



Tools for Safe Water Stations

Quality Module



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Introduction to the Quality Module

The Quality Module defines the steps and standards of quality assurance due diligence to ensure the continual performance of high-quality Safe Water Stations and delivery of treated drinking water to consumers.

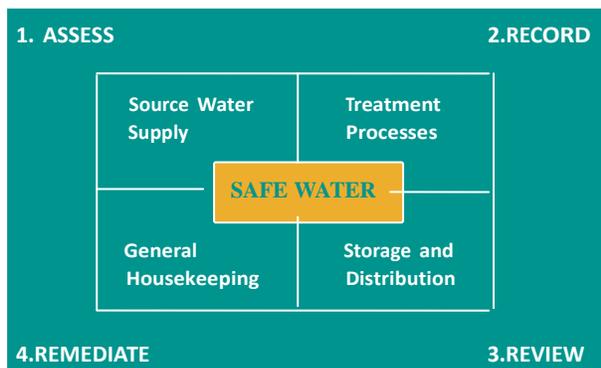
Specifically, the Quality Module contains tools that are to be applied at Safe Water Stations to observe and record:

- The condition of the source water and the environment surrounding the source
- Basic functions of the selected drinking water treatment process
- Housekeeping in and around the Safe Water Station
- The delivery of safe water in storage and distribution operations

It is important that the Safe Water Station operator and the station supervisor use the tools to document all aspects of water collection, treatment, and delivery to verify performance; identify hazards and actions to eliminate them; and communicate openly with customers and authorities.

The SWN's Approach to Quality Assurance

For the Safe Water Network, quality assurance is a passion and a process—not simply meeting drinking water quality standards. The network defines this process through four areas within each of the tools:



- **Assess** that the conditions around the Safe Water Station and water source do not change over time and that processes operate consistently and produce optimal outputs
- **Record** data that can be compared over time to validate conditions and outputs
- **Review** the findings of assessments and records to identify hazards, problems, or risks
- **Remediate** hazards, problems, or risks to ensure that Safe Water Station customers consistently receive a safe and valued product.

Each tool in this module is designed to guide the operator and supervisor through these steps and provide parameters against which the delivery of quality assurance can be measured.

Safety Measures

Quality assurance parameters provide a view of the level of safety across the entire Safe Water System, from source to treated water. The parameters are measured at predetermined times and locations, and they are reviewed for a determination of how the system is performing. These parameters can also be trended to provide predictors of the longevity of operational performance and guidance for system maintenance.

1. Source water parameters
Source water quality measures are based on the collection of periodic data that characterize the water source and its surroundings. These parameters are measured and recorded to create a data set that can be tracked over time and compared to a baseline to identify trends and risks. The types of data collected include both water quality parameters and physical characteristics of the source, such as volume, flow, surface elevation, and environmental conditions.
2. Water treatment process parameters
Process parameters include treatment unit operational parameters that are measured and recorded over time.

These are particularly important in all pressure-driven operations (e.g., measuring pressure differentials across the system), including both membrane systems (measuring the pressure head to detect scaling and fouling) and media-based filtration (ensuring that microbes do not grow on and foul the media). These also include parameters covering each unit operation, both at incoming and at key process stages of treatment in the Safe Water Station. The frequency of these tests varies, both by process unit as well as condition of the source water.

3. Housekeeping parameters

These parameters cover the general conditions of the Safe Water Station, including the surrounding grounds, structural upkeep, facility cleanliness, landscaping, pipeline maintenance, customer area upkeep, and other

factors of general cleanliness and appearance, such as control of yard debris, reject parts, and wastewater.

4. Water treatment process parameters

Managing drinking water quality beyond the treatment site - in the distribution channels, at site kiosks, and in the home—requires periodic measurements to determine strategies and steps to protect quality.

The tools in this module present detailed materials to ensure that each Safe Water Station successfully addresses these parameters. The material in the tools is summarized in these dos and don'ts to guide the station supervisor and operator and to serve as the first measurement of safety during station inspections by outside specialists.

The four tools in this module and the anticipated outputs from their use are presented graphically in **Figure 1**.

Do ...	Don't ...
1. Ensure that an area 50m in radius from the water source is clean of potential sources of contamination	1. Allow water and electricity to come into contact or any bare wires to be visible
2. Install a device to measure the highest level of ground or surface water used as the water source	2. Allow leakage of water from any part of the system, from the source to sale
3. Obtain, learn to use, and keep clean a portable water quality testing device and measure the chlorine concentration in treated water often	3. Neglect the constant measurement of pH. It may seem to be a minor parameter, but it is critically important.
4. Take immediate remediation action if any changes are noted in any aspect of the Safe Water Station	4. Allow the inside or outside of the Safe Water Station to become dirty or harbor trash or waste
5. Accurately and carefully complete any forms or logbooks chosen to describe the action and conditions at a Safe Water Station	5. Forget to record the weather conditions when measurements are made. Weather affects many parameters being measured.
6. Take duplicate measurements often, particularly of microbial contamination	6. Allow any cracks, seepage or mould to appear in any concrete structures at the source or the station
7. Make sure that all personal safety devices are always in good condition and easily accessible and that soap is always available for hand washing	7. Allow uncontrolled disposal of waste material from cleaning a sand filter or from the reject water in reverse osmosis systems into the environment
8. Make repairs or install replacements immediately when a problem is identified	8. Allow treated water to be placed in any unclean containers
9. Establish a regular schedule for all operation and maintenance tasks indicated in the module	9. Hide problems from customers—let them know how you have solved them
10. Communicate regularly with the community and with local government about your quality assurance activities	10. Allow children, customers, or the community to handle chemical or cleaning material used at the Safe Water Station

Figure 1: The Tools in the Quality Module of the Safe Water Station Local Operating Unit



TOOL KIT MODULES		
Quality Module Tools		Outcome
28	Ensuring Consistency of Source Water	Documented quality assurance that the water source is functioning as intended and the vicinity around the source remains free of unwanted potential sources of contamination.
29	Ensuring Consistency of Treatment Processes	Documented quality assurance that the treatment works—modular sand filters or reverse osmosis systems—are in good working condition and are providing drinking water that meets international standards.
30	Ensuring Consistency of Facility Operation	Documented quality assurance that the Safe Water Station and its environment are maintained to a high hygienic standard that is appealing to customers.
31	Ensuring Consistency of Storage and Distribution	Documented quality assurance that the high-quality drinking water produced by the Safe Water Station remains safe and healthy until it is consumed by the customer.



Reviewing quality control with the public builds customer confidence.

Quality Module Tool 28

Ensuring Consistency of Source Water

Purpose

Using tool 7 of the Tool Kit for Safe Water Stations, a water source was identified to serve the Safe Water Station and basic data were collected about the physical characteristics of the water source and its surroundings. The purpose of tool 28 is to establish a record of parameters that characterize the water supply and surroundings to create a data set that can be tracked over time. Using tool 7, a baseline of conditions was established. Using tool 28, trends can be readily correlated against the baseline.

Consistent with the Safe Water Network's approach to quality assurance, the tool addresses each of the key elements as follows:

- **Assess**—evaluates and documents the characteristics of the source water and the water source
- **Record**—provides a standard format for documenting information and data
- **Review**—directs discussion of implications of changes in the information and data over time
- **Remediate**—identifies remedial actions to take to protect the source water quality

Audience

Tool 28 is to be used regularly by the Safe Water Station operator. The operator will use the findings from the tool to make operational decisions, inform the Safe Water Station Committee of any identified risks and mitigation actions, and communicate with customers.

Prerequisites

Before using this tool, it is important for the Safe Water Station operator or supervisor to have access to several items. The first is a portable water quality testing device that can measure pH, total dissolved solids (TDS), and turbidity. Before use in the field, if the device uses probes for *in situ measurement*, it must be calibrated as per the manufacturer's recommendation to ensure the accuracy of field measurements. This may require that the Safe Water Station has commercially produced standard samples that are typically used to calibrate the device.

Second, the Safe Water Station must have an adequate supply of H₂S-based (or other if available and reliable) "presence/absence" microbial test kits. In these commercially available kits, if there is blackening of the

test medium when dosed with the sample water, this demonstrates a positive result and indicates that the water tested is likely contaminated with pathogens. In most cases, positive findings should be confirmed by a laboratory and more controlled and numerically accurate analyses.

Third, if the water source is from surface water, a height gauge needs to be installed to record the elevation of the surface of the water. A height gauge (pictured below) provides a secured reference point that allows an accurate measurement and recording of changes in the elevation of the top of the surface water and therefore of the volume of water available for treatment. The Safe Water Station Partners must ensure that a height gauge is installed when use of any surface water source begins.

These gauges are marked to provide the height in increments (usually centimeters) with 0 at the bottom and graduated to the expected highest level. A reading of the water's height is directly correlated to the available supply of water to the system. Monthly measurement and recording of the height establishes the supply trend and alerts the operator of unfavorable conditions, including low flows or flooding.

Materials Needed

This tool is based on field observation and simple measurements using the equipment described in the previous section. To complete the form, the supervisor must go to the water source with two pieces of equipment: a handheld meter equipped with probes to measure the



total dissolved solids (TDS), turbidity, and pH of each source; and a Global Positioning System (GPS) device to geo-locate each water source. If possible, the probes and meter should be calibrated against standard samples before going to the field to ensure the accuracy of field readings. Upon returning from the field, the meter and probes should be calibrated again against standard samples to ensure proper operation.

Materials Contained In This Tool

The tool is a one-page form on which uniform information can be recorded for the Safe Water Station water source. It is adapted from the Source Water Assessment Form contained in tool 7 and used for comparison of multiple water sources available to the community in which the Safe Water Station is located.

The form is divided into five sections. Section 1 reviews basic information that identifies the water source. Section 2 is for use only if the water source is groundwater. Section 3 is for use only if the water source is surface water. Section 4 updates information on a qualitative sanitary survey of the water source, identifying and evaluating the importance of pollution risks to the water source. Section 5 tabulates information gathered from field, or *in situ*, measurement of two critical water source criteria.

How To Use The Tool

The information required to complete Section 1 of the **Monthly Record—Water Source to Safe Water Station Inlet** should be self-explanatory. However, field examination of the water source will be required to complete Sections 2 and 3. Information in Section 4 will be obtained when the operator or the supervisor visits the water source, and Section 5 will be used to record measurements with water testing equipment. The following guidelines are intended to assist the operator or supervisor with each section. Adhering to the guidelines will ensure that information collected from each visit to the water source is consistent and comparable.

- **Section 1.e, average daily well yield to the Safe Water Station during the month, and Section 1.f, peak daily well yield to the Safe Water Station during the month:** The hydrologic conditions of some underground water sources (e.g., aquifers) are such that the static water level drops gradually when wells are pumped continuously or during times of limited rain. This can result in reduced amounts of water (yields) unless pumping levels are correspondingly lowered. This is not an indication of the failure of the well. If

either the average or the peak well yield does change, care should be taken to differentiate between those factors associated with normal wearing of pump parts and those directly associated with changing conditions in and around the well.

A well can show reduced yield because of a reduction in the capacity of the pump due to excessively worn parts. Excessive wearing of pump parts may be due to the pumping of sand entering the well through a corroded well screen, or corrosion may affect only the pump, reducing its capacity with little or no effect on a properly designed well.

Most commonly, a decrease in a well's capacity results from the clogging of the well screen openings and the water-bearing formation immediately around the well screen by encrusting deposits. If such deposits are occurring, the source water should be specifically analyzed for the following constituents:

- Carbonates and sulfates of calcium and magnesium if deposits are hard and concrete-like
- Iron and manganese hydroxides if deposits are soft, sludge-like forms
- Iron bacteria if deposits resemble gelatinous slimes
- Iron if the deposits are reddish-brown with a scale-like appearance

If yield reductions are noted without a simple explanation, the Safe Water Network recommends measuring the specific capacity of the well. The specific capacity is the yield per foot of drawdown by the pump and is the best indicator of problems in a well. Specific capacity should be checked periodically and compared with previous values, including those immediately after completion of the well, to determine whether significant reductions have taken place. A significant reduction in the specific capacity of a well is most often traced to blockage of the well screen by material around it—mostly by encrusting deposits as described above. Measuring specific capacity may require the involvement of specialists in groundwater hydrology.

- **Section 2.a, condition of wellhead:** Wellhead protection is a way to prevent drinking water from becoming contaminated by managing potential sources of contamination in the area that supplies water to a well. Much can be done to prevent pollution, such as the wise use of land and chemicals. Public health is protected and the expense of treating polluted water or drilling new wells is avoided through wellhead protection efforts. In this section, the general condition

of the wellhead for the Safe Water Station should be described. The description may include the following, all of which should be avoided or eliminated:

- Agricultural activity occurring within 50m of the wellhead
- Sanitation facilities or open defecation located within 50m of the wellhead
- Industries, mining, waste disposal, or garbage pits located within 50m of the wellhead
- Livestock or animal feces within 50m of the wellhead

If changes are noted in any of the following conditions, immediate repair should be completed:

- Cracked concrete slabs and covers
- Loosened anchor bolts
- Bolts or nuts missing

Power consumption records also provide valuable evidence of problems in wells. If an increase in power consumption is not accompanied by a corresponding increase in the quantity of water pumped, a problem is possible in either the pump or the well.

- **Section 2.b, condition of/ access to pump:** Combining electricity and water obviously brings a certain element of risk. Further, it is difficult and often impossible to know whether there is a problem once the pump is submerged. As a result, a Safe Water Station submersible pump has built-in protections that must be maintained to ensure safety, guard against damage to equipment, and ensure optimal operation. This description may include the following:
 - Cracks or other conditions that allow water into the motor housing
 - Confirmation that thermal overload sensors, which shut down the motor to prevent damage from overheating, appear functional
 - Wear, cracks, or exposed wires in the electrical cord to the pump
 - Confirmation that the mechanical seal lubricant is in place
 - Any noise, unusual heat, or emissions produced by the pump
- **Section 2.c, water depth and source of data:** The depth of groundwater can change by many meters seasonally in normal situations. Therefore, significant changes in water depth should be noted but not considered an immediate concern. The depth of groundwater itself is not critical if the well yield continues at the same rate at all depths and meets the needs of the Safe Water Station. If possible, the water

depth should be measured directly by the operator or the supervisor, but she/he can access water depth information through the other indicated sources if that is the only option to obtain data.

- **Section 2.d, taste:** The taste of groundwater should not change. If changes in taste are detected, the groundwater should be tested immediately. Change from a “sweet” to a “salty” taste indicates saltwater intrusion into the groundwater. A “rotten egg” taste indicates the presence of hydrogen sulfide. This taste is very often found in groundwater that also contains iron. Iron-containing groundwater also has a characteristic taste that some people find unpleasant.

- **Section 3.a, condition of intake:** In this section, the general condition of the intake structure from the surface water for the Safe Water Station should be described. This description may include the following items, all of which should be avoided or eliminated:

- Agricultural activity occurring within 50m of the intake
- Sanitation facilities or open defecation located within 50m of the intake
- Industries, mining, waste disposal, or garbage pits located within 50m of the intake
- Livestock or animal feces within 50m of the intake

If changes are noted in any of the following conditions, immediate repairs should be completed:

- Cracked concrete or other changes in any of the structures holding the intake in place
- Loosened anchor bolts
- Bolts or nuts missing
- Exposed wiring or any loosening or alteration of the electrical connection to the intake pump

As for wells as described above, power consumption records provide valuable evidence of problems in intake pumps. If an increase in power consumption is not accompanied by a corresponding increase in the quantity of water pumped, a problem is possible in either the pump or the intake structure.

- **Section 3.b, condition of/ access to pump:** The condition of the pump should be examined and documented as described above for Section 2.b.
- **Section 3.c, elevation at surface:** The elevation at the top level of surface water should be expected to change with seasons. It should be highest during times of rain and lowest during dry conditions. A higher surface elevation may correspond to increased turbidity and/or fecal contamination in the source water. A lower elevation may also result in higher turbidity.

- **Section 3.d, usage:** Surface water may become polluted before it reaches the intake from the activities occurring within a 50m radius of the intake structure. Intensification of contaminating activities as indicated in the form or an increase in population close to the intake should be noted, as each increases the risk of contamination of the surface water source.
- **Section 4.a/b/c/d, contamination risks:** During each visit to the water source—whether groundwater or surface water—a rapid reconnaissance should be made to detect any changes in any of the four key risk factors identified on the form. Any changes in their size, volume, or number should be immediately noted. Increases in any of these factors are very bad news and a severe threat to the cleanliness of the water source. Decreases in any of these factors are likely to be very good news for the station operator and supervisor.
- **Section 5, field testing information:** In this section, numerical values for four critical field measurements are recorded. During monthly reconnaissance, these values should be measured using portable field instruments and simple microbial presence/absence tests. Protocols to follow for sample collection and field testing are presented in **tool 29**.

Each parameter is to be measured at two locations: at the water source and at the point where source water first enters the Safe Water Station. These values should be identical or nearly identical. If they are not, there is either a problem with measurement or with contamination in the feed line between the source and the Safe Water Station. If the values are not the same, the first step should be to take the measurements again to confirm the difference. If a difference is confirmed, action must be taken to clean the feed line and measurements should be taken again. When the measurements at the two locations agree, no further action is necessary.

- **Section 5.a/f, total dissolved solids (TDS):** Increasing TDS measurements indicate an increasing concentration of minerals in the source water. Any changes in TDS should be noted after comparison with all previous measurements and with accepted national source water standards. Water with a high TDS content would present the taste, laxative, and other problems associated with the individual minerals. TDS should be measured at the water source (Section 5.a) and at the point where source water first enters the Safe Water Station (Section 5.f).
- **Section 5.b/g, pH:** pH is important in estimating

the corrosiveness of water. The pH should stay within the normal range of 6.5 to 8.5. Changes in pH over time may indicate chemical contamination of the water source, so these changes should be noted and recorded for as long as the water source is used. pH should be measured at the water source (Section 5.b) and at the point where source water first enters the Safe Water Station (Section 5.g).

- **Section 5.c/h, turbidity:** As noted earlier, turbidity can change due to naturally occurring events such as rainfall (in surface waters) or lowering of the water surface (in surface waters). If turbidity changes in groundwater, particularly after rainfall, there is a high likelihood that the well is being contaminated at the same time as turbidity increases. Turbidity should be measured at the water source (Section 5.c) and at the point where source water first enters the Safe Water Station (Section 5.h).
- **Section 5.d/e/i/j, microbial analysis:** Because microbial analysis is most critically related to the safety of the water source and public health, extra measurements should be made of this parameter. Two samples should be analyzed at the water source (Section 5.d/e), and two samples should be analyzed at the point where source water first enters the Safe Water Station (Section 5.i/j). This is an example of taking “replicate” samples. Replicate samples provide additional confidence in the measured values if the results from both samples at a location are identical. The analyses should be performed using a simple and inexpensive H₂S-based presence/absence kit. Changes in microbial analysis are very important to measure and note. If the results change over time from “absent” to “present,” the water source is polluted and immediate action will be required. The Safe Water Station probably does not need to be shut down if the microbial contamination is absent from the treated water.



A sanitary survey can rapidly identify contamination risks to water sources

Monthly Record—Water Source to Safe Water Station Inlet

MONTH: _____ YEAR: _____

Section 1: DESCRIPTORS

a. Community						
b. Water point name						
c. Type	Dam	River/stream	Spring	Borehole	Well	Other
d. GPS location	Latitude			Longitude		
e. Average daily well yield to the Safe Water Station during the month	m3 / day					
f. Peak daily well yield to the Safe Water Station during the month	m3 / day					

Section 2: GROUND WATER-PHYSICAL STATUS

a. Condition of wellhead				
b. Condition of pump				
c. Water depth and source of data	Meters:	Measured?	Official records?	From community?
d. Taste	Sour/acidic	Salty	Sweet	Bitter

Section 3: SURFACE WATER-PHYSICAL STATUS

a. Condition of intake				
b. Condition of/access to pump				
c. Elevation at surface				
d. Usage	Drinking	Animals	Washing	Other:

Section 4: CONTAMINATION RISKS

a. Upstream industries or businesses	
b. Location of sewer systems /septic tanks/pits	
c. Nearby agriculture/livestock/farms	
d. Surface fecal pollution	

Section 5: FIELD TESTING INFORMATION

a. TDS at source	
b. pH at source	
c. Turbidity at source	
d. Microbial analysis 1 at source	
e. Microbial analysis 2 at source	
f. TDS at station inlet	
g. pH at station inlet	
h. Turbidity at station inlet	
i. Microbial analysis 1 at station inlet	
j. Microbial analysis 2 at station inlet	

Person Providing Information: _____

Date: _____

Quality Module Tool 29

Ensuring Consistency of Treatment Processes

Purpose

Tool 28 provided guidance for ensuring the quality of water and equipment from the water source to its first arrival at the Safe Water Station. The purpose of tool 29 is to provide consistent guidance to ensure the continued quality of water and equipment through the Safe Water Station treatment process to the point where treated water is stored to leave the station. It covers the configuration of the most common unit operations being used to treat incoming water to potable standards, identifies parameters used to characterize the performance of each unit operation, and presents a protocol for monitoring finished water quality.

Consistent with the Safe Water Network's approach to quality assurance, the tool addresses each of the key elements as follows:

- **Assess**—identifies process measures and water quality
- **Record**—provides forms for regular data keeping on processes and quality
- **Review**—directs discussion of implications of data
- **Remediate**—recommends actions to take to maintain operational performance and outputs (especially water quality)

Audience

This tool is for use by agencies/organizations, Village Partners, Safe Water Committees, and particularly Safe Water Station operators. It presents a rigorous protocol that each should use and review to document that quality assurance steps have been regularly taken throughout Safe Water Station treatment process operation. The responsible party must evaluate operation and water quality conditions on daily, weekly, monthly, biannual, and annual bases to

make appropriate process changes and detect problems early, to plan for seasonal water quality variations and the necessary chemical dose rate adjustments, and to check and adjust process equipment.

Prerequisites

Before using this tool, the Safe Water Station operator and supervisor should demonstrate a comprehensive understanding of the entire Safe Water Station, from water source to consumer distribution. As part of using this tool, she or he will have multiple technical checks, adjustments, and repairs that will need to be done immediately upon identification of concerns. In addition, the operator and supervisor need to be fully trained and capable of performing multiple *in situ* water quality tests and recording a set of test results and other information every day.

Materials Needed

Using the forms and reports presented in this tool requires that the Safe Water Station operator and/or supervisor are equipped with the skills, tools, equipment, testing equipment, and chemicals to fully operate and monitor the Safe Water Station daily and continually. The forms and report support the ability of the operator and/or supervisor to properly use the skills, tools, and equipment in a regular, preventive routine.

Materials Contained In This Tool

The supervisor should not be left to pick up the necessary skills and knowledge merely by exposure to the job. Instead, he/she should understand the right way of doing the job from the beginning and why each task is important. The



Attention to detail at each step of Safe Water Station operation guarantees high quality product.

materials in this tool have been prepared to help organize and prioritize the supervisor's work routine to ensure that no key elements are neglected and all potential issues are dealt with through prevention rather than cure.

The tool is divided into three parts. The first is a primer on quality assurance in the operation of modular sand filter treatment systems, the second is a primer on quality assurance in the operation of reverse osmosis treatment systems, and the final section provides the core requirements of a water quality monitoring program that will ensure the quality of the product drinking water retailed at the Safe Water Station.

The primers provide checklists to follow and forms to complete daily and as needed. The water quality section instructs on the regularity of measurement of selected key parameters. The processes to be used in sample collection, sample handling, and recommended measurement techniques are described in detail in the Safe Water Station Source Module, tool 8: Water Quality Monitoring Guidelines.

How To Use The Tool

Every water supply system has to be operated and maintained properly to ensure its sustainability. The operator who will be responsible for the operation and maintenance of the Safe Water Station has a very important task. First, she or he must ensure that the treatment plant functions properly and delivers drinking water that meets the locally governing quality standards. The operator must also ensure that all of the electrical, mechanical, and piping components of the station are in top functional order and that repairs, replacement, or other maintenance tasks are undertaken as soon as their need is identified.

This means that the operator needs to know and understand all the tasks involved in routine operation and maintenance. The tasks directly involved in the upkeep of the Safe Water Station are described in the tool, and materials are presented to maintain records of test findings and actions taken. The tool contains the following materials:

Primer on Modular Sand Filters

- Description of the basic components of the filters
- **Daily Operating Record for Modular Sand Filters**, a form to document the daily performance of the treatment works
- **Cleaning Record for Modular Sand Filters**, a form to document the actions taken and the timing of comprehensive cleaning of the filter
- **Operation and Maintenance Daily Log Book for Modular Sand Filters**, a checklist for the supervisor

to follow during her or his daily work, noting which tasks are reviewed, documented, and signed off on

- **Operation and Maintenance Weekly/Monthly/Biannual/Annual Log Book for Modular Sand Filters**, a checklist for the supervisor to follow over the year to ensure that diligent operations are conducted and preventive maintenance is not neglected
- **Maintenance, Repair, and Replacement Record for Modular Sand Filters**, a form to be used by the Safe Water Station operator or supervisor to document any unusual efforts that were carried out to ensure that the performance and product of the Safe Water Station are maintained at high quality. This form requires identification of the unusual task, the reason for its performance, the date on which the work was undertaken, and the name of the person who completed the work.

Primer on Reverse Osmosis Filters

- Description of the basic components of the filters
- **Tasks for Operation and Maintenance for Reverse Osmosis Membranes**, a component-by-component checklist of regular tasks to perform
- **Operation and Maintenance Weekly/Monthly/Biannual/Annual Log Book for Reverse Osmosis Membranes**, a checklist for the supervisor to follow during her or his daily work, noting which tasks are reviewed, documented, and signed off on
- **Maintenance, Repair, and Replacement Record for Reverse Osmosis Membranes**, a form to be used by the Safe Water Station operator or supervisor to document the completion of critical evaluations of component performance and record any unusual efforts that were carried out to ensure that the performance and product of the Safe Water Station are maintained at high quality

Primer on Drinking Water Quality

- Key reliability concerns
- **Safe Water Station Testing Schedule—India**, a compilation of laboratory and on-site water quality tests and their timing as undertaken by Safe Water Stations in India throughout the year and in response to unique weather events
- **Safe Water Station Testing Schedule—Ghana**, a compilation of laboratory and on-site water quality tests and their timing as undertaken by Safe Water Stations in Ghana throughout the year and in response to unique weather events
- **Daily Log of Water Quality Measurements**, a form to complete each day providing a month-long record of the core water quality parameters measured daily

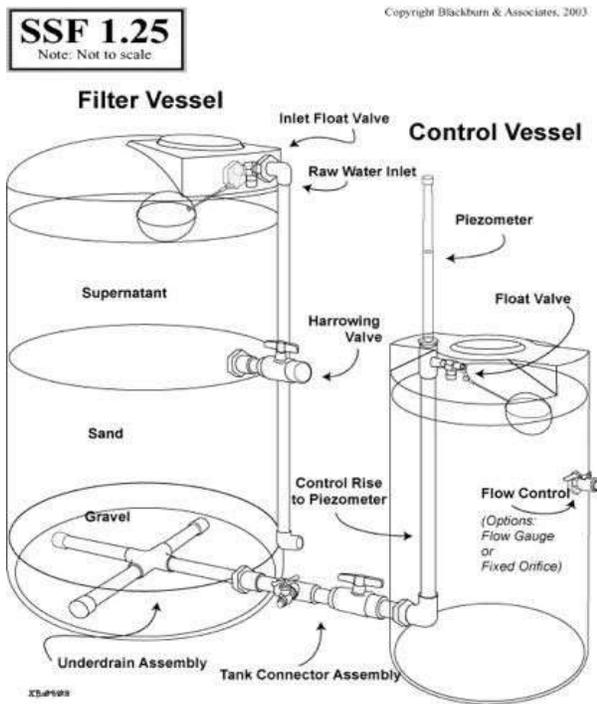
- **Illustrative Log of Laboratory Quality Measurements**, a listing of the most critical and common water quality parameters measured in certified laboratories and representative maximum allowable values of each. This log is intended to be adapted to other countries using their national standards for the indicated water quality parameters
- **Key Drinking Water Quality Parameters and International Recommended Standards**, a table containing the Safe Water Network's recommended minimum key parameters to be monitored regularly and the recommended maximum values for each, according to the World Health Organization (WHO), Bureau of Indian Standards (BIS 10500), the U.S. Environmental Protection Agency (USEPA), and the European Union (EU) in a NABL-certified laboratory.

Each piece of the tool is to be adapted and used by the Safe Water Station operator and/or supervisor to establish an auditable record of the efforts made toward quality assurance of each aspect of Safe Water Station operation from the moment source water enters the station until it is stored for sale to customers.

A Primer on Quality Assurance for Safe Water Treatment Systems: Modular Sand Filters

One of the treatment processes used by the Safe Water Network is a commercially available modular sand filter as illustrated below. It contains a minimal number of components, indicated in the schematic drawing and described in the table below. Each must be maintained at a high level of operation for the system to produce required quantities of high-quality drinking water. This primer was created to help Safe Water Station operators and supervisors achieve this level of consistent operation of the treatment works.

In modular sand filter systems, source water enters at the top of the filter unit. It then passes through a thick layer of sand and a thinner layer of gravel, a natural treatment system that has been used globally for over 100 years. The treated water enters a control vessel through an under drain assembly. The control vessel allows monitoring of any pressure buildup on the inlet side of the filter. As this pressure reaches a certain point, it will be time to harrow the top of the sand, removing any accumulated material. From the control vessel, the water is disinfected and readied for sale.



S/N	COMPONENT	FUNCTION
1	Inlet float valve	Controls the amount of raw water getting into the filter vessel
2	Raw water inlet	Allows the passage of raw water into the filter vessel
3	Harrowing valve	Allows removal of material scraped from the sand surface during harrowing of the top of the filter
4	Underdrain assembly	Collects treated water from the filter vessel to the control vessel
5	Piezometer	Indicates pressure loss in the filter
6	Float valve (in control tank)	Serves as a constant head device. It prevents the biofilm from drying up by controlling the amount of water flowing from the filter vessel
7	Flow control	Controls flow rate of water from the control vessel into the storage device

The primer provides forms that the operator/supervisor should complete as described to document the performance of the modular sand filter. The materials in this primer have been developed to simplify and systematize the tasks the Safe Water Station supervisor must undertake and document as regular, preventive care for the operation of modular sand filter systems. For each system, the precise regimen, timing, and protocols for operational oversight should be established, adapting the forms provided as appropriate.

The first form is a Daily Operating Record that is used to record basic operating parameters and measured conditions of the water. The second form is a Cleaning Record used

to document the occasions when the modular filters are cleaned according to the manufacturer's specifications. The third form is a checklist of the daily activities that an operator or supervisor must undertake to keep the filter operating at peak performance. The fourth form contains a checklist of the weekly, monthly, semi-annual, and annual tasks that the operator or supervisor must complete and document for proper operation and maintenance of the filter. The final form is to be used to record any unusual repairs, replacement of parts, or any other significant maintenance performed on the filter that is not described in the other forms.



Safe Water Station operators ensure and document the accurate performance of each component in the treatment process

Daily Operating Record for Modular Sand Filters

Location:					Station Identifier:					
Person Providing Information:					Date:					
Filter No.	Ti		Hours Operated			Head Loss (m)		Harrowing Time (minutes)	Notes on Conditions of Filters and Problems in Operation	
	Start	Stop	Today	To Date	Total	Start	Stop			
Production Report		Water Quality Sampling								
Shift		Filter No.	Location	Time	Turbidity (NTU)	Conductivity	Cl ₂	Micro-bio (P/A)	Temp (°C)	pH
Operator		1	Inflow							
Total Influent Water Filtered (m3)			Outflow							
Average Run (hours)		2	Inflow							
Average Filtration Rate (m3/hr)			Outflow							
No. of Filters Operating		3	Inflow							
No. of Filters Harrowed			Outflow							
Chemical and Amount Used		4	Inflow							
			Outflow							

Notes on use of the Daily Operating Record

1. Water quality sampling should be conducted at the same time each day.
2. Typical operational problems to examine daily for each filter include a rising *schmutzdecke*, unusual weather conditions, and any other observations.
3. A sudden increase in head loss across the sand filter may be an indication of surface sealing of the filter media. Early detection of this through analysis of daily head loss data in this form will permit appropriate process changes that reduce surface sealing, such as adjustment of the chemical feed rate or filtration rate.
4. The piezometer indicates the pressure loss in the filter. As the filter begins to clog and forms a buildup of solids on the top surface of the filter media, the water level in the piezometer will drop even though the filter vessel may be full. When the water level in the piezometer drops to the level of the harrowing valve, but the filter vessel is full of water, it is time to service the filter. Care should be taken to clean the filter only when necessary. Too frequent cleaning will negatively affect the beneficial bacteria that occupy the media and play a key role in treating the water as it filters through.

Cleaning Record for Modular Sand Filters

Location:			Station Identifier:			
Person Providing Information:			Date of Cleaning:			
Filter No.	Removal from Service		Return to Service		Piezometer Reading at Removal from Service (m)	Notes on Conditions of Filters, Amount and Type of Debris Removed, Problems in Operation
	Date	Time	Date	Time		

Notes on use of the Cleaning Record

1. Clean the filter when the water in the piezometer drops to near the level of the sand bed.
2. If influent control is used, clean the filter when the water level gets near the level of the float valve.
3. The date indicated on the record is the date on which the cleaning process was started.
4. The date and time of return to service is the *end* of the post-cleaning ripening period.

Operation and Maintenance Daily Log Book Modular Sand Filters

Date:

No.	Task	Done?	Time	Signature
1	Ensure that outlet valve from source water storage tanks is open			
2	Make sure harrowing valve is closed			
3	Confirm the operation of the float valve in the source water tank			
4	Check filtration plant flow rate in comparison to daily water demand. Adjust flow rate as required.			
5	Check whether chemical feed equipment is functioning properly			
6	Check the water level in the source water storage tanks			
7	Check and record head loss on each modular filter			
8	Check operation of flow meters			
9	Measure source and filtered water turbidity			
10	Visually inspect filter basins and piping for leaks or other unusual observations			
11	Check operation of all pumping equipment			
12	Check the water level in the treated water storage tank			
13	Complete Daily Operating Record			

Maintenance, Repair, and Replacement Record Modular Sand Filters

No.	Description of Work/Name of Worker/Unusual Events	Date	Time	Signature
1				
2				
3				

**Operation and Maintenance
Weekly/Monthly/Biannual/Annual Log Book
Modular Sand Filters**

No.	Task	Done?	Date/Time	Signature
Weekly Tasks				
1	Check and grease all pumps and other moving parts			
2	Check all pipes and taps for leaks or damage. Repair as necessary.			
3	Properly store all tools and equipment in and around the Safe Water Station			
4	Clean inlet structure of leaves, mud, and debris			
5	Review adequacy of chemical inventory			
6	Operate valves and other standby equipment, including the emergency generator			
Monthly Tasks				
1	Open the drain valve to flush mud and sediment from the filter			
2	Check and clean the outlet structure			
3	Check the pipelines leading to the modular sand filter for leaves, damage from fallen branches, earth movements, etc.			
4	Calibrate all analytical equipment and instruments used to analyze water quality			
5	Verify proper functioning of safety equipment, including fire extinguishers			
6	Inspect chemical feed equipment			
Biannual Tasks				
1	Open and release any air that may be present in air release valves (or create and patch holes at highest part of system)			
2	Visually inspect all pipes for leakage or misalignment. Repair or replace as needed.			
Annual Tasks				
1	Clean gravel by opening the chamber and pushing a steel rod into the gravel to agitate it and release filtered material			
2	Examine filter media and evaluate its overall conditions			
3	Measure filter media depth for an indication of media loss during the harrowing process			
4	Calibrate flow meters			

A Primer on Quality Assurance for Safe Water Treatment Systems: Reverse Osmosis Filters

The reverse osmosis filters used by the Safe Water Network are complex systems that can be easily operated and maintained by trained villagers, but diligent attention must be paid to multiple aspects of operation. This attention has led to the successful operation of reverse osmosis filter systems in multiple Safe Water Stations in India, particularly where naturally occurring nitrates and fluoride are prevalent and would not be removed by modular sand filters.

The reverse osmosis system used by the Safe Water Network is shown in the photograph below. Its separate components are described in the accompanying table and illustrated in the diagram on the page 221.

The reverse osmosis system consists of the following components, as illustrated in the diagram:

1. **Bore water storage tank**, which stores source water
2. **Feed pump**, which moves water from the bore water storage tank into the system
3. **Pressure sand filter** for removal of large solids from the source water
4. **Activated carbon filter** for removal of smaller solids from the source water
5. **Anti-scalant solution tank and dosing pump**
6. **Cartridge filter**, which provides micron screening before the reverse osmosis filters
7. **High pressure (HP) pump** as a feed to the reverse osmosis membranes
8. Multiple **reverse osmosis membranes**

9. Clean in Place (CIP) system, which maintains the efficient operation of the reverse osmosis membranes (**recirculation flow indicator, brine flow indicator**)
10. **UV (ultraviolet) light disinfection system** to provide additional on-site disinfection of product water
11. **Chlorine dosing unit** to provide residual disinfection to product water
12. **Product water tank**, where water is stored before sale

Managing Reject Water

The operation of this reverse osmosis system generates treated product water as well as “reject water” that does not pass through the treatment membranes and is not available for sale as a safe drinking water product. The Safe Water Network’s operations have demonstrated that for every liter of safe drinking water produced, one-half liter of reject water is generated. This water is not recirculated into the treatment system and requires controlled disposal.

The reject water from a Safe Water Station contains only the minerals and chemicals that are found in the source water from the bore well. This includes high concentrations of salts and low concentrations of any other chemicals found in the source water. Therefore, disposal of reject water needs monitoring to keep it from use as drinking water. Because reject water is primarily the salts removed from the source water by the reverse osmosis membranes, regular measurement of the total dissolved solids (TDS) concentration will describe the general quality of the reject water. A more comprehensive analysis of the quality of



Safe Water Network treatment systems appear complex but are designed to be operated by skilled, local entrepreneurs.

reject water must be conducted by an accredited laboratory annually to measure the concentration of any other chemicals present. The results of this analysis should be clearly displayed at the Safe Water Station.

At some Safe Water Stations, community members have expressed a desire to use reject water for non-drinking purposes. These include sanitation, domestic cleaning, and utensil washing. These are typically acceptable uses for this water, unless the laboratory analysis detects a contaminant in the water that is not consistent with these uses. To accommodate the importance of reject water to communities surrounding Safe Water Stations, storage structures for reject water are typically included as part of the station physical plant. This storage structure is fitted with taps and a tight-fitting lid so that access to the reject water is controlled but interested families can collect the water for domestic use.

A storage structure of 2,500 to 3,000 liters is typically sufficient to temporarily store reject water. An appropriate volume can be identified based on space available, the expected production volume of reject water, and the anticipated use of reject water by the community. Reject water enters the storage structure through a one-way valve at the top of the structure. An overflow outlet pipe should also be installed at the top of the storage structure to direct any overflow water to an existing wastewater disposal drain near the station. A few taps are fitted at the base of the storage structure to allow people to collect the reject water.

The storage structure must be clearly marked in all appropriate languages to indicate that the water inside is not for drinking. Due to the high concentration of salts in the reject water, it normally should not be used for agriculture unless diluted to natural conditions.

Assuring Safety

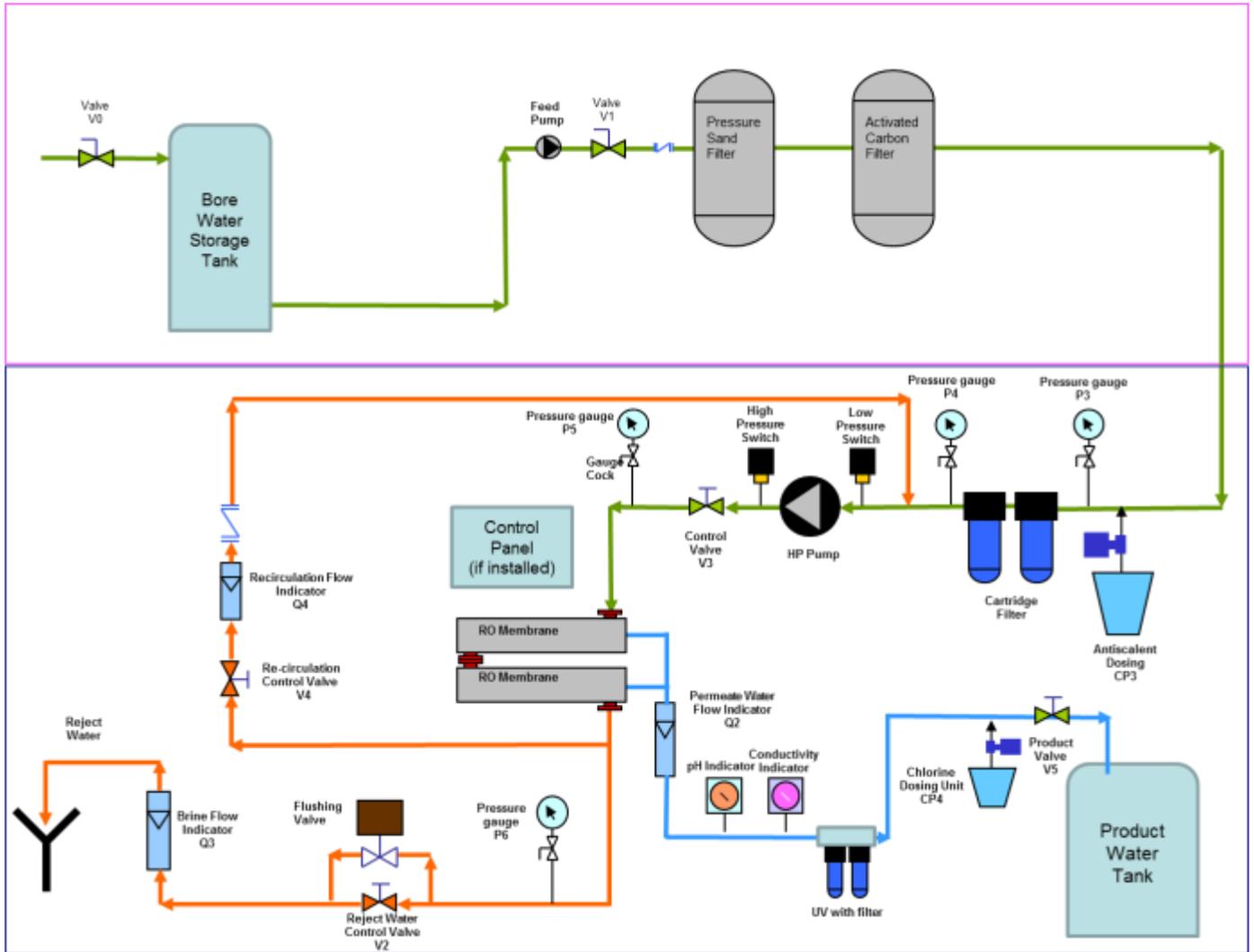
Quality assurance of the operation of this system requires the organization and structuring of many tasks, including regular in-plant water tests, water quality testing at external laboratories, adherence to frequency and monitoring schedules, regularity of sample-taking, and the tracking and notification of customers during downtime.

The materials in this primer have been developed to simplify and systematize the tasks the Safe Water Station supervisor must undertake and document as regular, preventive care for the operation of the reverse osmosis treatment system. For each system, the precise regimen, timing, and protocols for operational oversight should be established.

This primer introduces several forms that the Safe Water Network uses to document the operation and maintenance of reverse osmosis treatment works. The first form summarizes the tasks that need attention and a defined maintenance interval for each individual system. The second form is a checklist of the full range of operation and maintenance tasks that need to be performed on the entire system. The third form is to keep a record of the major maintenance, repair, and replacement efforts performed on the system. The final pages of the primer contain a brief introduction to the Safe Water Network's unique, on-line Remote Monitoring System, which enables managers of all of the Safe Water Stations in India to monitor key performance parameters remotely. This system was developed jointly with IBM and provides operational data to a web-based portal every 15 minutes while the station is in operation.



Diagram of Safe Water Network Reverse Osmosis Membrane Systems



Scheduling of Tasks for Operation and Maintenance Reverse Osmosis Membrane Systems

Process	Task	Timing* (Daily/Weekly/Monthly/ Biannually/Annually)	Comment
Pre-treatment Components			
Bore Water Storage Tank	Assess condition of storage tank		
	Date and process of tank cleaning		
Feed Pump	Document daily and cumulative pumping hours		
	Describe and record condition of pump		
Pressure Sand Filter	Note and record delta pressure between inlet and outlet		
	Note and record flow rate through filter		
	Establish and document backwash frequency		
	Establish timing and carry out sanitization of filter		
	Establish frequency and allowable range of microbial analyses of filtered water		
Activated Carbon Filter	Note and record delta pressure between inlet and outlet		
	Note and record flow rate through filter		
	Establish and document backwash frequency		
	Establish timing and carry out sanitization of filter		
	Establish frequency and allowable range of microbial analyses of filtered water		
Anti-scalant	Examine volume of solution in unit		

Scheduling of Tasks for Operation and Maintenance Reverse Osmosis Membrane Systems

Process	Task	Timing* (Daily/Weekly/Monthly/ Biannually/Annually)	Comment
Cartridge Filter	Note and record delta pressure between inlet and outlet		
	Note and record flow rate through filter		
	Establish and document replacement frequency		
High Pressure Pump	Document daily and cumulative pumping hours		
	Describe and record condition of pump		
Treatment Components			
Reverse Osmosis Inlet #1	Note and record system inlet pressure		
	Measure total dissolved solids (TDS) into filter		
	Note and record flow rate		
	Measure temperature into filter		
Reverse Osmosis Outlet #2	Note and record system outlet pressure		
	Measure total dissolved solids (TDS) after filtration		
	Note and record permeate flow rate		
	Measure pH into filter		

Scheduling of Tasks for Operation and Maintenance Reverse Osmosis Membrane Systems

Process	Task	Timing* (Daily/Weekly/Monthly/ Biannually/Annually)	Comment
Ultraviolet Disinfection	Document date of bulb replacement		
	Note and record unit flow rate		
	Examine and document quartz sleeve condition		
Chlorine Dosing Unit	Note and document chemical usage		
	Establish and check dosing rate		
	Establish and measure solution strength		
	Examine and document condition of dosing pump		
Product Water Tank	Measure and adjust pH (RO units can produce acidic, hazardous water)		
	Examine and record condition of tank		
	Establish and record chlorine dosage		
	Measure and record chlorine residual concentration		
Reject Water Storage Structure	Measure and record total dissolved solids (TDS)		
	Send sample of reject water to certified laboratory for full analysis		
Cleaning Components			
Clean-in-place (CIP) System	Document capacity of CIP system		
	Examine and document condition of pump		
	Note and record frequency of chemical cleaning		
	Measure and record amount of chemicals used		
	Measure and record pH of CIP solutions		
	Measure and record temperature of CIP solutions		
	Examine and document conditions of storage of CIP solutions		

*Timing to be determined by Safe Water Station Committee, operator, and supervisor before filter system is put into operation

**Operation and Maintenance
Weekly/Monthly/Biannual/Annual Log Book
Reverse Osmosis Membranes**

No.	Task	Done?	Date/Time	Signature
Weekly Tasks				
1	Check and grease all pumps and other moving parts			
2	Check all pipes and taps for leaks or damage. Repair as necessary.			
3	Properly store all tools and equipment in and around the Safe Water Station			
4	Clean station area and structures of leaves, mud, and debris			
5	Review adequacy of chemical inventory			
6	Operate valves and other standby equipment, including the emergency generator			
7	Check cleanliness and functioning of cartridge filter			
8	Confirm location of all tools and toolkit for station operation			
9	Ensure that there are no loose electrical wires on the floor or equipment of the Safe Water Station			
Monthly Tasks				
1	Check feed pumps for leaks and unusual noise and/or vibration			
2	Check that pump anchor bolts are tight and secure			
3	Check the pipelines leading to the reverse osmosis filter for leaves, damage from fallen branches, earth movements, etc.			
4	Calibrate all analytical equipment and instruments used to analyze water quality			
5	Verify proper functioning of safety equipment, including fire extinguishers			
6	Inspect chemical feed equipment for cleanliness and functioning of dosing pump			
7	Open and clean dosing tube with acid when cloudy or clogged, as necessary			
8	Check the safety of all electrical connections			
9	Replace micron cartridge filter			
10	Check and confirm complete cleanliness of flow meters. Clean with acid as necessary.			
11	Open and clean UV housing with water and a clean cloth			
12	Clean reverse osmosis membranes with cleaning chemical if inlet pressure is elevated or total dissolved solids are regularly high			
13	Confirm proper functioning of high-pressure switch and low-pressure switch			
14	Record inlet and outlet pressure on reverse osmosis membrane to monitor performance			
15	Confirm proper functioning of float level switches in water storage tanks			
16	Confirm contents and location of first aid kit and equipment			

**Operation and Maintenance
Weekly/Monthly/Biannual/Annual Log Book
Reverse Osmosis Membranes**

No.	Task	Done?	Date/Time	Signature
Quarterly Tasks				
1	Visually inspect all pipes for leakage or misalignment. Repair or replace as needed.			
2	Inspect all valves for correct positioning			
3	Clean bore water storage tank with chlorine solution			
4	Clean product water tank with chlorine solution			
5	Confirm tight closure of cover on bore water storage tank and product water tank			
Annual Tasks				
1	Calibrate flow meters			
2	Replace reverse osmosis membranes, if necessary*			
3	Check integrity of each electrical wire and outlet in the Safe Water Station			
4	Rinse media in pressurized sand filter with acid and water			
5	Rinse media in granular activated carbon filter with acid and water			
6	Repaint all Safe Water Station surfaces, including promotional wall paintings, as necessary			

* Reverse osmosis membrane should last 18 to 24 months. Replace sooner if unpleasant tastes or odors are noticed or if a noticeable decline in water production is noted, or the treated water TDS increases substantially even after chemical cleaning of the membranes. The precise life span of the membrane will depend on the quality of the water entering the system and the frequency with which it is used. Frequent use prevents filtered salts and minerals from building up on the membrane as scale. The more water the system is required to produce, the longer the membrane will last. It is recommended that the system be sanitized each time the membrane is changed. It is not necessary to sanitize the system when changing only the pre-filter. Sanitize the system by rinsing housings with water and dilute household bleach as directed by the manufacturer.

Maintenance, Repair, and Replacement Record Reverse Osmosis Membranes

Year _____ Begin Month _____ End Month _____

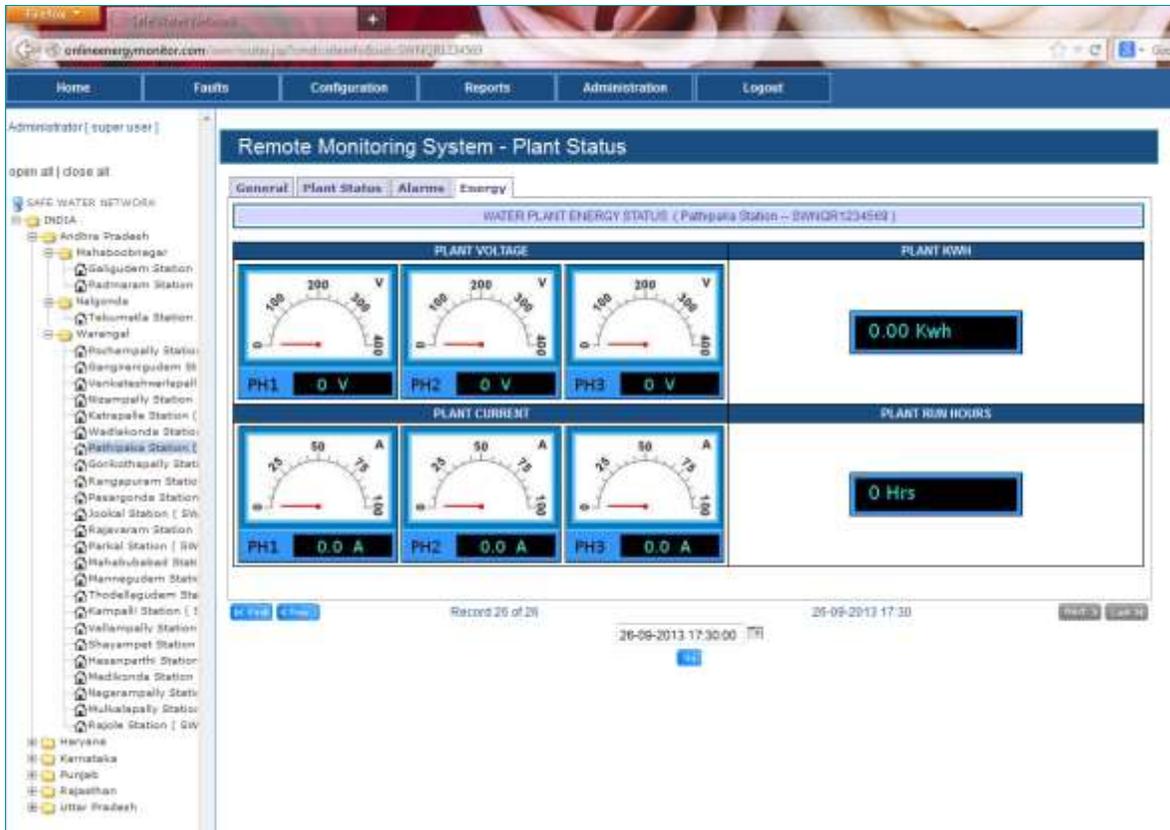
Backwash pressure sand filter	Date:									
	Start:	Stop:								
	Initials:		Initials:		Initials:		Initials:		Initials:	
Backwash activated carbon filter	Date:									
	Start:	Stop:								
	Initials:		Initials:		Initials:		Initials:		Initials:	
Inspect all lines and valves	Date:									
	Initials:		Initials:		Initials:		Initials:		Initials:	
Check feed pump(s)	Date:									
	Initials:		Initials:		Initials:		Initials:		Initials:	
Check anti-scalant solution pump	Date:									
	Initials:		Initials:		Initials:		Initials:		Initials:	
Disinfect product water tank	Date:									
	Initials:		Initials:		Initials:		Initials:		Initials:	
Check high pressure pump	Date:									
	Initials:		Initials:		Initials:		Initials:		Initials:	
Check CIP pump	Date:									
	Initials:		Initials:		Initials:		Initials:		Initials:	
Check chlorine dosing pump	Date:									
	Initials:		Initials:		Initials:		Initials:		Initials:	
Check electrical connections	Date:									
	Initials:		Initials:		Initials:		Initials:		Initials:	
Media or component replacement	Item:									
	Date:		Date:		Date:		Date:		Date:	
	Initials:		Initials:		Initials:		Initials:		Initials:	

The Safe Water Network (India) Remote Monitoring System

The Safe Water Network team in India worked with information technology partners to develop an online Remote Monitoring System that operates from each of its facilities. The system enables anyone with internet access anywhere to monitor parameters for each facility as illustrated below. A sample display of data is presented on the following page. Parameters that are measured and reported every 15 minutes include:

Bore Water Tank Level	Raw Water Temperature	Raw Water Volume	Raw Water Total Dissolved Solids	Feed Pump Pressure	Run Hours (bore well and treatment plant)
Treated Water pH	Pressure after Micron filter	Room Temperature	Residual Chlorine Reading	Status of Anti-scalant Dosing Unit	Status of pH Dosing Unit
Pressure into High-Pressure Pump Membranes	Pressure into Reverse Osmis	Outlet Pressure of Reverse Osmosis Membranes	Treated Water Volume	Status of UV Disinfection	Status of Chlorine Dosing Unit
		Product Water Volume	Product Water Tank Level	Product Water Total Dissolved Solids	





Without care and maintenance, the treatment system at Safe Water Stations will not provide high-quality drinking water

A Primer on Quality Assurance for Drinking Water

The final quality of the drinking water produced by a Safe Water Station is the ultimate measure of the assurance of the overall quality of the processes and systems that compose the station operation. If the product drinking water does not meet the Safe Water Network's drinking water quality standards, then all other quality assurance systems have failed.

The Safe Water Network has developed a set of Operational Water Quality Standards that it applies at all of its Safe Water Stations. These focus on regular monitoring, at a minimum, of nine key drinking water quality parameters: pH, conductivity, total dissolved solids, turbidity, total coliform count, fecal coliform count, arsenic, nitrate, and fluoride. These Operational Water Quality Standards and the methods by which they are measured are based on and align with the specific challenges the Safe Water Network faces in its areas of operation, any national drinking water standards in our countries of operation, and the World Health Organization guidelines for drinking water.

In addition to our focus on these nine parameters, the Safe Water Network also makes use of a range of monitoring tools, including presence/absence field tests for bacterial contamination and comprehensive, professionally conducted analyses of source, reject, and treated water from certified laboratories.

In this primer, the regimen for testing and analysis is presented. Tool 8 of the Source Module of the Safe Water Station Toolkit contains more detailed Water Quality Monitoring Guidelines, including a discussion of the recommended measurements and standards, frequency of water quality testing, procedures in response

to contamination detection, and sample collection and transportation, including chain of custody reporting. The key points raised in tool 8 that relate to ensuring the accuracy and reliability of drinking water quality monitoring are listed below:

1. Before planning for water quality monitoring, the agency/organization responsible for the Safe Water Station should obtain and become familiar with the national drinking water quality standards and/or regulations that apply in the country where the Safe Water Station will be established.
2. For accurate water quality monitoring to take place, a Safe Water Station needs access to three items: a handheld meter that has probes to measure total dissolved solids (TDS), electro-conductivity and pH; the means to create or obtain sterilized sample bottles; and a professional and/or certified laboratory that can conduct accurate analyses of a variety of chemical and bacterial parameters.
3. If a water quality problem is observed, the frequency of sampling must be increased until the problem is no longer found. As soon as any contamination is found in the treated water, the Safe Water Station will be closed and the entire facility, including the treatment works and all piping, will be cleaned thoroughly. Any manufacturer protocols will be followed in cleaning and/or disinfecting all components. After cleaning, a sample of treated water will be sent for testing before the facility is opened for public use. When the sample meets the applicable drinking water quality criteria, the station can be reopened. After such an event, the frequency of tests for the nine key parameters will be increased to monthly until two consecutive results are found completely within norms.

Developing Standards for Safe Drinking Water



4. It is absolutely necessary that water samples are collected in as sterile a way as possible and brought to the laboratory as soon as possible. Tool 8 describes the standard operating procedures used globally to ensure uncontaminated sample collection, efficient sample transport, and thorough documentation.
5. Duplicate samples will be collected at ten per cent of sample sites, and identical laboratory tests will be run on these duplicate samples. The results from the duplicate samples should be identical to the original tests. If this is not the case, there is a problem in sample collection and/or management that must be resolved.
6. *In situ* data should be collected in accordance with the manufacturer's instructions for any field equipment being used.

A summary of the required testing is presented on the following pages. The first has been developed to accompany stations in India using reverse osmosis filters. The second was developed to accompany Safe Water Network stations in Ghana using modular sand filters. These summaries cover regular facility operation and are not recommended sampling intervals in times of operational outages, equipment failure, or equipment replacement.

The first of two forms provided is to be used every day to record *in situ* measurements of five key parameters that must be documented and regularly compared. The second form is used to compare and report on the findings of laboratory analyses against Safe Water Network standards for a selection of the most important drinking water quality monitoring parameters.



Maintaining and publicly communicating water quality records enhances confidence in safe water

Safe Water Station Water Quality Testing Schedule—India

Parameter	Frequency	Jan-April	May-Aug	Sept-Dec	Testing Method	Remarks
Certified Laboratory Tests¹						
Source Water	2 times/year		1	1	Per laboratory	
Treated Water	2 time/year		1	1	Per laboratory	Test more often if quality change is observed through daily checks
Reject Water	1 time/year		1		Per laboratory	Test more often if quality change is observed
Tests to Be Conducted On-site						
TDS	Daily ²	Daily ⁴	Daily ⁴	Daily ⁴	Handheld meter	
pH	Daily ³	Daily	Daily	Daily	pH strips/ Handheld meter/ Test kit	Test range 6.5–8.5
Residual Chlorine	Daily	Daily ⁴	Daily ⁴	Daily ⁴	Commercial chlorine wheel / Option to use test kit	Chlorine residual target 0.2 ppm
Microbiology	Daily for initial month, weekly if satisfactory in 1st month ⁵	Daily followed by weekly	Daily followed by weekly	Daily followed by weekly	H ₂ S kit	

1. Certified Laboratory Tests: (1) India water quality analysis to comply with BIS 10500, 2012 from laboratory work at NABL-certified facility; (2) Ghana water quality analysis to comply with Ghana Standards Authority GS175.
2. India Safe Water Stations measure total dissolved solids at 15 minute intervals via its Remote Monitoring System (RMS).
3. All data should be directly collected in the field, but data for TDS and pH collected from the RMS is a valid record.
4. More intensive source water quality testing recommended pre-rainy season/monsoon and post-rainy season/monsoon.
5. Conduct the test daily for initial month of operation. If contamination is detected once, take remedial action for correction and continue testing daily for one week.

Safe Water Station Water Quality Testing Schedule—Ghana

Parameter	Frequency	Testing Method	Remarks
Certified Laboratory Tests¹			
Source Water	Quarterly first year; annually after first year	Per laboratory	
Treated Water	1 time/year	Per laboratory	Test more often if quality change is observed through daily checks
Tests to Be Conducted On-site			
TDS	Surface Water	Not applicable ²	Handheld meter
	Groundwater	Daily	Handheld meter
Conductivity	Daily	Handheld meter	
Iron and Manganese	Monthly		
Turbidity	Surface Water	1 sample weekly for baseline; then monthly ³	Handheld meter
	Groundwater	Quarterly; if stable, extend to biannually ³	
pH	Daily	pH strips/Handheld meter/ Test kit	Test range 6.5–8.5
Residual Chlorine	Daily ³	Commercial chlorine wheel/ Option to use test kit	Chlorine residual target 0.2 ppm
Microbiology	Daily for initial month, weekly if satisfactory in 1st month ⁴	H ₂ S kit	

1. Certified Laboratory Tests: (1) India water quality analysis to comply with BIS 10500, 2012 from laboratory work at NABL-certified facility; (2) Ghana water quality analysis to comply with Ghana Standards Authority GS175.
2. Only applicable if baseline measurements from source exceed 500ppm.
3. More intensive source water quality testing recommended pre-rainy season/monsoon and post-rainy season/monsoon
4. Conduct the test daily for initial month of operation. If contamination is detected once, take remedial action for correction and continue testing daily for one week.

Illustrative Log of Laboratory Quality Measurements

No.	Parameter	Units	Desirable Limit	Permissible Limit	[INSERT LOCATION]		
					Source	Treated	[OTHER]
					Date of sample collection		
					Date of sample testing		
Safe Water Network 9 Key Parameters							
1	pH	-	6.5 – 8.5	6.5 – 8.5			
2	Electro-conductivity	µS/cm	-	-			
3	Total dissolved solids	mg/l	500 max	2,000 max			
4	Turbidity	NTU	Max 5	Max 10			
5	Total coliforms	per 100ml	Absent	10 max			
6	Fecal coliforms	per 100ml	Absent	Absent			
7	Arsenic	mg/l	0.01 max	No relaxation			
8	Nitrate	mg/l	45 max	No relaxation			
9	Fluoride	mg/l	1.0 max	1.5 max			
10	Color	Hazen Units	Max 5	Max 25			
11	Total hardness	mg/l	300 max	600 max			
12	Alkalinity	mg/l as CaCO ₃	200 max	600 max			
13	Calcium	mg/l	75 max	200 max			
14	Magnesium	mg/l	30 max	100 max			
15	Sodium	mg/l	-	-			
16	Potassium	mg/l	-	-			
17	Chloride	mg/l	250 max	1,000 max			
18	Sulphates	mg/l	200 max	400 max			
19	Nitrite	mg/l	-	-			
20	Iron	mg/l	0.3 max	1.0 max			
21	E.coli	per 100ml	Absent	Absent			

Note: Adapted from India standards. Local standards should be inserted and “desirable” limit eliminated if only single limit exists.

Key Drinking Water Quality Parameters and International Recommended Maximum Values

Criteria	Units	WHO Recommended Value	USEPA Allowable Value	EU Allowable Value	Testing Methodology Reference ⁵
pH	none	6.5–8.5	6.5–8.5 ¹		In situ probe or 4500–H ⁺
Electro-conductivity	µSiemens/cm	-	-	2500 ⁴	2510
Total Dissolved Solids	mg/l	1,000	500 ¹	-	In situ probe
Turbidity	NTU	5	5 ²	Acceptable to consumers	2130
Total Coliforms	MPN/100ml	0	0	0	9221
Fecal Coliforms	MPN/100ml	0	0 ³	0	9222 D or 9221 E
Arsenic	mg/l	0.01	0.01 ³	0.01	3500
Nitrate as NO ₃	mg/l	50	10 ³	50	4500–NO ₃ ⁻
Fluoride	mg/l	1.5	2.0 ¹	1.5	4500–F ⁻

1. USEPA Secondary Drinking Water Standards—National Secondary Drinking Water Regulations (NSDWRs or secondary standards) are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. The USEPA recommends secondary standards to water systems but does not require systems to comply. However, localities may choose to adopt them as enforceable standards.
2. The U.S. Surface Water Treatment Rule requires systems using surface water or groundwater under the direct influence of surface water to disinfect their water and filter their water to meet criteria for avoiding filtration so that the following contaminants are controlled at the indicated levels.
3. USEPA 141.23 Detection Limits for Inorganic Contaminants
4. EU—Council Directive 98/83/EC of November 3, 1998—on quality of water intended for human consumption. Annex I pages L 330/41-330/45
5. Standard Methods for the Examination of Water and Wastewater, 19th edition. Prepared and published jointly by the American Public Health Association, the American Water Works Association, and the Water Environment Federation, 1995.



On-site and laboratory measurements certify the safety of water ready for sale

Quality Module Tool 30

Ensuring Consistency of Facility Operations

Purpose

Assuring the quality of the operation of a Safe Water Station requires more than simply attention to the technical operations needed to obtain and treat drinking water. Safe Water Stations are commercial operations and as such must provide a safe and appealing environment to customers. This was initially addressed as part of station start-up in the Purify Module tool 13 of the tools for Safe Water Station.

Equal attention must be paid throughout the duration of the operation of the station to the civil works and environment of the Safe Water Station if customers are to view it as a valued location to visit and obtain safe drinking water. The purpose of this tool is to provide guidance and protocols for the “housekeeping” and cleanliness of a Safe Water Station and its site.

Consistent with the Safe Water Network’s approach to quality assurance, the tool addresses each of the key elements as follows:

- **Assess**—identifies the attributes and challenges to hygienic operations
- **Record**—provides forms to guide realistic housekeeping activities
- **Review**—supports reporting on critical needs and challenges
- **Remediate**—suggests ways to address poor site conditions

Audience

This tool is for use by the Safe Water Committee and the station operator and supervisor to establish and agree to a set of regular activities that will maintain the civil works of a Safe Water Station and its appearance as a hygienic and well-managed facility.

Prerequisites

Before this tool can be used, the operator and the supervisor should have an agreement with the Safe Water Committee regarding the realistic standards of upkeep for the building and grounds of the Safe Water Station. The operator and/or the supervisor should also be equipped with all necessary tools and materials needed to undertake the cleaning, maintenance, and cleanup required to comply with the checklists provided in the tool.

Materials Needed

No special materials are needed to implement tool 30. The most important skills that will be required are a keen eye and a hygienic approach to comprehensively maintaining the condition of the station and its environment.

Materials Contained In This Tool

This tool consists of four pieces. The first three are simple checklists to follow that guide the Safe Water Station supervisor and operator in reviewing key aspects of the



No special skills are needed, just a keen eye for detail and a focus on hygiene

housekeeping needs of the property. The fourth is a log of the concerns identified when applying each checklist documenting problems and their solutions.

How To Use The Tool

The first piece of the tool guides the operator and/or supervisor through an assessment of the key aspects of hygienic management of the Safe Water Station building. The user simply moves down the checklist and ensures that each item is assessed regularly. If all of the listed items are satisfied, no action is necessary. Any identified issues require an immediate action plan of improvement.

The second piece of the tool guides the operator and/or supervisor through a careful assessment of the electrical components of the Safe Water Station. Electricity is both critical to the operation of the station and is a source of risk. Electricity and water can be a lethal combination. The user moves down the checklist and ensures that all electrical connections and components are in safe operating condition. If any of the listed items are not satisfactory, an immediate action plan must be developed and acted on.

The third piece of the tool guides the operator and/or supervisor through a basic checklist of the functioning and operation of the piping inside the Safe Water Station.

There can be no tolerance for leaks or malfunctioning components. The water moving through the system is the lifeblood of the Safe Water Station. If any of the checklist items are not satisfactory, immediate remediation action must be taken.

The fourth piece of the tool similarly guides the operator and/or supervisor through a comprehensive assessment of the environment surrounding the Safe Water Station. A pleasing and well-managed exterior is important for drawing customers to the station. The user moves through the checklist and ensures that the station grounds are clean and appealing. If any items are not in satisfactory condition, an action plan is developed and remedial tasks are completed.

The final piece of the tool is a logbook to be used when each checklist is completed. It contains space for the operator and/or supervisor to document the date on which each checklist was reviewed, any problems that were identified, proposed solutions to the problems, and any actions that are planned or taken to resolve the problems. This log would become part of the record keeping of the supervisor to document the ongoing condition of the building, its critical electrical and piping components, and the upkeep of the station property.



Keeping the building clean inside and out demonstrates to customers the emphasis of the operator on hygiene, quality, and safety.

Building Checklist

The most visible parts of a Safe Water Station to customers are the building and grounds. If the quality assurance planning completed in accordance with tools 28 and 29 are followed to the letter but the cleanliness of the building and grounds is neglected, customers will not view the Safe Water Station as a high-quality operation.

During station construction and launch, if tools 13 and 17 were followed, the Safe Water Station was sited, constructed, and decorated to draw in customers. During regular operation, the civil works and its environment need to be inspected daily to make sure that the following basic criteria are met:

	The concrete foundation on which the building is constructed is free of cracks, water damage, holes, and vegetation.
	The customer flow pattern allowing control of and access to the station is clear of obstructions, including garbage, vegetation, and abandoned equipment and materials.
	The station's concrete floor is swept and cleaned with soap and water and does not show signs of filth or heavy use.
	The doors to the station operate smoothly; close and lock securely; are clean of handprints, footprints, and wear marks; and function without effort or noise.
	The glass in all windows is cleaned on the inside and out with a glass cleaning solution and clean cloths or paper.
	Security bars on all doors and windows fit tightly, are anchored solidly, and are free of dirt, leaves, or other garbage.
	Open spaces around the water treatment works are free of equipment, loose objects, evidence of water leakage, and signs of excessive wear.
	All components of the water treatment works appear brand-new and are free of dirt and signs of damage or leakage.
	All chemicals not being used in the treatment system are safely stored out of reach of children and customers, preferably inside locked storage cabinets for protection at a convenient but safe distance from the treatment system and all station operations.
	Floor and wall tiles are spotlessly clean and free of breakage, stains, dirt, or other signs of unhygienic operation.
	The ground surrounding the Safe Water Station slopes away from the building so that rainwater does not run into or form pools around the base of the building.
	An elevated and permanent walkway is kept dry, clean, and clear of debris so that customers are not affected by mud or slippery ground conditions.
	The building's gutters, downspouts, and channels control rainwater, direct it away from the building, do not create wet areas where mosquitos and other vermin can thrive, and keep customers as dry as possible.
	All decorations, posters, and informational materials on the building or on the grounds are free of chips, cracks, tears, or markings.

Electrical Checklist

Reliable and safe electricity is core to the functions of a Safe Water Station. It functions to keep the station in operation, but it also needs to be controlled so that the station is safe and looks finished. After construction, the electrical network of the Safe Water Station must be inspected to ensure that it meets the following criteria:

	Electrical power is provided to the station legally and was installed by knowledgeable professionals. No loose wires are visible, and preferably all electrical works are behind closed panels.
	The electrical panel containing working fuses is accessible, and open space is maintained around it that is free of garbage, debris, and abandoned equipment and materials.
	All wall sockets are sealed in boxes and have no bare wires or evidence of damage.
	Ceiling fan(s) inside the station are functioning, free of dirt, and show no signs of bare wires, damage, or unusual wear.
	Exterior light fixture(s) are functioning, show no signs of damage or unusual wear, and have no bare wires.
	All electrical wiring is anchored securely to walls and/or ceilings so that no wires are loose.
	No bare electrical wires are visible anywhere, in either the electrical connections or anywhere in the treatment works.

Piping Checklist

It is very simple for a qualified operator to maintain a leak-proof piping network. The key items to pay attention to are that the system has no leaks, that each of the valves in the system is smoothly functioning, and that the station supervisor can easily reach each valve and all of the in-line equipment. If leaks or unusual wear are detected on any pipe, fitting, gasket, tube, valve, or housing, it is possible that chemicals are leaching from that component into the water supply. If such conditions are detected, a thorough water quality analysis must be conducted by a certified laboratory. To confirm the continued safe and professional operation of the station, the following should be inspected to ensure that:

	The ball valve between the bore well and the bore well storage tank is clear of debris and smoothly functioning.
	All ball valves function smoothly, from fully closed to fully open.
	All non-return valves are functioning and not leaking. The safety of the entire system relies on these valves.
	All the pumps are fully functional and lubricated for immediate and continuous use.
	All piping that contains chemicals - pH dosing lines, chlorine dosing lines, anti-scalant dosing lines - is leak-proof and protected from children and customers.
	The inlet pipe, taps, and overflow pipe on the reject water storage structure (if present) are leak-proof.
	The cover of the reject water storage structure is tightly sealed and does not allow animals or insects to enter the structure.
	The ground in the vicinity of the taps on the reject water storage structure is free of spillage and the accumulation of salts.

Grounds Management Checklist

The appearance of the outside of a Safe Water Station is as important as the building and the operation of the treatment works. Customers are attracted to a property that is well maintained. At least weekly, the following should be inspected and attended to:

	The grounds around the station—front, back, and sides—are free of pooled water, garbage, animals, discarded equipment and materials, and overgrown vegetation from the building to the secure edge of the property.
	All vegetation on the site is trimmed or cut back so that it is controlled, there is free access to the Safe Water Station, there is no risk of fire, and the station and its decorations are clearly visible.
	The grounds are free of tall weeds, and any dead branches on vegetation are pruned and disposed of.
	If appropriate, flowerbeds and other decorative vegetation are planted and maintained throughout the site.
	Soil erosion on the site is controlled. The ground slopes away from the building, and drains are constructed and kept clean to control rainwater so that it does not form pools on the site or create erosion or other damage to adjacent sites.
	Any fencing on or around the property shows no signs of damage, deterioration, or unplanned access. Gates are secure and, if appropriate, equipped with a lock to control access to the property.
	A clear location is used for disposal of all garbage and waste materials and equipment. The location is covered, and arrangements are made to haul away garbage and other waste for final, environmentally friendly disposal.
	Access ways for the elderly or disabled are provided and kept clear of any blockages or material that may cause unstable footing.
	A clear pathway is identified that will allow rapid departure from the station and the property in the event of an emergency.
	There is no evidence on the ground of spillage of reject water or of dried salts from reject water.



Safe Water Station buildings take many forms. All must present a professional face to potential customers.

Building and Grounds Compliance Log

Year _____ Begin Month _____ End Month _____						
Reviewed Building Checklist		Date:	Date:	Date:	Date:	Date:
		Initials:	Initials:	Initials:	Initials:	Initials:
	Problems Identified					
	Solutions to Problems					
	Actions Taken					
Reviewed Electrical and Piping Checklist		Date:	Date:	Date:	Date:	Date:
		Initials:	Initials:	Initials:	Initials:	Initials:
	Problems Identified					
	Solutions to Problems					
	Actions Taken					
Reviewed Ground Management Checklist		Date:	Date:	Date:	Date:	Date:
		Initials:	Initials:	Initials:	Initials:	Initials:
	Problems Identified					
	Solutions to Problems					
	Actions Taken					



Electricity and water can be a dangerous combination. Operators must ensure electrical safety.

Quality Module Tool 31

Ensuring Consistency of Storage and Distribution

Purpose

When treated drinking water leaves the Safe Water Station, the station supervisor's responsibility for the quality of the product does not end. The supervisor and operator are expected to make every effort to ensure that the drinking water quality remains high through the various modes of distribution—piping, trucking, carting, or hand carrying. The purpose of this tool is to provide guidance for keeping treated water clean from the product water tank into homes and businesses where it is consumed.

Consistent with the Safe Water Network's approach to all aspects of quality assurance reflected in this module, this tool addresses each of the key elements as follows:

- **Assess**—identifies critical points of quality assurance along the distribution chain
- **Record**—documents the actions taken to ensure that quality is maintained
- **Review**—determines the success of critical point actions
- **Remediate**—mitigates risks to water quality and the “last mile” of distribution

Audience

This tool is for use by the Safe Water Committee and the station operator and supervisor to establish and communicate the measures for distributors and consumers to take that reduce the loss of quality after safe drinking water leaves the Safe Water Station.

Prerequisites

Before this tool can be used, the operator and the supervisor should have a reliable source of hypochlorite disinfection powder, an appreciation for the care that must be taken in handling this powder, and a strong commitment to the hygienic delivery of safe drinking water to customers regardless of the delivery method.

If the tool user has any concerns about the care that must be taken, he/she should immediately read the **Personal and Station Safety with Powdered Chlorine** material included in this tool.

Materials Needed

No special materials are needed to implement tool 31. The tool is primarily for information and communication

regarding cleaning procedures, hygienic upkeep of delivery, and principles of chlorination that need to be part of the knowledge base and regular practice of Safe Water Station supervisors and operators.

Materials Contained In This Tool

This tool consists of six pieces. They are primarily informative regarding procedures to follow in cleaning tanks and containers. However, there is also a very important section on Personal and Station Safety with Powdered Chlorine.

How To Use The Tool

The first piece in this tool provides the operator and/or supervisor with a detailed step-by-step procedure to follow to clean and disinfect the product water storage tank, from which drinking water is dispensed to customers. This is a 24-hour procedure that is necessary any time the residual chlorine concentration of product water is not consistently between 0.2 and 0.5 mg/l for any period of time.

The second piece of the tool reminds the operator and/or supervisor of the importance of customers collecting, carrying home, and storing their drinking water in narrow-neck containers with a watertight seal. Some of this material was originally presented in tool 20 of the Distribution Module, but it is worth presenting here because the third piece of the tool provides a step-by-step procedure to follow to clean and regularly disinfect these containers each time a customer comes to the Safe Water Station.

The fourth piece of the tool addresses the hygiene and on-site checks that are needed to ensure that drinking water that is distributed from the Safe Water Station—whether by pipe, containers in vehicles, or in bulk containers—remains safe all the way until it reaches the consumer.

The final two pieces of the tool are technical briefs regarding the safe storage and handling of concentrated chlorine powder and the important distinction between *combined* and *free chlorine* residual. For all aspects of Safe Water Station operation, we are interested in providing measurable free chlorine residual from the water product tank into bulk or household containers, at remote distribution kiosks, and up until the moment that safe drinking water is consumed.

Product Water Tank Cleaning

Maintaining a hygienic product water tank is critical to the successful operation of a Safe Water Station. The treatment system, whether it uses modular sand filters or reverse osmosis membranes, should be expected to produce safe drinking water. Ultraviolet and/or chlorine disinfection should result in a high-quality product for sale. But if this safe water is placed in anything less than a spotlessly clean product water tank, all of the effort and resources put into treatment are wasted.

All storage tanks should be completely covered and constructed to prevent the possibility of contamination of the tank contents by outside water or other foreign matter. Concrete and brick tanks should be made watertight by a lining of rich cement mortar. The Safe Water Network prefers the use of manufactured, plastic storage tanks for reasons of convenience, cost, durability, and watertightness. All tanks require adequate screening of any openings to protect against the entrance of small animals, mosquitoes, flies, or other small insects.

In general operations, the product water tank should be drained and cleaned as often as necessary to generate a sustained, equal use of chlorine and a free chlorine concentration of at least 0.2 mg/l at the outlet from the tank. However, it is always necessary to clean the product water tank under the following conditions:

1. Disinfection of a tank that had received contaminated water before filling the tank with treated water

2. Disinfection of a new tank upon completion and preparatory to placing in operation with treated water
3. Disinfection of the tank after completion of maintenance or repair operations.

Procedure

The tank should be thoroughly flushed with water to remove any sediment that may have collected during operation. After flushing, the tank should be filled with a disinfecting solution of calcium hypochlorite and treated water. This solution is prepared by adding 1.2 pounds of 70 percent calcium hypochlorite to each 1,000 gallons of water, or by adding 2 gallons of ordinary household liquid bleach to each 1,000 gallons of water. A mixture of this kind provides a solution having not less than 100 mg/l of available chlorine.

The disinfectant should be retained in the tank for not less than 24 hours, then examined for residual chlorine and drained out. If no residual chlorine is found, the process should be repeated. When adequate chlorine is detected, the system is then flushed with treated water and put into operation.

When the tank is cleaned, the date, reason, and person who undertook the cleaning should be reported on the Maintenance, Repair, and Replacement Record for the type of filter operating in the Safe Water Station. These records can be found in **tool 29**.



Transportation of safe water takes many forms. All must pay attention to quality control.

The Importance of Narrow Neck Containers

According to the World Health Organization, some of the key factors influencing the impact of household containers on drinking water quality are:

1. Portability and ease of use, based on capacity, size, shape, weight, and presence of handles
2. Durability, weight, and other properties related to resistance and longevity
3. The presence of a coverable (preferably screw-cap) opening for filling and cleaning access that is small enough to reduce the potential for introducing contaminated hands, utensils, and other vehicles (e.g., airborne dust), vectors, or other sources
4. Ability to withdraw water in a sanitary manner, such as via a tap, spigot, spout, or by tilting the container
5. The presence and accessibility of documentation describing how to properly use the container for water treatment sanitary storage

For these reasons, the Safe Water Network promotes the purchase and use of narrow-neck, plastic drinking water containers for household users. In most cases, distributed water is also transported in these containers for delivery to households and commercial operations. The five key advantages of the selected containers are presented below:

Five key advantages of a Safe Water Storage Container



Stackable for easy transport



Easy to pour rounded bottom



Strong, sturdy body with a good handle grip



Narrow mouth to keep water safe and provide easy flow



Easy to carry

Container Cleaning at the Safe Water Station

During a Safe Water Network study undertaken in Ghana, researchers found that 11 percent of the water leaving Safe Water Stations tested positive for microbial contamination. This increased to 62 percent by the time it reached consumers in their homes. The principle reasons for this drastic increase were the reliance on wide-mouth containers and water containers that were not adequately cleaned before being refilled with safe water. Unclean containers are an automatic source of contamination.

The Safe Water Network is not satisfied with just producing safe water. It is also committed to keeping water safe all the way to consumption. This requires promoting and providing narrow-neck containers as described in the previous section of this tool. In addition, Safe Water Stations offer a cleaning area with materials so customers can disinfect their water containers on-site each time they visit the station.

The Customer Flow Diagram shown on the following page was introduced in **tool 13**, Civil Works Planning, of the Toolkit for Safe Water Stations. It shows how each Safe Water Station design controls ingress and egress at the station and directs customers first to wash themselves at the Handwashing Sink. When this is complete, the container is then rinsed with a chlorine solution.

The rinse solution is prepared by adding 1.2 pounds of 70 percent calcium hypochlorite to 1,000 gallons of water, or by adding 2 gallons of ordinary household liquid bleach to 1,000 gallons of water. A mixture of this kind provides a solution having not less than 100 mg/l of available chlorine.

This solution is poured into each customer's container and used to thoroughly rinse the inside of the container. The rinse water is then poured to waste and the container is further rinsed with clean, treated water before it is filled and the purchase is completed.



Regular cleaning of 5000 liter product storage tanks is fundamental to safe water delivery

Ensuring Continued Quality during Remote Water Delivery

In addition to direct sales of drinking water at Safe Water Stations, the Safe Water Network also makes it available at remote, off-site locations. This occurs in three ways: piping from the Safe Water Station to remote kiosks, transportation of sealed containers by vehicle, and transportation of bulk water in large volume, sealed containers for use in filling smaller containers at the location of customers.

Quality Assurance at Remote Kiosks. When water is treated at a Safe Water Station and then piped to a remote kiosk for sale to customers, there are three quality assurance concerns. The first is that the drinking water sold at the kiosk maintains a residual free chlorine concentration of between 0.2 and 0.5 mg/l. Maintaining this residual concentration is the most accurate indicator of the safety of the drinking water at any location. The second concern is that the same volume of water that leaves the Safe Water Station arrives at the kiosk. This is measured by comparing the volume of water measured by a flow meter as the water leaves the station with the volume of water measured by an identical meter as the water enters the storage tank at the kiosk. Comparison of the two values, which should be identical, indicates whether water is being lost—and therefore probably contaminated—between the station and the kiosk. The third concern is that the kiosk and the area around the kiosk are maintained to the same hygienic standard as the Safe Water Station. Each checklist presented in tool 30 for Building, Electrical, Piping, and Grounds should be applied to each remote kiosk to ensure the high quality of the facilities.

Quality Assurance during Transportation of Sealed Containers. In this case, containers are filled at the Safe Water Station and closed with a tight, screw-cap seal. The water in these containers is safe and ready for consumption. They are loaded onto a vehicle that carries the containers for delivery to customers. There are two quality assurance concerns during this delivery. Each has to do primarily with the representation of the Safe Water Station and its brand before customers. The first concern is with the quality and appearance of the vehicle. The vehicle should be clean, well maintained, and in top working order. Anything less than this reflects badly on the professional operation of the Safe Water Station. The second concern is with the quality and appearance of the deliverer. This person—who is often the station operator or supervisor—should appear healthy and hygienic and wear clothing that represents the professional quality of the station.

Quality Assurance for Bulk Water Delivery. Many Safe Water Stations deliver safe drinking water to customers in 1,000 liters or larger containers. These deliveries may be made to individual household customers, filling their containers with water from the bulk water tank, or they may be made to commercial customers such as restaurants, which store the water in large containers at their place of operation. There are two quality assurance concerns with this type of delivery system. The first concern is with the cleanliness of the customer's container. To the extent possible, before delivery the customer's container should be rinsed with a chlorine solution and then a small amount of safe water before being filled with bulk safe water. The second concern is ensuring the presence of an adequate free chlorine residual in the bulk water and in the customer's container. At all points, free chlorine residual concentration of between 0.2 and 0.5 mg/l should be maintained. If this chlorine concentration is not present, it is highly likely that the drinking water is not safe.



Quality of water and delivery must both be maintained when safe water is distributed to customers

Personal and Station Safety with Powdered Chlorine

Safe Water Station operators commonly use calcium hypochlorite, also called HTH (high test hypochlorite), for disinfection. HTH looks harmless, but it can be dangerous and even deadly. HTH typically contains a chlorine concentration of 65 to 70 percent. Exposure to HTH can damage skin, eyes, and the human respiratory system.

Operators, supervisors, and Safe Water Station Committee members should not be fooled by the apparently safe appearance of this chemical. Anyone handling HTH should wear eye protection, a face shield, protective clothing, and gloves. The operator and/or supervisor must be especially careful about dispersing the powder, as it can be inhaled and result in harmful airborne concentrations.

HTH reacts violently with many substances, including hydrocarbons (fuels, oils, and greases), ammonia, and many metals. HTH must be stored in its original container, tightly closed. Operators and/or supervisors must be especially careful that any secondary containers used for applying HTH are clean and made of compatible materials. HTH is an extremely dangerous product that can endanger both emergency responders and the general public with its potential for creating violent, intense fires and explosions. It severely accelerates combustion and burns with extremely high temperatures.

Key safety and preventive measures for proper HTH handling include the following:

1. Never allow contact between HTH and combustible materials, especially hydrocarbons, ammonia, and metal.
2. Prevent dispersion of HTH dust.
3. Ensure local exhaust or breathing protection when handling HTH.
4. Wear protective gloves and protective clothing when handling HTH.
5. Wear a face shield or eye protection when handling HTH.
6. Do not eat, drink, or smoke while handling HTH.
7. Always wash hands thoroughly after handling HTH.
8. Do NOT let this chemical enter the environment. Sweep any spilled chemical into airtight, dry containers and remove it to a safe place.
9. Store HTH only in a well-closed area without drain or sewer access and separated from food and feedstuffs.
10. It should be noted that HTH decomposes rapidly on heating above 175°C and on contact with acids, producing chlorine and oxygen and causing a fire and explosion hazard.

11. In the event of contamination, contaminated clothes should be immediately rinsed with plenty of water. The symptoms from lung inhalation often do not become manifest until a few hours have passed, and they are aggravated by physical effort. Rest and medical observation is therefore essential. Immediate administration of an appropriate inhalation therapy by a doctor or a person authorized by him/her should be considered.

The Critical Role of Chlorine Residual

The practice of chlorination has become so widespread and generally accepted that its chemical contribution to drinking water safety is frequently misunderstood and taken for granted. It is critically important that Safe Water Station operators and supervisors are familiar with the basic chemistry and practice of chlorination so that they understand the relationships between chlorine dosage, water characteristics, and chlorine residual—the real determinant of the safety of drinking water supplies.

Chlorine is used in Safe Water Stations in the form of hypochlorites - typically commercially available calcium hypochlorite, sometimes referred to as “high test hypochlorite” or HTH. HTH acts as a potent oxidizing or disinfecting agent. But it often dissipates itself in side chemical reactions in impure water so rapidly that little disinfection is accomplished until amounts exceeding this side “chlorine demand” of the water are added. It is critical to know how much HTH needs to be added to complete these side reactions. They create a higher than anticipated “chlorine demand,” which is defined as the difference between the amount of chlorine applied and the quantity of free chlorine residual measured in the water at the end of a specified time of contact.

All forms of chlorine chemically react with a wide variety of impurities in water. These include ammonia, hydrogen sulfide, iron, manganese, nitrite, and organic materials. These side reactions complicate the use of chlorine for disinfection. Their demand for chlorine must be satisfied before chlorine becomes available to accomplish long-term disinfection.

Chlorine demand arises from the chemical reactions of chlorine with water and with impurities in water. Chlorine combines with water in several chemical reactions that result in the dissolved ions that produce its disinfectant power. The extent of these reactions depends on the pH of the water. When calcium hypochlorite is used as a disinfectant, as is the case in Safe Water Stations, the resulting ions are hypochlorite ions that are effective disinfectants. At pH 7.5,

the dissolved calcium hypochlorite in water is approximately evenly divided between hypochlorite ions and a more stable form of hypochlorous acid. As pH moves lower, more of the stable form is present. As pH moves higher, more of the disinfectant ions are dissolved into the water. It has become common practice to refer to all of these ions as *free chlorine residuals*. Any chlorine that has reacted with impurities in the water is referred to as *combined chlorine*. Free chlorine is a much more potent disinfectant.

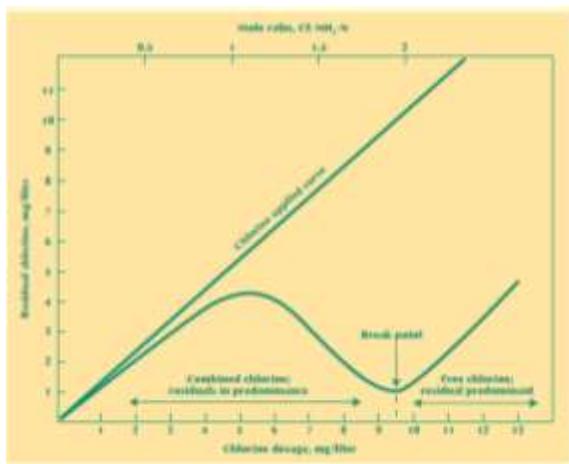
Chlorination of water to the point at which all chemical reactions with impurities of the water are complete and any chlorine is present as free chlorine residual is referred to as “break-point chlorination” because of the unique characteristics of the chlorine residual curve shown below.

When chlorine is added to water with no chlorine demand, a linear relationship results between the chlorine dosage and the free chlorine residual. However, when chlorine is added to water containing impurities, the breakpoint phenomenon occurs. The breakpoint is that dosage of chlorine that produces the first detectable amount of free chlorine residual. This is what is measurable by a standard chlorine test kit.

All Safe Water Stations must know the breakpoint of their water—which should be expected to change with seasons—and use the appropriate dosage of chlorine to pass the breakpoint and yield a final concentration of free chlorine residual between 0.2 and 0.5 mg/l. This is the value measured by the operator or the supervisor during product delivery.

Two additional factors are extremely important to understand in disinfection with chlorine: *time of contact* and *chlorine concentration*. Where other factors are constant, the disinfecting action of chlorine is proportional to the product of multiplying the contact time and the concentration. A higher concentration of chlorine requires a shorter contact time with water, and a lower concentration requires a longer contact time to achieve the same level of disinfection.

The occurrence of reactions giving rise to the breakpoint is most rapid in the pH range between 7.0 and 7.5. At pH less than 6 or greater than 9, the breakpoint is not significant. In the pH range 7.0 to 7.5, the breakpoint is about half developed within 10 minutes at 15–20°C and is substantially completed within about two hours.



Custom Flow Pattern at a Safe Water Station



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