Water Quality Testing

Water Issues

Diarrheal diseases (DD) are extremely common in virtually all developing country settings and particularly rural and peri-urban locations. Infective diarrhea is the 3rd highest cause of death due to infection in the world. Global deaths from diarrhea of children aged less than 5 years were estimated at 1.87 million, approximately 19% of total child deaths. Ninety percent of the ~4 billion annual global episodes of diarrhea can be attributed to three major environmental causes; poor sanitation, poor hygiene, and contaminated water and food.

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Water supply system- work camp

Cleaning water tanks

Artisanal Camp water storage unit

Local rain water collection tank

Unsecured local hand dug borehole

Local rainwater collection system

A substantial number of the DD are fecal-oral so that water supply issues (known as water-washed problems) predominate. Water washed is differentiated from water quality since it appears that absolute supply is more critical than quality. During a rapid assessment it is critical to consider both water volume and quality. Hence, the team needs to consider and document these critical elements:

- What are the sources of water supply for households? Possibilities include rainwater, surface water, e.g., streams, lakes, hand dug shallow boreholes or professionally constructed community supply systems including deep secure boreholes.
- What is the distance between the water source(s) and the household? Numerous studies indicate that as the time distance to the water source increases, i.e., greater than 20 minutes, the absolute volume of water utilized at the household level rapidly declines.
- What is the quality of the household water supply? Is there a simply field method for determining fecal coliform levels?
- What is the water supply and storage system, i.e. rainwater catchment using roof and gutters, 20 litre containers, large 50 litre containers?

With the exception of measuring water quality parameters, all of these questions can be answered by field observations.

These pictures illustrate the variety of catchment and storage systems that can be found. The degree of sophistication is quite varied ranging from deep boreholes with elaborate piping and storage tanks to simple unsecured boreholes and large thermos jugs. An important consideration for any water supply system is the transport system. This system can range from (i) elaborate piping from a deep borehole to storage tanks to (ii) simple gutters that facilitate roof catchment and distribution to storage tanks. As part of the field evaluation, we recommend that the team carefully trace the entire system from source to end-user. We have frequently found that the water source is satisfactory; however, problems can and do occur because of faulty transport systems. Contaminated piping and catchment surfaces (e.g., roofs) can significant affect the water quality. Examples of contaminated piping are shown below

Contaminated piping systems

Testing Equipment

Field level water testing systems should be simple and require minimal specialized equipment. The intent of testing is to (i) measure a few critical chemical parameters such as pH and turbidity, (ii) determine residual chlorine levels if a water system is using chlorine disinfection and (iii) determine the presence or absence of coliforms, particularly fecal coliforms. The coliforms are indicator organisms that are used to assess the microbiological quality of the water. In many situations the other bacteria, viruses and parasites are actually causing an individual who ingests the water to become sick.

Simple water testing equipment that can measure pH, turbidity and residual chlorine

The presence of general coliforms indicates that the water has come in contact with plant and/or animal life. General coliforms can be found in most water sources, including spring water. Even rainwater is affected due to contamination present on the catchment surface. At very high levels, general coliforms can include pathogens from mammal or bird feces.

The fecal indicator bacteria are known as fecal coliforms. Thermotolerant fecal coliforms are typically *E. coli* but can also include other organisms that are more resistant to chlorine disinfection than *E. coli*, e.g., intestinal enterococci, *Clostridium perfringes* spores, etc. In terms of absolute levels of contamination, typical drinking water standards (e.g., US EPA) for fecal coliforms are1 per 100cc of water. This roughly equates to one part per billion of feces, or one milligram/m3. Low levels of general coliforms are of little concern to human health but do indicate the presence or absence and degree of effectiveness of any external disinfection system such as chlorination.

When chlorinating water, it is very important to realize that the administered chlorine reacts with compounds in the water. The added chlorine must be at a sufficient level so that a significant amount of the chlorine remains in the water for disinfection. This residual chlorine is affected by:

- pH of the water- more alkaline (pH greater than 7.0) requires a longer chlorine contact time;
- Contact time- this may be 30 minutes to one hour depending upon the water quality and chemical parameters
- Temperature – chlorine is very sensitive to light and temperature and may lose reactivity if improperly stored, a situation that often occurs in the tropics
- Turbidity- this affects the efficiency of disinfection
- Number and types of organisms present and amount of organic matter in the water.

Chlorine is added to the water source until the "breakpoint chlorination level" is reached, i.e., the point where there is only free chlorine remaining in the water. Breakpoint chlorination is usually achieved by adding chlorine concentrations greater than 1 mg/L. To kill bacteria, about 0.2-0.4 mg/L is needed. However, as pH becomes more alkaline, greater free residual chlorine levels are required: (i) pH 6-8 0.4-0.5 mg/L and (ii) 0.6 mg/L at pH 8-9. Unfortunately, chlorination may be ineffective at pH levels greater than 9.0.

The WHO drinking water standards state that 2-3 mg/L chlorine should be added to water in order to gain a satisfactory disinfection and residual concentration. The maximum amount of chlorine one can use is 5 mg/L. Taste does not give a reliable indication of chlorine concentration. For a more effective disinfection the residual amount of free chlorine should exceed 0,5 mg/L after at least 30 minutes of contact time at a pH value of 8 or less. *(WHO, Guidelines for drinking water quality. 3rd edition)*. The failure of disinfectant systems can be quite high. In 2007, testing by the Guyana Ministry of health demonstrated that more than 50 per cent of samples collected from suppliers of treated water failed the government's microbiology testing protocol. Test failure is usually due to a combination of factors as water systems are extremely vulnerable, particularly in the tropics.

In a field setting, we use simple techniques that (i) measure basic chemical parameters including residual chlorine, (ii) identify the presence or absence of coliforms above a US EPA drinking water standard, (iii) further identify if the contamination contains fecal coliforms and (iv) the numerical level and type of contamination that is present.

After determination of basic chemical parameters, we use simple test systems that determine the "Presence or Absence (P-A)) of contamination. There are several commercially available kits that within 24 hours can determine the presence or absence of contamination at a level of 1 coliform per 100 ml test sample. All of these kits require sample collection, usually in the test bottle followed by 24-48 hours of incubation at room temperature. A color change (yellow to green) indicates the presence of contamination. There are several inexpensive commercially available systems tat are available and are shown.

The Colitag™ detects 1 colony-forming unit (CFU) of E. coli and Fecal Coliform bacteria in 100mL of water. For detection of E. coli, Colitag™ utilizes the fluorogenic enzyme substrate 4-methylumbelliferyl-ß-D-glucuronide (MUG). If any MUG-positive E. coli are present in the sample, a bright blue fluorescence is emitted when the sample is subjected to a long wavelength (366 nanometer) ultraviolet light placed 3-4 centimeters away. The UV lamp is a simple handheld battery operated device that can be inexpensively purchased and easily carried to the field. The blue fluorescence is illustrated in the photos shown below.

Positive blue fluorescence in control and test sample

More sophisticated sample testing can be performed using the Coliscan® Easygel® medium. This system involves introduction of a 5 cc sample into a prepackaged bottle of Coliscan Easygel. The test mixture is plated on a sterile petri dish which is included in the test kit. According to the manufacturer (Micrology Laboratories, LLC), the gel contains a sugar linked to a dye which, when acted on by the enzyme p-galactosidase (produced by coliforms including *E. coli*), turns the colony a pink color. Similarly, there is a second sugar linked to a different dye which produces a blue-green color when acted on by the enzyme p-glucuronidase. Because E. coli produces both p-galactosidase and p-glucuronidase, *E.Coli* colonies grow with a purple color (pink + blue). The combination of these two dyes makes possible the unique ability to use one test to differentiate and quantify coliforms and E. coli. (Because *E. coli* is a member of the coliform group, add the number of purple colonies to the number of pink colonies when counting total coliforms.)

The plates are incubated for 24-48 hours at ambient temperature. In the tropics the higher temperatures facilitates growth and we typically obtain reliable results within 24-48 hours. At room temperatures, the best procedure is to watch the plates by checking them at 10-12 hour intervals until one observes whether some pink or purple colonies are starting to form. At 24--30 hours these colonies are typically mature. Since the coliforms (including *E. coli*) are generally the fastest growing organisms, these will be the first to grow and be counted.

Colonies that may show up at a later time are likely to not be coliforms. Creating a stable uniform temperature is not difficult if there is any electricity and we have created simple cardboard incubators using a box and a light bulb. In the absence of electricity, the system still works and we can use a box and "insulation materials (old clothes)" to maintain a uniform and appropriate temperature. We also carry a simple electronic kitchen thermometer for measuring temperatures inside our box. There is also less probability of variation from batch to batch when the incubation temperatures are kept at one uniform level. A higher incubation temperature will tend to inhibit the growth of non-coliforms that may prefer lower temperatures. In our experience, the system is safe, simple and extremely useful for testing the key points along a water supply system. In addition, the ability to visually "show " the results is extremely powerful and useful.

Sample Preparation

Light bulb incubator

Positive cultures

Minimal growth sample

Incubator and thermometer

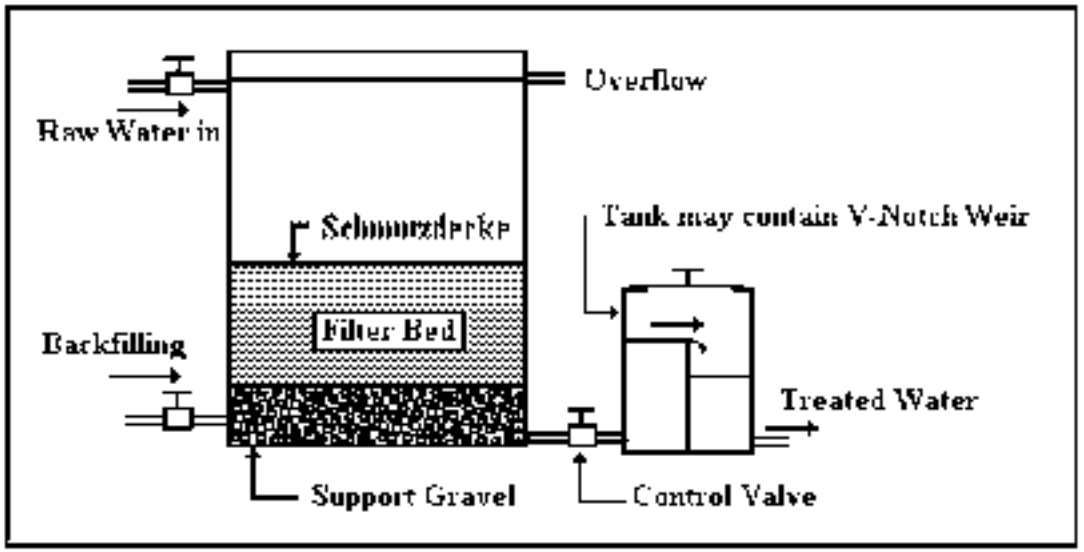
Test results form a small water "Igloo" tank

Treatment Options

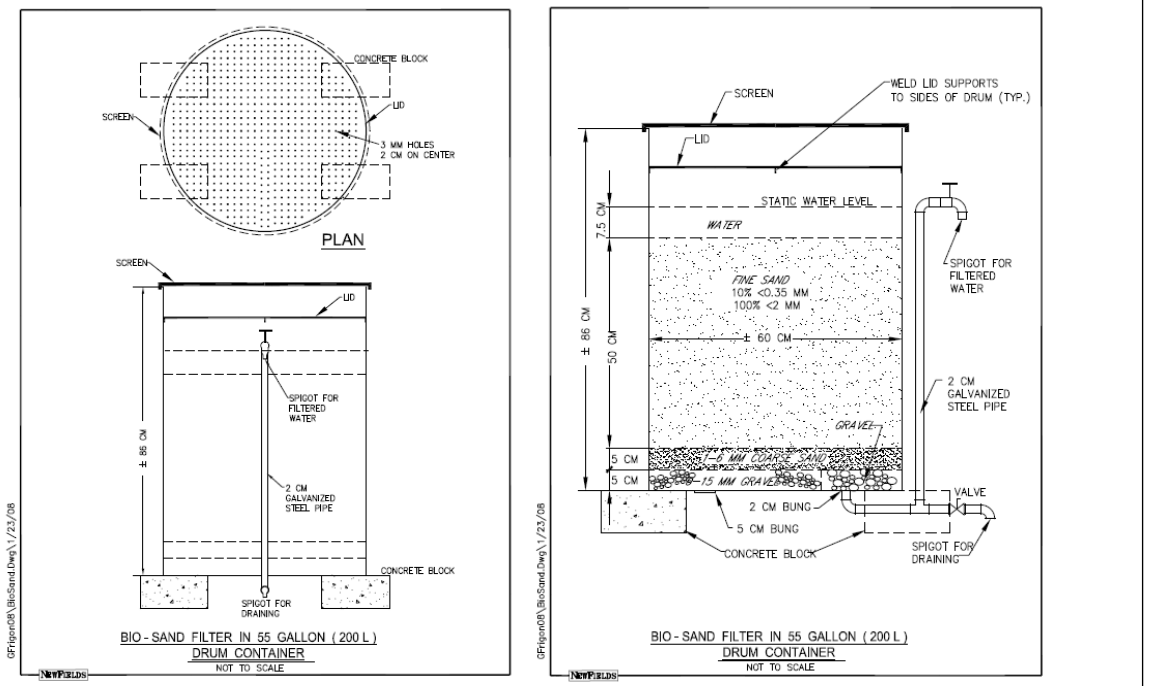
Aside from chlorination, there is another well established non-chemical treatment option that is available for communities, i.e., construction of a simple sand filter. Slow sand filtration (SSF) has existed as a water treatment option for over one hundred years. SSF has been widely employed in treating community water supplies in developing countries against water-borne disease and numerous WHO publications are available.

Slow sand filtration relies on both physical and biological activity in controlling plant pathogens. In a slow sand filter, water passes through the sand from top to bottom. The larger suspended particles are left behind in the top layers of sand. Organic sediment particles are eaten by microscopic organisms including bacteria and protozoans which 'stick' in the layers of slime that form around the sand particle (known as the schmutzdecke"s . Provided that the grain size is around 0.1mm in diameter, a sand filter can remove all fecal coliforms (bacteria that originate from feces) and virtually all viruses. Some of the key operating factors include (i) the particle size distribution of the sand, (ii) the ratio of surface area of the filter to depth and (iii) the flow rate of water through the filter.

A schematic of a simple sand filter using basic materials is shown. This design was prepared by NewFields water engineers to be easily constructed using simple , inexpensive materials.



Source: Oasis Design (http://www.oasisdesign.net/water/treatment/slowsandfilter.htm)



Slow Sand Filter Design