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GREEN EMPOWERMENT

MANUAL OF DRINKING WATER QUALITY STANDARDS:

Green Empowerment Partners Guide to Metrics, Measurement and Mitigation

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When constructing new water systems or conducting a water system rehabilitation, it is important to ensure potable water is being delivered. Green Empowerment has a set of water quality standards which it expects all of its water system projects to meet. This document provides information on the basic water system components, Green Empowerment water quality parameters, and ongoing water quality testing and maintenance.

Green Empowerment is a registered 501(C)(3) Non-Profit Organization.

Green Empowerment partners with rural communities and NGOs in developing countries to improve access to affordable and renewable energy, safe drinking water, sanitation systems, and fuel-efficient cookstoves.

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1. Basic Water Systems

In small communities, where resources and technology are limited, the water systems are typically comprised of the following:

WATER SOURCE → **RESERVOIR (may also include water treatment such as: aeration, coagulation, flocculation, sedimentation, filtration and/or water treatment infrastructure)** → **HOUSEHOLD/TAP STAND**

The needed water treatment infrastructure varies with every water source. The infrastructure can include aeration systems, coagulation and flocculation basins, sedimentation basins, filtration systems and disinfection systems, all of which are crucial in providing safe water to the community. Each of these components has a specific function, which is described below.

1.1 Aeration

Aeration is used to increase the oxygen content in water, to remove dissolved gases such as carbon dioxide or hydrogen sulfide and to remove volatile organic compounds. Aeration can also help reduce substances such as iron and manganese that impart a bitter or metallic taste to the water.

1.2 Coagulation and Flocculation

Coagulation may be required for water that contains large amounts of colloidal and clay particles as such waters will not clarify with just sedimentation. After a coagulant is added, flocculation occurs. Flocculation is a process that allows small suspended particles to attach to each other and grow in size and density and eventually settle out of solution. These types of water treatment can be very difficult for community operated systems to treat since proper coagulation requires access to a chemical coagulant to destabilize the colloidal suspension. The most commonly used coagulants are expensive and difficult to obtain in rural areas, but parts of some locally available plants have been found to serve as coagulants, such as the opuntia cactus.

1.3 Sedimentation

Sedimentation allows solid contaminants (those sufficiently large and dense enough) to settle. For water systems that require chlorination, sedimentation is important because any sediment present will react with the chlorine. This reaction consumes the chlorine and consequently there may not be sufficient residual chlorine to properly inactivate biological contaminants, making the chlorine treatment ineffective. For filters, sedimentation is important because without sedimentation the filters could become clogged more quickly, blocking the flow and requiring more frequent filter maintenance.

1.4 Filtration

Filtration is accomplished by passing water through a bed of granular material to remove suspended particles. Removing the particles also removes many of the bacteria, protozoa, cysts and viruses as these often attach to particles as well. All filters need some form of maintenance as they clog with sediment or reach their capacity for adsorbing chemicals. Maintenance methods can include backwashing, scraping or filter replacement.

1.5 Water Treatment

The two main types of water treatment Green Empowerment implements are chlorination and biological sand filters (biosand filters). Chlorine is used to kill microorganisms or bacteria in the water and help keep the water clean until distribution. Sodium hypochlorite liquid (bleach) is used for point of use treatment while calcium hypochlorite (tablets or powder) is typically used in water storage tanks. The amount of chlorine needed depends on the type of chlorination system being utilized and the water demand. Biosand filters are used to decrease sediment load and remove harmful bacteria from the water. These filters utilize both sand and a biological film layer to remove the contaminants. More information on chlorination systems and biosand filters can be found on the Green Empowerment website under the Technical Documents tab (www.greenempowerment.org/techtools/).

2. Source Selection and Protection

Selecting a water source suitable for the community is critical. Once the water source is selected, it must be properly maintained and protected. Below describes the advantages and disadvantages of different water sources and the Green Empowerment requirements in protecting the water source.

2.1 Source Selection Options

Water source selection is based on ease of access to the water source, amount of water available year round, and whether the contaminants in the water can be treated or not. There are also different types of water sources that can be selected. Below is a list of the different water source types and their advantages and disadvantages.

Source Option	Advantages	Disadvantages
Surface water (e.g. stream, lake etc.)	-Easy to identify and access	-Typically requires extensive treatment and filtration -Quantity could vary by season
Groundwater (e.g. springs, wells)	-More stable supply, if available -Often, the most sanitary option -Easy to protect and maintain the water source -Could be close to the community -For a spring located above a community, gravity flow eliminates the need for a pump	*Springs*: -Pump may be required if the spring is below the users -For gravity flow, if the distance to the community is great, piping cost can be high *Water wells*: -Excavation or drilling is required to build the well -Pump is required to move the water from wells
Atmospheric water (e.g. rainwater harvesting)	-Could provide a clean water supply -Distributed supply and storage, with each household having its own system	-Requires rain or fog which are not always available year-round

When selecting a source, make sure there is no upstream or uphill fumigation, agriculture or other potential sources of contamination. Also, check to ensure there are no latrines, open defecation, animals, trash disposal, vehicle washing/maintenance, and washing within 30-meters of water source (WHO, Water and Sanitation for Health, 2017).

2.2 Source Protection

Once the water source is selected, it is key to protect it from contamination which can result in increased water treatment costs. Green Empowerment requires the following water source protection:

-No latrines, open defecation, animals, trash disposal, vehicle washing/maintenance and washing within 30-meters of water source
-A secure enclosure around the water source
-Water source remains clean of garbage
-Plants around water source maintained to keep water source easily accessible
-Ensure there are no leaks, all lids are in place with locks and all air vents are screened

3. Water Quality Parameter Check-list

Water quality parameters have been divided into two groups: essential and aspirational. Essential parameters have a direct and immediate effect on health and acceptability. It is a Green Empowerment requirement to monitor these when the water source is selected and once project construction is completed. This will ensure the water system is working correctly and the water is being treated as needed. The aspirational parameters could affect health in the long term, but may not be monitored or regulated in all countries. If testing for these parameters is available, or if it is required by national regulations, it should be conducted. All testing should be conducted in certified, approved laboratories (a list of suggested laboratories can be found in Appendix 1). A detailed rationale for the selection of essential and aspirational parameters can be found in the "Drinking Water Quality: Parameter Review" document on the Green Empowerment website under the Technical Documents tab.

3.1 The Essential Set

For all water systems, Green Empowerment requires basic physiochemical and total coliform testing. Green Empowerment also requires country-specific testing such as arsenic in Nicaragua and Borneo or cadmium in Ecuador, as these parameters are common in these countries. The testing of these parameters is required once the water source is selected and after water system construction is completed. For springs, surface water sources and rehabilitation of existing wells, water samples should be taken from the water source before construction starts. For new groundwater wells, any available data on nearby wells or springs should be reviewed, and samples taken if possible. Once construction is completed, water samples should be taken from the water source, after the water passes through the treatment process, and at the first, middle, and final house/tap stand of the system. The physiochemical and total coliform tests measure a variety of parameters. Those of most concern to Green Empowerment, including the country-specific parameters, can be found in the list below. For a full list of parameters measured in the physiochemical and total coliform testing, see Appendix 2. All parameter testing should be conducted in a certified, approved laboratory. A list of country-specific laboratories used by Green Empowerment can be found in Appendix 1.

Parameter	Maximum Suggested Limit	Mitigation	Notes/Rationale
Fecal Coliform	0 detectable /100 mL *(EPA, National Primary Drinking Water Regulations, 2017)*	-Chlorination -Biosand filters	Causes diarrhea, stomach ailments and dehydration.
Fluoride	1.5 mg/L *(WHO, 2011)*	-Filtration with alumina	Causes skeletal and dental health issues and tooth discoloration.
Nitrate	50 mg/L *(WHO, 2011)*	-Membrane filtration -Source protection	Usually due to fertilizer runoff. High levels of nitrites and nitrates can cause Blue-Baby syndrome in children.
Nitrite	3 mg/L *(WHO, 2011)*	-Membrane filtration -Source protection	Usually due to fertilizer runoff. High levels of nitrites and nitrates can cause Blue-Baby syndrome in children.
pH (alkalinity, acidity)	6.5-8.5 *(EPA, Secondary Drinking Water Standards: Guidance for Nuisance Chemicals, 2017)*	-Calcite/lime treatment or aeration to raise the pH	Acidity causes corrosion, and can affect taste as well.
Sulfate	250 mg/L *(WHO, 2011)*	-Membrane filtration -Source protection	Excess amount of sulfate is presumed to cause intestinal disorders. Sulfate is known to corrode pipes.
Total Iron	0.3 mg/L *(EPA, Secondary Drinking Water Standards: Guidance for Nuisance Chemicals, 2017)*	-Aeration & rapid sand filtration -Greensand or pyrolucite filtration -Water softeners	Causes stains in pots and clothes, unacceptable flavor. Long-term health issues such as joint pain and heart disease.
Turbidity	<5 NTU *(EPA, National Primary Drinking Water Regulations, 2017)*	-Sedimentation (may need prior coagulation & flocculation) -Rapid or slow sand filtration	Affects color of water. If chlorine is being used, high turbidity decreases its effectiveness and increases amount needed. If filtration is being used, high turbidity will clog the filter more rapidly, increasing frequency of filter maintenance.
Cadmium (*Requirement for Ecuador*)	0.003 mg/L *(WHO, 2011)*	-Source protection -Coagulation/ Filtration -Reverse Osmosis	Usually contaminated due to waste products in the manufacturing of steel, plastics, etc. Can affect the kidney, skeletal and respiratory systems. Also a human carcinogen.
Arsenic (*Requirement for Nicaragua and Borneo)*	10 µg/L *(WHO, Arsenic, 2017)*	-Choosing a different source -Fe treatment -Ion exchange	Arsenic causes severe physical and mental growth issues in children. Most mitigation methods have negative side effects; the best option may be finding a new water source free of arsenic.

3.2 The Aspirational Set

Aspirational parameter testing falls into three categories: metal parameters, organic compound parameters, and pesticide parameters. The measurement techniques for most of these are complicated and expensive. If testing for these parameters is available, or if it is required by the national authority, it should be conducted, as there could be long-term health effects if present. The list of parameters and their suggested limits are listed in Appendix 3. The Green Empowerment document, "Drinking Water Quality: Parameter Review", goes into more detail about the health effects and treatment methods of these contaminants.

4. Ongoing Water Quality Testing and System Disinfection

Once the water system is installed and operating, and the essential parameter list has been tested to confirm proper water treatment, the water system operator/technician should perform periodic water quality testing and system disinfection. This is to ensure the water reaching the household/tap stand is to the drinking water quality standards of Green Empowerment. Green Empowerment utilizes three water treatment methods: water chlorination, slow sand filters and biosand filters. Below explains the periodic water quality testing and system maintenance the operator should be performing on the three types of systems.

4.1 Ongoing Water Quality Testing for Chlorination Systems

The table below explains the parameters to be tested, the required limit, how to test it, the frequency, and how to mitigate the parameter if it is above or below the acceptable range. This information, including a more in-depth explanation and document to share with the water system operator, can be found in Appendix 4. Training materials on this topic can be found under the Technical Documents tab on the Green Empowerment website.

Parameter	Maximum Suggested Limit	Detection	Frequency	Mitigation	Notes/Rationale
Residual Chlorine	0.5 mg/L – 1.0 mg/L (Oxfam, 1996)	Chlorine test kit	2 days after chlorine is recharged, should be checked at first house/tap stand on the system, middle house/tap stand, and last house/tap stand on the system	Control amount of chlorine added	Usually the closest house/tap stand will have the highest amount of chlorine and the house/tap stand farthest away will have the lowest, adjust chlorine level based on need. Levels higher than 0.6 mg/L will affect taste.
Turbidity	<5 NTU or Secchi disk visibility inside the reservoir	Secchi disk or equivalent instrument	Before chlorine is recharged or after a big rain event; should be measured inside of the reservoir	Sedimentation	If water is being chlorinated, turbid water can decrease the effect of the chlorine. Sedimentation usually occurs in the reservoir.

To ensure source protection, conduct a bi-monthly monitoring of the area, including:

-No latrines, open defecation, animals, trash disposal, vehicle washing/maintenance, and washing within 30-meters of water source
-From water source, no uphill or upstream fumigation or agriculture
-The perimeter fence is secure and no repairs are needed
-Water source remains clean of garbage
-Plants around water source maintained to keep water source easily accessible
-Ensure there are no leaks, all lids are in place with locks and all air vents are screened
-Check clean out line for blockages

After a heavy rainfall, operators should check turbidity and chlorine levels, as the heavy rain can cause an influx of sediment in the system. They should also check for garbage and plants around the water source

Operators should also ensure the government required water quality testing is conducted.

4.2 Ongoing Water Quality Testing for Slow Sand Filters

The table below explains the parameters to be tested, the required limit, how to test it, the frequency, and how to mitigate the parameter if it is above or below range. This information, including a more in-depth explanation and document to share with the water system operator, can be found in Appendix 5. Training materials on this topic can be found under the Technical documents tab on the Green Empowerment website.

Parameter	Maximum Suggested Limit	Detection	Frequency	Mitigation	Notes/Rationale
Fecal Coliform	0 detectable /100 mL, 0 colonies present (see test kit directions as needed)	-3M Petrifilm or other E. coli test kit	Once a month, should be checked at first, middle, and last house/tap stand of the system	Clean out slows sand filter	Fecal coliforms are a parameter to check for contaminated water. If above the maximum suggested limit, the filtration system is not functioning properly and maintenance is needed.
Turbidity	<5 NTU or Secchi disk visibility inside the reservoir	Secchi disk or equivalent instrument	Weekly, after a big rain event, should be measured inside of the reservoir	Sedimentation	If water is turbid, it is an indicator the filter is not functioning properly.

To ensure water quality and source protection, conduct the following:

-Monitor the water flow from the filtration system, if flow is low the filtration system may need further cleaning (cleaning typically is needed every two weeks but should be conducted as needed)
-No latrines, open defecation, animals, trash disposal, vehicle washing/maintenance, and washing within 30-meters of water source
-From water source, no uphill or upstream fumigation or agriculture
-The perimeter fence is secure and no repairs are needed
-Water source remains clean of garbage
-Plants around water source maintained to keep water source easily accessible
-Ensure there are no leaks, all lids are in place with locks and all air vents are screened
-Check cleanout line for blockages

After a heavy rainfall, operators should check turbidity levels, as the heavy rain can cause an influx of sediment in the system. They should also check for garbage and plants around the water source.

Operators should also ensure that any government-required water quality testing is conducted.

4.3 Ongoing Water Quality Testing for Biosand Filters

The table below explains the parameters to be tested, the required limit, how to test it, the frequency, and how to mitigate the parameter if it is above or below range. This information, including a more in-depth explanation and document to share with the water system operator, can be found in Appendix 6. Training materials on this topic can be found under the Technical documents tab on the Green Empowerment website.

Parameter	Maximum Suggested Limit	Detection	Frequency	Mitigation	Notes/Rationale
Fecal Coliform	0 detectable /100 mL	3M Petrifilm or other fecal coliform test kit	Once a month, should be checked at first house/tap stand on the system, middle house/tap stand, and last house/tap stand on the system	Clean out biosand filter	This is an indicator of contaminated water. If above the maximum suggested limit, the filtration system is not functioning properly and maintenance is needed.
Turbidity	<5 NTU or Secchi disk visibility inside the reservoir	Secchi disk or equivalent instrument	Weekly, after a big rain event, should be measured inside of the reservoir	Sedimentation	If water is turbid, it is an indicator the filter is not functioning properly.

To ensure source protection, conduct a bi-monthly monitoring of the area, including:

-Monitor the water flow from the filtration system, if flow is low the filtration system may need further cleaning
-Check the upflow pre-filter; if it appears muddy it needs to be cleaned
-No latrines, open defecation, animals, trash disposal, vehicle washing/maintenance, and washing within 30-meters of water source
-From water source, no uphill or upstream fumigation or agriculture
-The perimeter fence is secure and no repairs are needed
-Water source remains clean of garbage
-Plants around water source maintained to keep water source easily accessible
-Ensure there are no leaks, all lids are in place with locks and all air vents are screened
-Check cleanout line for blockages

After a heavy rainfall, operators should check turbidity levels, as the heavy rain can cause an influx of sediment in the system. They should also check for garbage and plants around the water source.

Operators should also ensure that any government-required water quality testing is conducted.

4.4 Ongoing System Maintenance

Water system operators should clean and disinfect the water storage tank every three months and disinfect the water distribution network every 6 months. This will keep the water storage tank and distribution network free of dirt and algae, ensuring the community is receiving clean drinking water.

A more in-depth explanation on water reservoir and system disinfection and a document to share with the water system operator can be found in Appendix 7. Training materials on this topic can be found under the Technical Documents tab on the Green Empowerment website.

APPENDIX 1

GREEN EMPOWERMENT SUGGESTED LABORATORIES

Ecuador:

Inbiotec Lab
Dr. Hernan Riofrio
Phone number: +593099984322554
E-mail: Hernan_riofrio@hotmail.com

Sample instructions: Double wash PE containers in the source water, bottle without leaving an air gap, transport on ice in under 24 hours to the lab.

Nicaragua:

Universidad Nacional de Ingenería, Programa de Investigación Estudios Nacionales y Servicios Ambientales (PIENSA-UNI)
Cellphone number: 8152-7314 o 5847-6823
E-mail: piensa@uni.edu.ni or atencion.cliente@piensa.uni.edu.ni

Sample instructions: Double wash PE containers in the source water, bottle without leaving an air gap, transport on ice in under 24 hours to the lab.

APPENDIX 2

PHYSIOCHEMCIAL AND TOTAL COLIFORM PARAMETERS

The table below lists the parameters tested in a physiochemical and total coliform lab analysis and their suggested limit. This is an expanded version of the Essential Parameters List provided in the main section.

Parameter	Maximum Suggested Limit	Mitigation	Notes/Rationale
Bicarbonate	NE*	-Water softener	Causes water hardness. Affects people with kidney issues but not considered significant.
Calcium	100 mg/L**	-Water softener (ion-exchange)	Causes water hardness.
Calcium hardness	NE*	-Water softener	Makes it difficult to remove soap which affects community acceptability.
Carbonate	NE*	-Water softener	Can cause a build-up of scale deposits.
Chloride	250 mg/L *(WHO, 2011)*	-Reverse osmosis -Distillation -Ion exchange	Affects taste and community acceptability. Can corrode pipes.
Fecal Coliforms	0 detectable /100 mL *(EPA, National Primary Drinking Water Regulations, 2017)*	-Chlorination -Biosand filters	Causes diarrhea, stomach ailments and dehydration.
Dissolved Oxygen	14 mg/L** *(NIH, 2012)*	-Purge with argon or nitrogen	Excess dissolved O_2 causes corrosion of pipes.
Electrical conductivity	400 µS/cm**	-Nanofiltration -Reverse osmosis -Distillation	Indicates amount of salt present in water. If levels are high, a total dissolved solids test may need to be conducted.
Fluoride	1.5 mg/L *(WHO, 2011)*	-Filtration with Alumina	Causes skeletal and dental health issues and tooth discoloration.
Lead	0 mg/L *(EPA, National Primary Drinking Water Regulations, 2017)*	-Reverse osmosis -pH mitigation -Remove lead pipes, plumbing systems, etc.	Usually due to presence of lead pipes, plumbing system, etc. Children and pregnant women are most at risk. Increased lead levels can affect the nervous system.
Magnesium	50 mg/L**	-Water softener	Causes hardness of water.
Manganese	0.05 mg/L *(EPA, Secondary Drinking Water Standards: Guidance for Nuisance Chemicals, 2017)*	-Greensand or pyrolusite filtration -Oxidation plus sand filtration	Naturally occurring, often with iron. May also come from industrial emissions. Affects central nervous system and aesthetics (bad taste, "black water," stains)

Nitrate	50 mg/L *(WHO, 2011)*	-Membrane filtration -Source protection	Usually due to fertilizer runoff. High level of nitrites and nitrates cause Blue-Baby syndrome in children.
Nitrite	3 mg/L *(WHO, 2011)*	-Membrane filtration -Source protection	Usually due to fertilizer runoff. High level of nitrites and nitrates cause Blue-Baby syndrome in children.
pH (alkalinity, acidity)	6.5-8.5 *(EPA, Secondary Drinking Water Standards: Guidance for Nuisance Chemicals, 2017)*	-Calcite/Lime treatment -Air stripping to raise pH	Acidity causes corrosion, and can affect taste as well.
Potassium	10 mg/L**	-Reverse osmosis	Affects people with kidney diseases.
Sodium	60 mg/L* *(EPA, 2003)*	-Reverse osmosis -Distillation	Due to agricultural and industrial waste. High levels of sodium affect taste and cause changes in blood pressure.
Sulfate	250 mg/L *(EPA, Secondary Drinking Water Standards: Guidance for Nuisance Chemicals, 2017)g*	-Membrane filtration -Source protection	Excess amount of sulfate is presumed to cause intestinal disorders. Sulfate is known to corrode pipes.
Total Hardness	400 mg/L**	-Water softener (Use in moderation because sodium and potassium levels will go up)	Is due to high calcium and magnesium concentrations. Does not affect health in a negative way, but affects community acceptance (hard to remove soap when washing).
Total Iron	0.3 mg/L *(EPA, Secondary Drinking Water Standards: Guidance for Nuisance Chemicals, 2017)*	-Oxidation plus sand filtration -Greensand or pyrolusite filtration	Causes stains in pots and clothes, unacceptable flavor. Long-term health issues such as joint pain and heart disease.
True Color	15 UC** *(EPA, Secondary Drinking Water Standards: Guidance for Nuisance Chemicals, 2017)*	-Activated charcoal filters	Indicates non-dissolved particles, testing should be done to determine what the particles are.
Turbidity	<5 NTU *(EPA, National Primary Drinking Water Regulations, 2017)*	-Sedimentation (may need prior coagulation & flocculation) -Rapid or slow sand filtration	Affects color of water. If chlorine is being used it will decrease its effectiveness. If filtration is being used it can clog the filter.

*No specific suggested limit
**Green Empowerment recommended limit

APPENDIX 3

ASPIRATIONAL PARAMETERS

Aspirational parameter testing falls into three categories: metals, organic compounds, and pesticides. Below is a description of each and the constituents that are of most concern to Green Empowerment.

Metals

Increased metal concentrations can be due to a variety of reasons, such as: natural occurrence, pollution due to manufacturing and production of materials, use of detergents, chemicals, etc. High metal concentrations can cause elevated blood pressure, gastrointestinal problems, muscle weakness, and kidney issues in the short term and can also have long-term carcinogenic implications. Metals of concern are explained in the list below.

Parameter	Maximum Suggested Limit	Remarks (Sources/Occurrence)
Antimony	0.02 mg/L *(WHO, 2011)*	Antimony is a contaminant from pipe and fitting materials. It is not a raw water contaminant.
Barium	0.7 mg/L *(WHO, 2011)*	Barium occurs naturally as trace elements in both igneous and sedimentary rocks.
Boron	2.4 mg/L *(WHO, 2011)*	Boron is present in surface water due to the discharge of treated sewage effluent, which still contains detergents.
Cadmium	0.003 mg/L *(WHO, 2011)*	Cadmium is used in the manufacturing of steel, plastics, etc.
Chromium	0.05 mg/L *(WHO, 2011)*	Occurs in wastewater in certain industries.
Mercury	0.006 mg/L *(WHO, 2011)*	Usually due to industrial and mining contamination. Affects brain and kidneys, and fetus development.
Lead	0.01 mg/L *(WHO, 2011)*	Usually caused by water system piping that contains lead. Affects health of children and infants, and fetus development.

Organic Compounds

Increased organic compound concentrations in a water source can be due to many reasons: manufacturing and production of materials use of detergents, chemicals etc. Benzene, explained below, is of most concern.

Parameter	Maximum Suggested Limit	Remarks (Sources/Occurrence)
Benzene	0.01 mg/L *(WHO, 2011)*	Benzene seeps into ground water from gasoline and petroleum products. Benzene is a known carcinogen.

Pesticides

High levels of pesticides contamination are becoming more common throughout the world. There are a variety of pesticides, but of most concern to Green Empowerment is DDT, which has been banned in many countries but is still used, and often misused, in those countries where it is not banned. A list of other pesticides that can have negative health effects can be found in the "Drinking Water Quality: Parameter Review" on the Green Empowerment website.

Parameter	Maximum Suggested Limit	Remarks (Sources/Occurrence)
DDT	0.001 mg/L *(WHO, 2011)*	DDT is highly persistent in the developing world. It is highly cariogenic for women, resulting in breast cancer, and is known to cause developmental defects in young adults.

APPENDIX 4

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DRINKING WATER TREATMENT WITH CHLORINATION SYSTEM: OPERATOR MANUAL

Maintaining water at drinking water quality standard is important to the health of the community. It prevents malnourishment, diarrheal diseases, and other illnesses. This manual discusses the testing parameters required to maintain water suitable for human consumption.

The chart below describes the basic parameters to be monitored to ensure water quality, the suggested limit, what can be used to test, test frequency, why it is important, and how to mitigate.

Parameters	Maximum Suggested Limit	Detection	Frequency	Mitigation	Notes/Rationale
Residual Chlorine	0.5mg/L – 1.0 mg/L	Chlorine test kit	2 days after chlorine is recharged, should be checked at the first, middle and last house/tap stand of the system	Control amount of chlorine added	Usually the closest house will have the highest amount of chlorine and the house farthest away will have the lowest, adjust chlorine level based on need. Levels higher than 0.6 mg/L will affect taste.
Turbidity	<5 NTU (or Secchi disk visibility inside the reservoir)	Secchi disk or equivalent instrument	Before chlorine is recharged, after a big rain event, water should be measured in the reservoir	Sedimentation	If water is being chlorinated, turbid water can decrease the effect of the chlorine. Sedimentation usually occurs in the reservoir.

To ensure source protection, conduct a bi-monthly monitoring of the area, including:
-No latrines, open defecation, animals, trash disposal, vehicle washing/maintenance, and washing within 30-meters of water source
-From water source, no uphill or upstream fumigation or agriculture
-The perimeter fence is secure and no repairs are needed
-Water source remains clean of garbage
-Plants around water source maintained to keep water source easily accessible
- Ensure there are no leaks, all lids are in place with locks and all air vents are screened
-Check cleanout line for blockages

After the first heavy rainfall, make sure to check turbidity and chlorine levels. Also look for garbage and plants around the water source.

Do not forget to conduct required government water quality testing.

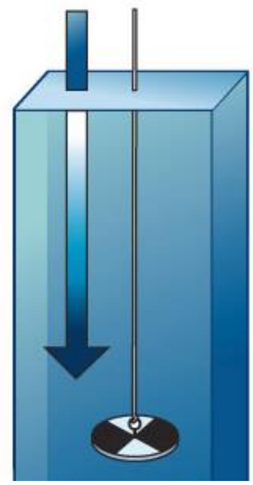
Troubleshooting:

-People complaining about strong chlorine taste: The taste of chlorine can start to be detected at 0.2 mg/L. If the community is saying the water tastes like chlorine, first check the concentration in the first, middle and last house/tap stand of the system. If the concentration is more than 1.5 mg/L, decrease the amount of chlorine being mixed in (see chlorination manual). If you recently started chlorinating, remember it takes time for the community to get used to the taste, add it little by little, eventually reaching the desired concentration and giving the community enough time to become accustomed.

-Water is discolored: This could be due to suspended solids. Check the reservoir to see how much sand is on the bottom. Make sure you are cleaning the reservoir once every 3 months. It can be cleaned more often as needed. If there is still a problem with discoloration, take a water sample to get tested for metals. If the source is groundwater, untreated iron can lead to red water and high manganese concentrations can cause black water.

-Chlorine levels are significantly lower in the last house/tap stand than the first house/tap stand: This is most likely due to the distribution system having bacterial growth. Conduct a water system disinfection of the reservoir and distribution system.

-No Secchi disk: If a Secchi disk is not available to test turbidity, one can be created with an old CD or DVD disk. With a permanent marker, divide the disk into quarters and paint it black and white, as seen in the picture below. Using a 15-meter-long string, put one end through the center of the disk and securely tie it to the disk. Tie it in a way to see the painted side of the disk when it is immersed in water. Also add weighted objects (i.e. washers, PVC pipe) as needed to ensure the disc sinks. At the water storage tank, slowly lower the Secchi disk into the reservoir until it reaches the bottom. At the bottom, if the colored part of the Secchi disk can be seen clearly, the water is not turbid. If it cannot be seen clearly, the water is turbid.



APPENDIX 5

DRINKING WATER TREATMENT WITH SLOW SAND FILTRATION SYSTEM: OPERATOR MANUAL

Maintaining water at drinking water quality standard is important to the health of the community. It prevents malnourishment, diarrheal diseases, and other illnesses. This manual discusses the testing parameters required to maintain water suitable for human consumption.

The chart below describes the basic parameters to be monitored to ensure water quality, the suggested limit, what can be used to test, test frequency, why it is important, and how to mitigate.

Parameter	Maximum Suggested Limit	Detection	Frequency	Mitigation	Notes/Rationale
Fecal Coliform	0 detectable /100 mL, 0 colonies present (see test kit directions as needed)	-3M Petrifilm or other E. coli test kit	Once a month, should be checked at first, middle, and last house/tap stand of the system	Clean out slow sand filter	Fecal coliforms are a parameter to check for contaminated water. If above the maximum suggested limit, the filtration system is not functioning properly and maintenance is needed.
Turbidity	<5 NTU or Secchi disk visibility inside the reservoir	Secchi disk or equivalent instrument	Weekly, after a big rain event, should be measured inside of the reservoir	Sedimentation	If water is turbid, it is an indicator the filter is not functioning properly.

To ensure water quality and source protection, conduct the following:
-Monitor the water flow from the filtration system, if flow is low the filtration system may need further cleaning (cleaning typically is needed every two weeks but should be conducted as needed)
-No latrines, open defecation, animals, trash disposal, vehicle washing/maintenance, and washing within 30-meters of water source
-From water source, no uphill or upstream fumigation or agriculture
-The perimeter fence is secure and no repairs are needed
-Water source remains clean of garbage
-Plants around water source maintained to keep water source easily accessible
-Ensure there are no leaks, all lids are in place with locks and all air vents are screened
-Check cleanout line for blockages

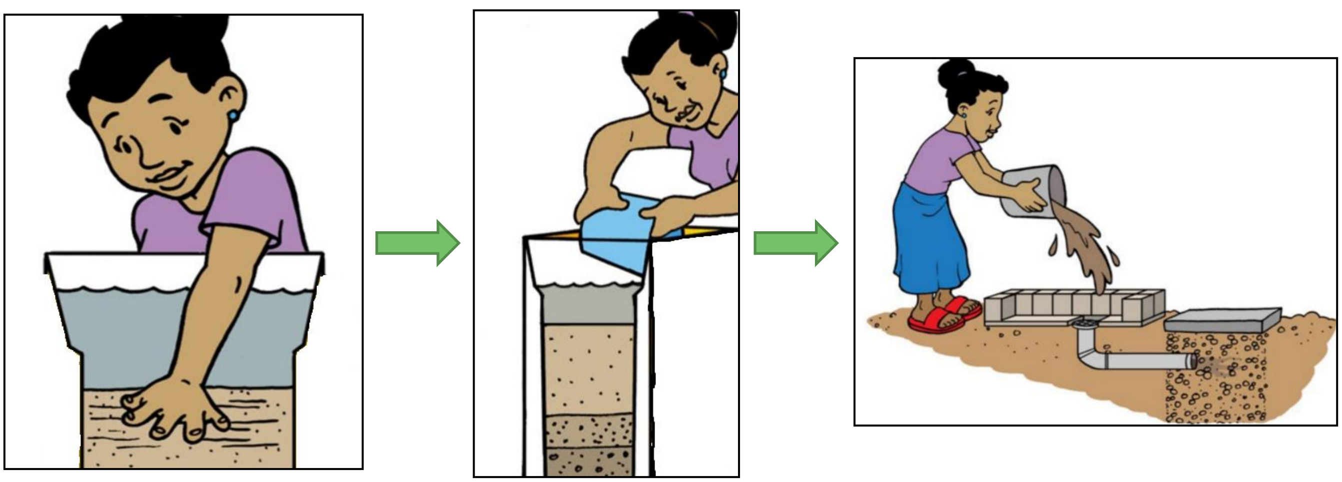
After the first heavy rainfall, make sure to check turbidity and fecal coliform levels. Also look for garbage and plants around the water source

Do not forget to conduct required government water quality testing.

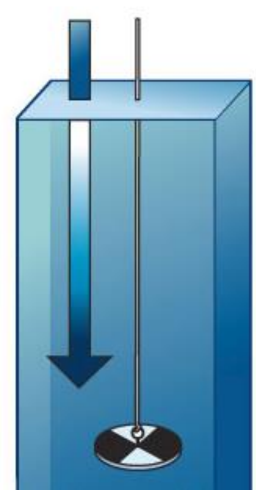
Troubleshooting

-Biosand filter is clogged/low flow coming from the biosand filter to the reservoir: The contaminants trapped by this filter remain in the first layer of fine sand, and as they accumulate, they can cover the filter. Therefore, every two weeks or more frequently if the filter is overflowing or the flowrate is slower than normal, a simple cleaning should be carried out. For cleaning:

1. Ensure that the pump is switched off.
2. Remove the filter tank cover.
3. Remove the diffuser tubes that are inside the upper part of the tank (only if they interfere).
4. Stir the first 5 to 10 cm of sand with your hand or a clean broom handle so that the dirt from the sand comes out of the water.
5. Then remove the dirty water with a bucket and throw it where it can filter through the earth, away from the filters and where it will not cause much mud.
6. Finally, replace the diffuser tubes, close the tank lid tightly, and return the pump to normal operation.



-Water from tap is turbid: If the water coming from the tap is turbid, the filtration system most likely needs to be cleaned. See "Biosand filter is clogged/low flow coming from the biosand filter to the reservoir" section above. If the water continues to be turbid, there is likely a break in the water line where sand is entering. Walk the water system to check for water leaks.



-No Secchi disk: if a Secchi disk is not available to test turbidity, one can be created with an old CD or DVD disk. With a marker, divide the disk into quarters and paint it black and white, as seen in the picture below. Using a 10-meter long string, put one end through the center of the disk and securely tie it to the disk. Tie it in a way to see the painted side of the disk when it is immersed in water. Also add weighted objects (i.e. washers, PVC pipe) as needed to ensure the disc sinks. At the reservoir, slowly lower the Secchi disk

into the reservoir until it reaches the bottom. At the bottom, if the colored part of the Secchi disk can be seen clearly, the water is not turbid. If it cannot be seen clearly, the water is turbid.

APPENDIX 6

DRINKING WATER TREATMENT WITH BIOSAND FILTRATION SYSTEM: OPERATOR MANUAL

Maintaining water at drinking water quality standard is important to the health of the community. It prevents malnourishment, diarrheal diseases, and other illnesses. This manual discusses the testing parameters required to maintain water suitable for human consumption.

The chart below describes the basic parameters to be monitored to ensure water quality, the suggested limit, what can be used to test, test frequency, why it is important, and how to mitigate.

Parameter	Maximum Suggested Limit	Detection	Frequency	Mitigation	Notes/Rationale
Fecal Coliform	0 detectable /100 mL, 0 colonies present (see test kit directions as needed)	-3M Petrifilm or other E. coli test kit	Once a month, should be checked at first, middle, and last house/tap stand of the system	Clean out biosand filter	Fecal coliforms are a parameter to check for contaminated water. If above the maximum suggested limit, the filtration system is not functioning properly and maintenance is needed.
Turbidity	<5 NTU or Secchi disk visibility inside the reservoir	Secchi disk or equivalent instrument	Weekly, after a big rain event, should be measured inside of the reservoir	Sedimentation	If water is turbid, it is an indicator the filter is not functioning properly.

To ensure water quality and source protection, conduct the following:
-Monitor the water flow from the filtration system, if flow is low the filtration system may need further cleaning
-Check the upflow pre-filter; if it appears muddy it needs to be cleaned.
-No latrines, open defecation, animals, trash disposal, vehicle washing/maintenance, and washing within 30-meters of water source
-From water source, no uphill or upstream fumigation or agriculture
-The perimeter fence is secure and no repairs are needed
-Water source remains clean of garbage
-Plants around water source maintained to keep water source easily accessible
-Ensure there are no leaks, all lids are in place with locks and all air vents are screened
-Check cleanout line for blockages

After the first heavy rainfall, make sure to check turbidity and fecal coliform levels. Also look for garbage and plants around the water source

Do not forget to conduct required government water quality testing.

Troubleshooting

-Upflow pre-filter media appears muddy: Stir the gravel to disturb the muddy sediments until the water becomes brown. Then, open the filtration cleanout valve to flush the turbid water. Refill the gravel filter and repeat the process until the gravel filter media is thoroughly clean.

-Biosand filter is clogged/low flow coming from the biosand filter to the reservoir:

1. Check the gate valve between the filtration system and reservoir. Adjust as necessary. If completely open and flow is still low, proceed to step 2.

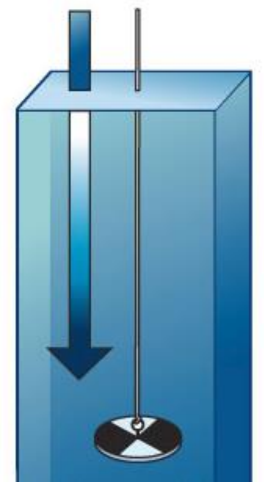
2. Check the upflow pre-filter to make sure the water is moving to the biosand filter. If water is not flowing to the biosand filter, the biosand filter inlet might be blocked or the upflow pre-filter might need to be cleaned. Once checked and if the flow from the biosand filter is still low, proceed to step 3.

3. Open the cleanout plug located on the biosand filter outlet pipe. Empty out all the water, making sure to remove anything that could be causing the reduction of water flow to the reservoir. If the problem is not resolved, proceed to step 4.

4. *Wet harrowing cleaning method*: Shut the gate valve located at the outlet pipe of the filtration system and inlet pipe of reservoir and let the water from the filtration tank overflow. Opening the biosand filter manhole, disturb the water inside by rotating your hand until the suspended particles on the top layer of sand are disturbed and become suspended. DO NOT touch the sand bed as you could disturb the biological layer. Do this until the water becomes brown. With water still flowing into the biosand filter from the upflow pre-filter, let the water overflow through the biosand filter overflow pipe until the water becomes clear. Repeat these steps until the water does not become brown when you disturb the water. Open the gate valve and let the water flow into the reservoir. Monitor the water flow by measuring the volume of water flowing in to the reservoir. If after doing this method water flow is still limited, proceed to step 5.

5. *Scraping method*: Shut the inflow valve into the filtration system. Open the cleanout valve of the biosand filter and flush out and drain the water. Using the biosand filter manhole, enter the biosand filter. Make sure to wash your feet thoroughly before entering the tank to prevent further contamination. Using a tape measure, measure 2 centimeters down into the sand. Mark the spot along the wall. Carefully remove 2 centimeters of sand off the entire biosand filter. Put removed sand in a clean, dry sack. Close the cleanout pipe and fill the biosand filter with water. Then, flush the water from the biosand filter via the biosand filter cleanout valve to remove the remaining sediments at the bottom of the of biosand filter. After completing the process, let the water flow through the filtration system for at least 10 to 15 days before using the water (this is sufficient time for the biological layer to form). DO NOT throw out removed sand. Keep the sand in the clean sack, stored in a safe place. The sand will be used, after cleaning, in the next scraping process to replace the sand that will be taken out. This will prevent reduction of the filter media. Make sure to clean the sand in the sack before putting it back into the biosand filter.

-**Water from tap is turbid**: If the water coming from the tap is turbid, the filtration system most likely needs to be cleaned. First check the upflow pre-filter. If it appears muddy, clean as described above. Then check the biosand filter. If flow is limited it needs to be cleaned as well. Follow the steps described in the "Biosand filter is clogged/low-flow" section above. If this does not decrease the water turbidity, the water distribution network needs to be cleaned/disinfected. See "Steps for Cleaning and Disinfection of Water Storage Tank and Distribution Network" document.



-**No Secchi disk**: if a Secchi disk is not available to test turbidity, one can be created with an old CD or DVD disk. With a marker, divide the disk into quarters and paint it black and white, as seen in the picture below. Using a 10-meter long string, put one end through the center of the disk and securely tie it to the disk. Tie it in a way to see the painted side of the disk when it is immersed in water. Also add weighted objects (i.e. washers, PVC pipe) as needed to ensure the disc sinks. At the reservoir, slowly lower the Secchi disk into the reservoir until it reaches the bottom. At the bottom, if the colored part of the Secchi disk can be seen clearly, the water is not turbid. If it cannot be seen clearly, the water is turbid.

APPENDIX 7

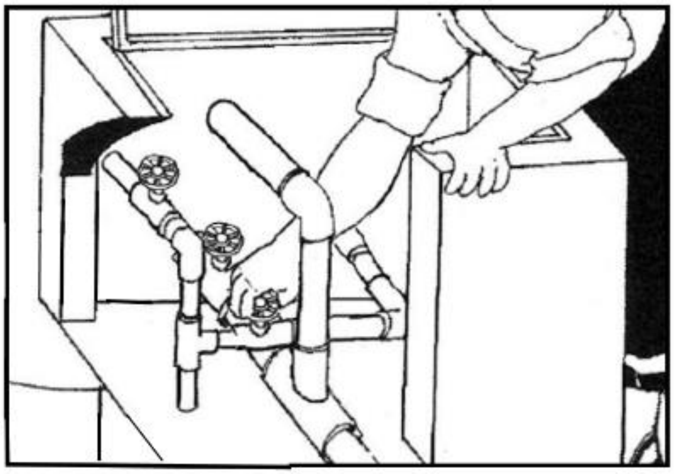
Cleaning and Disinfection of Water Storage Tank and Distribution Network

Note: It is very important to notify the water system users 2 days before cleaning and disinfection that they should not use the water the day of the disinfection. If your system has two water storage tanks, disinfect the tanks at different times to not completely cut off water supply. Also, ensure all equipment is on-hand.

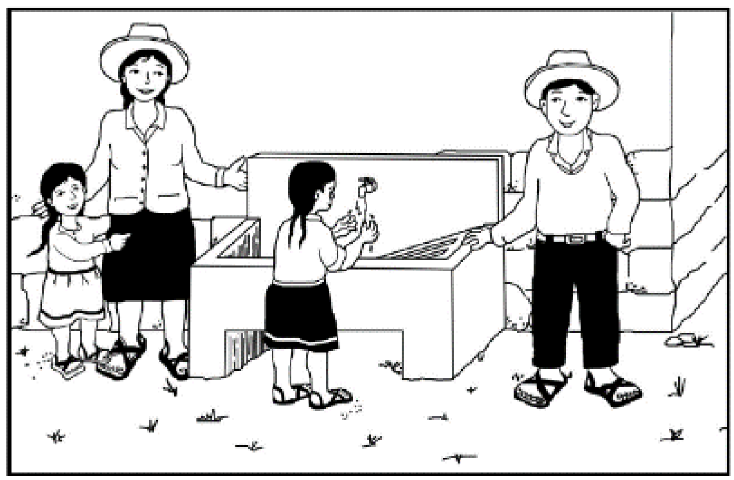
Two days prior to disinfection, make sure you have all of the necessary materials:

- 3-6 People
- Hand Scale
- Mixing Stick
- Ladder
- 3 or more Pairs of Rubber Gloves
- 3 or more Protection Masks
- 2 or more Brooms
- 65%-75% Powdered Chlorine
- Rubber Boots
- 3 or more Protective Glasses
- 3 or more Brushes
- 3 Buckets
- Machete
- Soup spoon

The Night Before

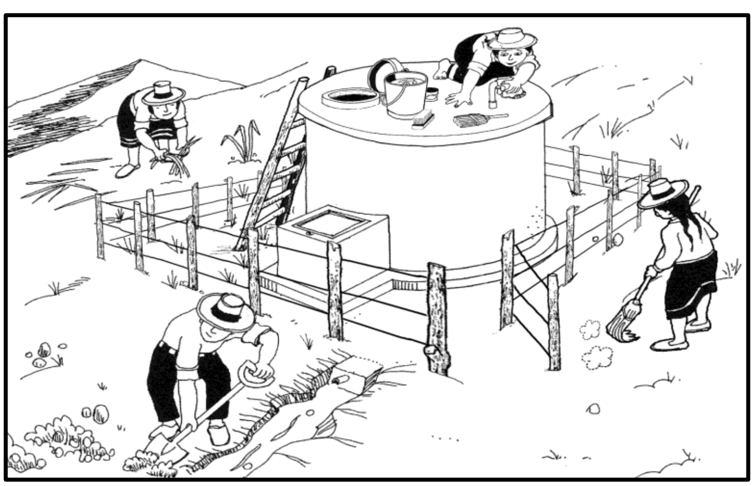


The night before the tank is cleaned, turn off the pump or cut off the water at the tank entrance, allowing the community to use the water to drain the tank.



The day of the cleaning, confirm the community has been notified.

Day 1: External Cleaning (every 3 months)

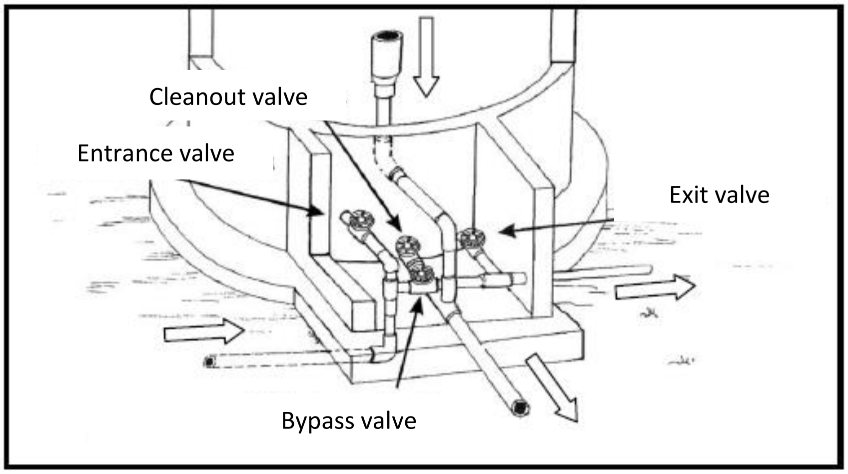


Clean the rocks, undergrowth and dirt from the zone around the tank, including the tank cleanout line or drainage canal.

Remove the sanitary lid of the water storage tank and close the water storage tank inflow and outflow (to distribution network) valves.

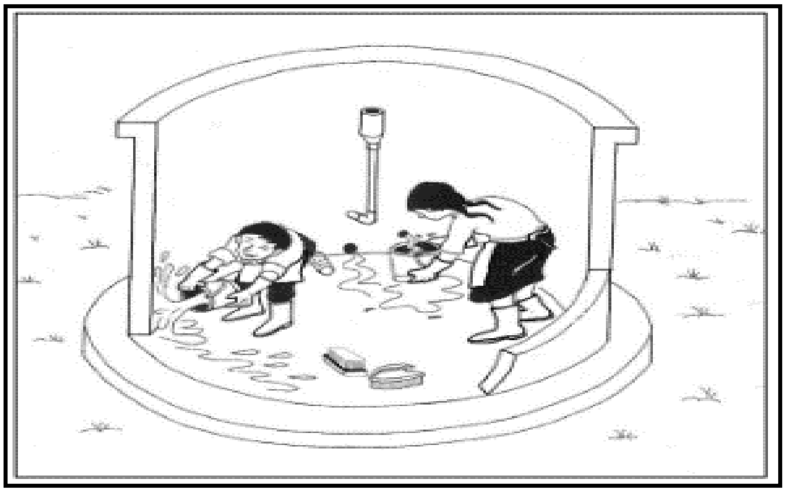
Remove the water in the water storage tank by opening the washout valve.

Clean out the dirt and/or water in the valve box and check the valves for breaks or leaks.



*Every system is different

Day 1: Internal Cleaning (every 3 months)



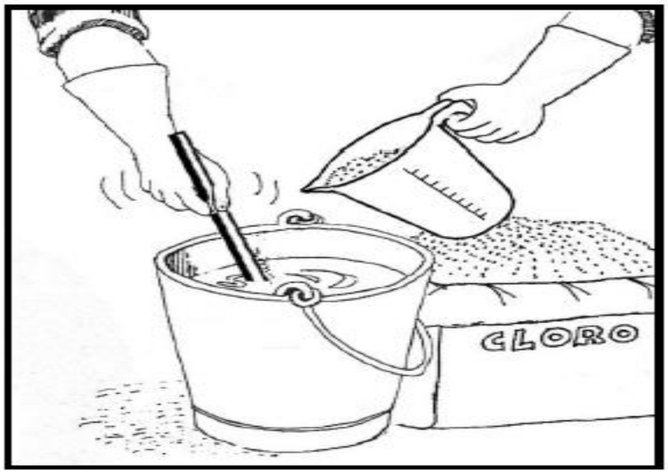
Using a clean broom, remove the dirt from the floor of the water storage tank.

Clean the interior water storage tank walls and accessories with the brooms and brushes. Throw out the dirty water.

Day 1: Tank Disinfection (every 3 months)

Always use the proper protective equipment when working with chlorine powder or chlorine solution:

- Protective Mask
- Rubber Boots
- Protective Glasses
- Rubber Gloves

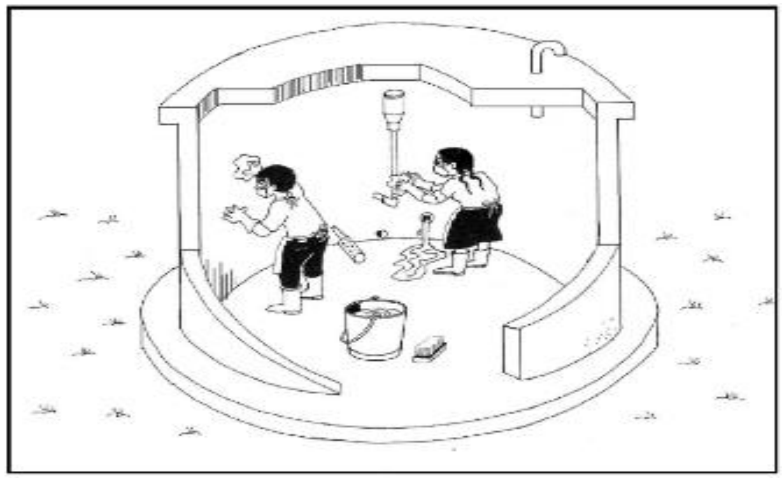


Using the powdered chlorine, dissolve 4 tablespoons of powder chlorine in a 20L bucket. More than one bucket of chlorine solution can be prepared if necessary.

With this solution and a brush, scrub the walls, floor, roof, sanitary lid and accessories in the water storage tank. Take turns with who is inside the tank.

Do not stay in the tank for a prolonged period of time (maximum 10 minutes), since the chlorine produces toxins and can cause suffocation.

Using the buckets, rinse the walls of the tank with fresh water to remove the chlorine.



Refill the tank during the night and the next morning. The time it takes to fill the tank is different for each system.

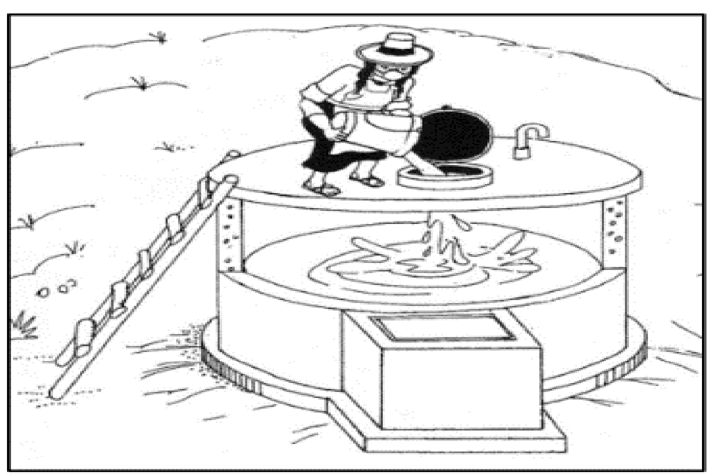
Day 2: Tank Disinfection (every 3 months)

When the water level in the tank is halfway, prepare the chlorine solution using the appropriate quantity.

Volume of water storage tank: ___

Concentration of Chlorine (provided by vendor)	65%	70%	75%
Weight of Chlorine (kg or lbs)			

Mix in parts (0.5 kg or 1 lb at a time) using a 20 L bucket. Carefully add the solution to the tank little by little.



Finish filling the storage tank with water and leave the solution for 2 hours.

Day 2: Tank Disinfection/Distribution Network Disinfection

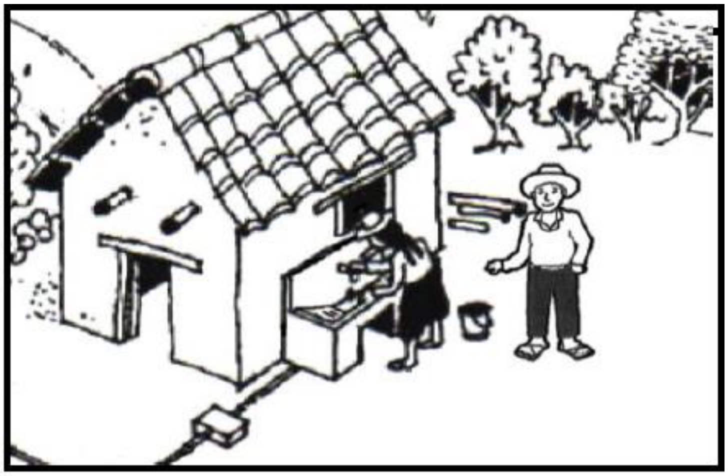
If you are not going to disinfect the distribution network:

2 hours, empty the water storage tank by opening the clean out valve.

If you are going to disinfect the distribution network (every 6 months):

After 2 hours, open the outflow valve to the water distribution network, simultaneously, open faucets in all houses and have each household remove 10 buckets of water. Then close the faucets and place a plastic bag over them to ensure no one drinks the disinfection water.

Day 2: Distribution Network Disinfection (every 6 months)



Let the chlorinated water sit in the distribution network for 4 hours.

After 4 hours, remove the chlorinated water from the water storage tank and distribution system by opening all household/tap stand valves.

Have each household keep their faucets open until no water comes out.

Refill the storage tank with water and continue with normal water service.

How to Calculate the Amount of Chlorine:

$$P = \frac{CV}{BK} = \frac{(50\,\frac{mg}{L})(V)}{(B)(10)}$$

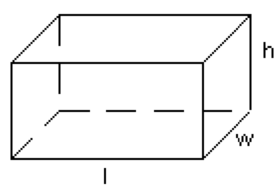
P= Weight of Chlorine (grams)
C= Concentration Desired in Water Storage Tank (50 mg/L)
V= Volume of Water Storage Tank (L)
B= Chlorine Concentration (65% or 70% or 75%)*
K= Constant (10)

*This varies with vendor, ask vendor the concentration of the chlorine.

How to calculate the volume of the water storage tank:

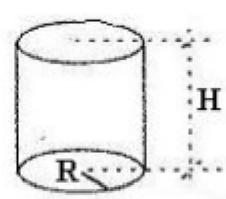
-Rectangular/Square (using the measurements from inside the water storage tank)

$$V = (L)(W)(H)$$



-Cylinder (using the measurements from inside the water storage tank)

$$V = \pi R^2 H$$



Example:

We have a rectangular water storage tank (2m x 2.5m x 3m). The chlorine concentration of the chlorine is 70%. How much chlorine do we need by weight?

$$V = (2m)(2.5m)(3m) = 15m^3$$

$$Conversion: m^3\ to\ L = 15m^3\left(\frac{1000\ L}{1\ m^3}\right) = 15{,}000\ L$$

$$P = \frac{CV}{BK} = \frac{(50\frac{mg}{L})(15{,}000)}{(70)(10)} = 1071\ gramos = 1.07\ kg$$

The quantity of chlorine needed is 1.07 kg.

Table: Quantity of Chlorine Needed

Volume of Water in the Water Storage Tank (L)	Chlorine Concentration (%)		
	65	70	75
	Weight of Chlorine (lbs)		
10000	1.7	1.57	1.47
11000	1.87	1.73	1.62
12000	2.04	1.89	1.76
13000	2.2	2.05	1.91
14000	2.37	2.2	2.06
15000	2.54	2.36	2.2
16000	2.71	2.52	2.35
17000	2.88	2.68	2.5
18000	3.05	2.83	2.65
19000	3.22	2.99	2.79
20000	3.39	3.15	2.94
21000	3.56	3.31	3.09
22000	3.73	3.46	3.23
23000	3.9	3.62	3.38
24000	4.07	3.78	3.53
25000	4.24	3.94	3.67
26000	4.41	4.09	3.82
27000	4.58	4.25	3.97
28000	4.75	4.41	4.12
29000	4.92	4.57	4.26
30000	5.09	4.72	4.41
31000	5.26	4.88	4.56
32000	5.43	5.04	4.7
33000	5.6	5.2	4.85
34000	5.77	5.35	5
35000	5.94	5.51	5.14
36000	6.11	5.67	5.29
37000	6.27	5.83	5.44
38000	6.44	5.98	5.59
39000	6.61	6.14	5.73
40000	6.78	6.3	5.88

Volume of Water in the Water Storage Tank (L)	Chlorine Concentration (%)		
	65	70	75
	Weight of Chlorine (kg)		
10000	0.77	0.71	0.67
11000	0.85	0.78	0.73
12000	0.93	0.86	0.80
13000	1.00	0.93	0.87
14000	1.08	1.00	0.93
15000	1.15	1.07	1.00
16000	1.23	1.14	1.07
17000	1.31	1.22	1.13
18000	1.38	1.28	1.20
19000	1.46	1.36	1.27
20000	1.54	1.43	1.33
21000	1.61	1.50	1.40
22000	1.69	1.57	1.47
23000	1.77	1.64	1.53
24000	1.85	1.71	1.60
25000	1.92	1.79	1.66
26000	2.00	1.86	1.73
27000	2.08	1.93	1.80
28000	2.15	2.00	1.87
29000	2.23	2.07	1.93
30000	2.31	2.14	2.00
31000	2.39	2.21	2.07
32000	2.46	2.29	2.13
33000	2.54	2.36	2.20
34000	2.62	2.43	2.27
35000	2.69	2.50	2.33
36000	2.77	2.57	2.40
37000	2.84	2.64	2.47
38000	2.92	2.71	2.54
39000	3.00	2.79	2.60
40000	3.08	2.86	2.67

How to Use the Pre-Calculated Tables:

Chlorine Concentration=70%
Volume of water storage tank=15000 L
Weight of chlorine needed: ?

Volume of Water in the Water Storage Tank (L)	Chlorine Concentration (%)		
	65	70	65
	Weight of Chlorine (kg)		
10000	0.77	0.71	0.67
11000	0.85	0.78	0.73
12000	0.93	0.86	0.80
13000	1.00	0.93	0.87
14000	1.08	1.00	0.93
15000	1.15	1.07	1.00
16000	1.23	1.14	1.07
17000	1.31	1.22	1.13
18000	1.38	1.28	1.20

The quantity of chlorine needed is 1.07 kg.

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REGISTRY OF THE CLEANING AND DISINFECTION OF THE WATER STORAGE TANK AND DISTRIBUTION NETWORK

Time and Date	Person Who Conducted Activity	Activity Completed	Notes

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