-Line Chlorinator

In the past there have been some problems using MINSA's in-line chlorinator is systems where there is a very high flowrate entering the storage tank. This high flowrate causes a large amount of pressure to be exerted on the chlorinator when installed before the storage tank. This has caused operational problems leading to inconsistent chlorination, reduced water flow to the storage tank and in some instances an inability to use the chlorinator. To fix this problem a break pressure tank needs to be installed before the chlorinator. This potential solution should be discussed with a MINSA technician as there is a significant cost associated with constructing a break pressure tank and proper placement of this tank needs to be considered to insure the system functions correctly.

Turbidity Problems Affecting Free Chlorine Residual

In some stream catchment systems, when large storm events hit a region a large amount of dirt and debris enter the catchment system. This dirt and debris can greatly increase the chlorine demand of the water and often as a result there is very little leftover free chlorine concentration in the water (see Figure 6). Therefore the MINSA in-line chlorinator is unable during these times to effectively chlorinate the water. A solution to this problem is to buy or construct a filter system to be installed before the chlorinator. If you believe this is a problem in your aqueduct system talk with your local MINSA technician about this potential solution.

High Free Chlorine Concentration Entering the Storage Tank and Low Free Chlorine Concentration at the Last House in the Distribution System

In some systems there is a problem of having a very high free chlorine concentration measured entering the storage tank and then a very low free chlorine concentration measured at the last house in the distribution system. The reason for this is normally because the system is very long. A solution to this problem is to have a secondary chlorinator installed within the distribution system to boost the free chlorine residual. If you believe this is a problem in your system talk with your local MINSA technician about this potential solution. If your distribution system is not very large and you are having this problem there is a good chance one of the pipes in your distribution system is broken and the free chlorine residual is being used up disinfecting contaminated water entering through the broken pipe.

7. Example - Ct Calculation and Determination of the Amount of Chlorine Tablets Need in a System - For the Community of Kuite

The community of Kuite wanted to chlorinate their water system and invited a MINSA technician (the great Rubin Miranda) to their community to instruct them on how to install and use their chlorinator. After Rubin's presentation he told the community to start chlorinating with 2 chlorine tablets. The community chlorinated their water and measured the free chlorine residual during the first week at the following locations: the pipe bringing water to the community (influent pipe), the cleanout valve of the storage tank and the last house in the distribution system. Table 3 presents their free chlorine measurements:

Table 3: Free Chlorine in Kuite with 2 Tablets Over One Week

Time Sample was Collected	Free Chlorine Concentration (mg/L Cl_2)		
	Influent	Effluent	Last House
Hour 2	0.30	0.20	0.01
Day 1	0.15	0.03	0.02
Day 2	0.15	0.09	0.15
Day 3	0.34	0.06	0.03
Day 4	0.30	0.11	0.08
Day 5	0.17	0.09	0.10
Day 6	0.10	0.04	0.01
Day 7	0.06	0.02	0.00

Before we can calculate the Ct Values for the system over the week we need to calculate the contact time for the system. Kuite has the following water system characteristics:
When measuring the inside of the storage tank the height was 7 feet 5 inches (from bottom to the overflow pipe) and the inside width and length were both nine 9 feet 6 inches. The storage tank is always overflowing and the flow into the tank (from the influent pipe) fills up a 5 gallon bucket in 24 seconds. There are two sizes of pipes between the storage tank and the first house in the distribution system. The first pipe has a diameter of 2 inches and is 922 feet long. The second pipe is ½ inch in diameter and 6.5 feet long.

Using equation 2 the tank volume is found to be:

$$\text{Tank Volume (gal)} = \text{Length (ft)} \times \text{Width (ft)} \times \text{Height (ft)} \times 7.48 \left(\frac{\text{gal}}{\text{ft}^3}\right)$$

$$= 9.5\text{ft x } 9.5 \text{ ft x } 7.42 \text{ ft x } 7.48 \text{ gal/ft}^3 = \sim 5000 \text{ gallons}$$

Using equation 4 the flow into the storage tank is found to be:

$$\text{Flow into storage tank } \left(\frac{\text{gal}}{\text{min}}\right) = \left(\frac{\text{5 gallons}}{\text{time elapsed (sec)}}\right) \times 60 \left(\frac{\text{sec}}{\text{min}}\right)$$

$$= 5 \text{ gallons} / 24 \text{ sec x } 60 \text{ sec/min} = 12.5 \text{ gallons/min}$$

The example states that the storage tank is always overflowing and therefore, the flow into the storage tank is used for the max flow. Using equation 5 the contact time in the storage tank is found to be:

$$\text{Contact time in storage tank (min)} = \frac{\text{Tank Volume (gal)}}{\text{Max Flowrate } \left(\frac{gal}{\text{min}}\right)} \times 0.3$$

= 5,000 gallons / 12.5 gallons/min x 0.3 = 120 minutes

We now need to determine the contact time in each of the pipes. Using equation 6 the volume in each of the pipes was found to be:

$$\text{Volume in Pipe (gal)} = \text{Length of Pipe (ft)} \times \pi \times \left(\frac{\text{Pipe Diameter (in)}}{2}\right)^2 \times \left(\frac{7.48 \left(\frac{gallons}{ft^3}\right)}{144 \left(\frac{in^2}{ft^2}\right)}\right)$$

(Pipe 1) = 922ft x π x $(2\text{in}/2)^2$ x (7.48/144) = 150 gallons
(Pipe 2) = 6.5ft x π x $(0.5\text{in}/2)^2$ x (7.48/144) = ~ 0 gallons

Using equation 7 the total volume in the piped system is:

$$\text{Total Volume in Piped System (gal)} = \text{Volume in Pipe of Diameter}_1 + \text{Volume in Pipe of Diameter}_2 + \text{Volume in Pipe of Diameter}_3 \ldots$$

= 150 gallons + 0 gallons = 150 gallons

Using equation 8 the contact time in the pipes is:

$$\text{Contact time in Pipes (min)} = \frac{\text{Total Volume in Piped System (gal)}}{\text{Influent Flowrate } \left(\frac{\text{gal}}{\text{min}}\right)}$$

= 150 gallons / 12.5 gallons/min = 12 minutes

Therefore using equation 9 the total contact time for the system is found to be:

$$\text{Total Contact Time (min)} = \text{Contact time in Tank (min)} + \text{Contact time in Pipes (min)}$$

= 120 minutes + 12 minutes = 132 minutes

Equation 1 can now be used to calculate running Ct values. This is done by using the measured free chlorine values found during the week at the effluent pipe and multiplying them by our calculated total contact time (132 minutes). For example the effluent sample at hour 2 has a calculated Ct value of:

$$\text{Ct} \left(\frac{\text{mg-min}}{\text{L}} \text{Cl}_2\right) = \text{C} \left(\frac{\text{mg}}{\text{L}} \text{Cl}_2\right) \times \text{t (min)}$$

= 0.20 mg/L x 132 minutes = 26.4 mg-mg/L

This should be done for all effluent values. Table 4 shows all the calculated Ct values:

Table 4: Calculated Ct Values for Kuite with 2 Chlorine Tablets

Time Sample was Collected	Effluent Chlorine Concentration (mg/L)	Total Chlorine Contact Time (min)	Ct (min-mg/L)
Hour 2	0.2	132	26.4
Day 1	0.03	132	3.96
Day 2	0.09	132	11.88
Day 3	0.06	132	7.92
Day 4	0.11	132	14.52
Day 5	0.09	132	11.88
Day 6	0.04	132	5.28
Day 7	0.02	132	2.64

Consulting Figure 7 the first question asks us if our Ct values are ≥ 40.0 min-mg/L at all times. The answer to this after reviewing table 4 is no. Therefore we need to add a ½ tablet and chlorinate for another week. This resulted in measured free chlorine values presented in Table 5:

Table 5: Free Chlorine in Kuite with 2 and ½ Tablets Over One Week

Time Sample was Collected	Free Chlorine Concentration (mg/L Cl_2)		
	Influent	Effluent	Last House
Hour 2	0.85	0.25	0.17
Day 1	0.60	0.26	0.18
Day 2	0.58	0.27	0.18
Day 3	0.72	0.30	0.28
Day 4	0.55	0.30	0.33
Day 5	0.50	0.25	0.31
Day 6	0.58	0.29	0.12
Day 7	0.50	0.18	0.10

The contact time in the system is still the same therefore using equation one we can calculate the new running Ct values over one week when using 2 and ½ chlorine tablets:

Table 6: Calculated Ct Values for Kuite with 2 and ½ Chlorine Tablets

Time Sample was Collected	Effluent Chlorine Concentration (mg/L)	Total Chlorine Contact Time (min)	Ct (min-mg/L)
Hour 2	0.25	132	33
Day 1	0.26	132	34.65
Day 2	0.27	132	34.98
Day 3	0.30	132	39.6
Day 4	0.30	132	39.6
Day 5	0.25	132	33
Day 6	0.29	132	38.28
Day 7	0.18	132	23.76

Again, consulting Figure 7 the first question asks us if our Ct values are ≥ 40.0 min-mg/L at all times. The answer to this after reviewing table 6 is again no. Therefore we need to add another ½ tablet and chlorinate for another week. This resulted in measured free chlorine values presented in Table 7:

Table 7: Free Chlorine in Kuite with 3 Tablets Over One Week

Time Sample was Collected	Free Chlorine Concentration (mg/L Cl_2)		
	Influent	Effluent	Last House
Hour 2	1.42	0.33	0.29
Day 1	1.10	0.50	0.35
Day 2	0.94	0.44	0.19
Day 3	1.16	0.63	0.52
Day 4	0.88	0.48	0.57
Day 5	0.90	0.63	0.52
Day 6	0.91	0.54	0.22
Day 7	0.34	0.27	0.20

The contact time in the system is still the same therefore using equation one we can calculate the new running Ct values over one week when using 3 chlorine tablets:

Table 8: Calculated Ct Values for Kuite with 3 Chlorine Tablets

Time Sample was Collected	Effluent Chlorine Concentration (mg/L)	Total Chlorine Contact Time	Ct (min-mg/L)
Hour 2	0.33	132	42.9
Day 1	0.50	132	65.34
Day 2	0.44	132	58.08
Day 3	0.63	132	82.5
Day 4	0.48	132	62.7
Day 5	0.63	132	82.5
Day 6	0.54	132	71.28
Day 7	0.31	132	40.92

Again, consulting Figure 7 the first question asks us if our Ct values are ≥ 40.0 min-mg/L at all times. The answer to this after reviewing table 8 is yes. Again, consulting Figure 7 the next question asks us if the maximum total chlorine concentration is < 5 mg/L (or is the maximum free chlorine concentration < 3.0 mg/L) and the answer to this question is yes. Figure 7 therefore tells us we have the correct # of tablets. Therefore, Kuite should use 3 tablets in their chlorinator every week to effectively disinfect their water.

8. References

CDC. "Effect of Chlorination on Inactivating Selected Pathogen." *Centers for Disease Control and Prevention*. Centers for Disease Control and Prevention, 21 Mar. 2012. Web. 1 Oct. 2013. <http://www.cdc.gov/safewater/effectiveness-on-pathogens.html>.

HACH. "Chlorine Test Kits ." *Chlorine Test Kits – Hach*®. HACH Company, 2013. <http://www.hach.com/chlorinetestkits>

Orner, Kevin D. "Effectiveness of In-Line Chlorination of Gravity Flow Water Supply in Two Rural Communities in Panama." Thesis. University of South Florida, 2011. *USFMI Theses/Reports*. <http://usfmi.weebly.com/thesesreports.html>.

Yoakum, Benjamin A. “Improving Implementation of a Regional In-Line Chlorinator in Rural Panama Through Development of a Regionally Appropriate Field Guide.” Thesis. University of South Florida, 2013. *USFMI Theses/Reports*. <http://usfmi.weebly.com/thesesreports.html

Free or Total Chlorine Test, 0–3.4 mg/L Cl_2

For Test Kits 223101 (CN-66), 223102 (CN-66F) and 223103 (CN-66T)

DOC326.98.00008

Note: *This product has not been evaluated to test for chlorine and chloramines in medical applications in the United States.*

Additional copies available on www.hach.com

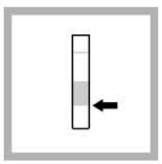
NOTE: Smallest increment is 0.1 mg/L. See step 7 below for reading instructions.

Test preparation

- Assemble the color comparator by placing the color disc on the center pin with the lettering facing out.
- Rinse vials with the sample water before testing. Rinse with deionized water after testing.
- Accuracy is not affected by undissolved powder.
- Monochloramine causes a gradual drift of free chlorine readings to higher values. Read immediately after the addition of the free chlorine reagent. At 3.0 mg/L monochloramine, a 0.1 mg/L increase in the reading will be obtained after 1 minute.
- Read the mg/L chlorine at the matching disc segment or as the value halfway between the two segments closest in color.
- If the disc becomes wet, carefully separate the two halves of the plastic case and dry them and the colored plastic insert with a soft cloth. Reassemble when the parts are completely dry.

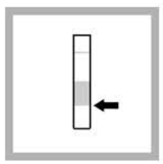
CAUTION: Handle chemical standards and reagents carefully. Review Material Safety Data Sheets before handling chemicals.

Free or total chlorine test procedure



1. Fill a tube to the first (5-mL) line with sample.

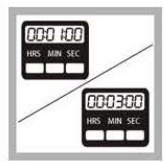
2. Insert the tube into the left opening of the comparator.



3. Fill another tube to the first (5-mL) line with sample.

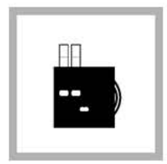
4. If testing free chlorine, add one DPD Free Chlorine Reagent Powder Pillow to the second tube. Swirl to mix.

If testing total chlorine, add one DPD Total Chlorine Reagent Powder Pillow to the second tube. Swirl to mix.

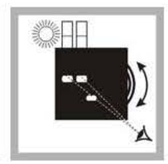


Note: If testing free chlorine, complete the test and read the result within one minute of adding the reagent.

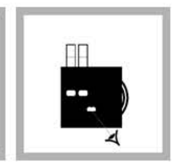
Note: If testing total chlorine, read the test result after three minutes but before six minutes after adding the reagent.



5. Insert the second tube into the right opening of the comparator.



6. Hold the comparator so that daylight or a fluorescent light source is directly behind the tubes. Rotate the color disc until the colors in the front windows match. The best match might occur between two color segments.



7. Read the result in mg/L in the scale window. If the best match occurs between two color segments, determine the value halfway between the two printed numbers.

Replacement items

Description	Unit	Catalog no.
Color Comparator Box	each	173200
Color Disc, DPD Chlorine, 0–3.4 mg/L	each	990200
Color Viewing Tube, plastic, with cap	4/pkg	4660004
DPD Free Chlorine Reagent Powder Pillows	100/pkg	1407799
DPD Total Chlorine Reagent Powder Pillows	100/pkg	1407699

Optional items

Description	Unit	Catalog no.
Caps, for plastic viewing tubes 4660004	4/pkg	4660014
Color Viewing Tube, glass	6/pkg	173006
Stoppers, for glass viewing tubes 173006	6/pkg	173106
Deionized Water	500 mL	27249

 For technical assistance or ordering information: visit www.hach.com, call 800-227-4224 or email techhelp@hach.com

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