Water Quality Assessment Tools for Small Reservoirs

Water reservoirs provide the basic, domestic and agricultural water needs in many rural communities. Thus, it is paramount that water quality in reservoirs is assessed every so often to determine suitability and safety for varying purposes.

Locals can assess water quality through simple and inexpensive methods such as observing color, transparency, taste and smell. More sophisticated technical methods to monitor changes in water quality include the analysis of biomedical, biological and physicochemical parameters. Some of these methods for measuring water quality are discussed here. When possible, relatively simple protocols in the field with a simple laboratory may also be used.

Before actually conducting water quality assessment, it is best to first evaluate the suitability of water based on its intended use, which may be done using the following steps:

1. Select the reservoirs for which water quality is to be monitored.
2. Identify the main water uses and determine key water quality parameters.
3. Do a qualitative survey on water quality to determine the people's perceptions. Dialogues between and among experts and community members help to identify parameters, after which systematic collection and analysis of water samples can be performed.
4. Take water samples from different water sources: reservoirs, canals, wells, water collected at the site and in the household and drains.

Biomedical parameters

Experts consider parasites to be silent epidemics as these are the main causes of chronic diseases and poor health in many people. More than 130 parasites are known to infest humans but these are often left undiagnosed. Some parasites live part of their lives in water and can be transmitted through drinking of contaminated water. The following are the steps in sampling water for parasites sampling *(Shorttet al. 2006):*

1. Collect water samples from various sources.
2. Filter the water using a hand pump with a flow rate of approximately 5 liters per minute. For each sampling, pump 49 liters of water through a single cylindrical filter, made from an inlet hose and a plastic filter holder, with a 25–cm long yarn-wound polypropylene filter.
3. Wash the filter with distilled water using a squirt bottle, then scrape it with a scalpel to obtain a concentrated specimen.
4. Preserve 200 ml of the concentrated specimen in 10% formalin for further analysis.
5. Store the concentrated specimen at room temperature until it is processed for microscopic analysis.
6. During further evaluation, centrifuge the specimen to a volume of 5 ml (containing all the sediment visually detectable in the original 200 ml). Microscope identification can be used to classify pathogens such as *Giardia* cysts and *Cryptosporidium* oocysts.

***Giardia spp.* and *Cryptosporidium* spp. are common intestinal parasitic pathogens in vertebrates, including birds and mammals. Transmission of these parasites occurs by ingestion of *Cryptosporidium* oocysts or *Giardia* cysts, either by fecal-oral contact or fecal-related contamination. In humans, these parasites can cause persistent diarrhea for 2-3 weeks or longer. In some cases, infected humans and animals continue to shed these parasites asymptomatically.**

Under the microscope, *Giardia* cysts appear as elongated structures with visible flagella inside. They have a mean size of 12 µm. *Cryptosporidium* oocysts, on the other hand, appear red and usually have dimensions of 5.0 µm x 4.5 µm. But prior to microscope viewing, certain preparations for identification of *Giardia* cysts and *Cryptosporodium* oocysts need to be undertaken (see Shortt *et al.* 2006 for more information).

Coliform sampling and analysis

Coliform bacteria are organisms present in the environment and in the feces of most animals and humans. These bacteria may not cause illnesses, but they indicate presence of disease-causing organisms. Sampling for coliform bacteria should

be done even more frequently than for parasites (e.g., once a month for various seasons). For a given round of measurement, all selected water sites should be sampled within the 5-7 day-period so that findings can be compared. At each site, three samples should be taken.

The thermotolerant coliform analysis method can be done using the membrane filter technique as outlined by Csuros and Csuros (1999) and the American Public Health Association (1998). In this technique,

1. Filter the water samples through a membrane (0.47 µm pores) that retains thermotolerant coliform bacteria.
2. Incubate this membrane on a growth-promoting medium.
3. Count the resultant colonies of thermotolerant bacteria within 1 hour of being removed from the incubator.
4. In case of high contamination levels, prior to filtration, dilute the samples with a sterile phosphate, magnesium chloride solution. Hence, no more than 500 colonies per filter are used to calculate the concentration of colony-forming bacteria per 100 ml.

Composite sample analysis

This method can help improve precision and lower the variance of estimated average contaminant concentrations (Million 2008). Moreover, by testing for *Enterococcus* and *Streptococcus*, a distinction can be made between contamination from people and that from animals.

1. Prepare three replicate samples of 10 ml from each site.
2. Subject the samples to membrane filter analysis of total coliforms, fecal coliforms and *Enterococcus*/fecal *Streptococcus*. The latter are

important indicators of fecal contamination of animal origin.
3. Filter the composite samples under a hood using a membrane filtration apparatus with a 47 mm diameter sterile and gridded membrane, with a pore size of 0.45 mm.
4. Aseptically (pathogen-free) transfer the membranes to glass petri dishes with different media: m-Endo Agar LES for total coliforms (TC), m-FC agar with rosolic acid for thermotolerant coliforms (TTC) and m-Entrococcus agar media for fecal *Streptococcus* (FS).
5. Invert the prepared culture dishes and incubate for 24 h at 35 °C (TC), 24 hours at 44.5 °C (TTC) and for 48 h at 35 °C (FS).
6. After incubation, count the typical TC colonies (pink to dark red with sheen), TTC colonies (blue), and FS colonies (dark red) on the surface of the membrane filter, using a low-power binocular wide-field dissecting microscope, with a cool white fluorescent light source for optimal viewing sheen.
7. Rinse the funnel between each site sample filtration using buffer rinse water (APHA 1998).

8. Do verification tests by transferring growth from each colony and place growth in lauryl tryptose broth at 35±0.5 °C for 48 h. Gas formed in lauryl tryptose broth within 48 h verifies the colonies as TC. Inclusion of EC broth for 44.5±0.2 °C incubation verifies the colonies as TTC/FC.

Physicochemical parameters

Electrical conductivity

This method can measure water salinity, which can serve as an indicator of salinity-causing salts (ions), such as chlorides, sulphates, carbonates, sodium, magnesium, calcium, and potassium. Water bodies tend to have a relatively consistent range of electrical conductivity values that, once known, can be used as a baseline against which to compare regular measurements of conductivity. Significant changes in conductivity may then indicate that a discharge or some other source of contamination has entered the waterway.

Chemical characteristics

The assessment of the physical and chemical characteristics of water helps to determine its suitability for domestic, industrial and agricultural uses, as it gives a good impression of the status, productivity and sustainability of the water body. Changes in physical characteristics such as temperature, transparency, and chemical element content of water (e.g., dissolved oxygen, biochemical oxygen demand, and nitrate and phosphate content) provide valuable information on the quality of water, the sources of variations, and their impacts on functions and biodiversity of the reservoir (Mustapha 2008).

1. Collect samples for anion analysis in 100-ml polyethylene bottles. Filter the samples using 0.20-m cellulose acetate filters prior to anion analysis (Rajasooriyar 2003).
2. For cation analysis, collect samples in 200-ml polyethylene bottles and add 4% (by volume) nitric acid in the field. Before analysis, filter the samples using 0.45-m cellulose acetate filters.
3. Analyze the samples for Na, K, Mg, Ca, Mn, Al and Si by spectrometry—e.g., inductively coupled plasma atomic emission spectroscopy (ICP-AES - Varian Vista - axial system).
4. For Cl-, NO3-, SO4 2- and PO4 3- analysis, use ion chromatography,—e.g., DIONEXTM series 4000 I instrument. The total alkalinity (HCO3 -) is best determined by titration. Fluoride determinations can be made using a fluoride ion combination electrode (ORION - Model 96-09) and TISAB III buffer. Using these techniques, reproducibility for duplicate samples is less than 2%.

For indication of the (seasonal variation in) concentration of fertilizer nutrients in water of reservoirs:

1. Collect samples at least once during the rainy and dry season in reservoirs built from different parent soil materials. Collect samples from the middle of the reservoirs.
2. Determine cation and anion concentration through ion chromatography (Metrohm) in column Metrosep A Supp5 -100 e Metrosep C2. In some water bodies, the results demonstrate the influence of geology on the water quality and a low level of water contamination due to nutrients.

Biological Parameters

Cyanobacteria monitoring

Cyanobacterial proliferation, caused by blue-green algae that produce toxins (which cause water coloration that may vary from olive-green to red), also needs to be evaluated, as it has become a considerable threat in many areas. There has been a growing concern related to the development of toxic cyanobacterial populations. Twenty genera and more than 40 species of cyanobacteria are known for their potential toxicity.

A first step in monitoring can be based solely on visual information. However, visual detection often provides information after the occurrence of the phenomenon and should be considered more as an alarm than as a monitoring tool. Taxonomic composition and specific abundance of phytoplanktons can be analyzed with an inverse microscope. This standardized method, based on morphological traits of organisms, allows cyanobacteria detection before the blooms appear.

The epifluorescence microscopy developed by Andersen and Throndsen (2003) allows the detection of low concentrations (10^2 to 10^4 cells. L-1) of cyanobacteria when using fluorescent printers as orange acridin and DAPI.

An alternative method is molecular fingerprinting for identifying potentially toxic species, although it involves delays and requires adequately trained personnel and discrete sampling of water. The same limitations arise when liquid chromatography (which allows identification of a large panel of pigments) is used in conjunction with software such as CHEMTAX, so that the specific biomass of phytoplankton classes, including cyanobacteria, can be inferred.

High bloom levels can be detrimental to ecosystems and water treatment processes. If cyanobacteria reappear frequently in the same area, the following actions are recommended:

- **Avoid all direct contact with the water.**
- **Do not drink or use the water to prepare or cook food (boiling the water will not eliminate the toxins).**
- **Avoid eating fish or other aquatic species from the affected area.**
- **Do not let animals drink or bathe in the water.**
- **Do not use algicides to destroy cyanobacteria (more toxins are released when cells die).**
- **Toxins can persist after cyanobacteria have disappeared.**

Fluorescence properties of phytoplanktons are currently used as monitoring tools. Based on the optical properties of their pigments, several methods allow the determination of biomass and the distinction between different groups of organisms. The *in vivo* fluorescence characteristic of pigment-containing micro organisms, such as cyanobacteria and microalgae, thus offers attractive possibilities (Leboulanger *et al.* 2002; Gregor *et al.* 2007).

In vivo fluorescence can be measured on individual samples, with flow-through fluorometers, *in situ* or remote-sensed. Different materials and instruments are available, with huge variations in price and sensitivity. Whichever method is used, systematic taxonomic (microscopic) validations are required.

In situ multiparameter probes, including *in vivo* fluorescence, constitute the ideal compromise for rapid and efficient surveys or monitoring. However,

their use requires substantial funds for field resources such as cars, boats, sampling equipment, reagents, calibration, routine maintenance, and laboratory facilities for taxonomic validations.

Conclusion

- Results from water quality analysis can be explained in terms of reservoir water-use and land management practices in reservoir watersheds. This knowledge can help water managers develop strategies to maintain satisfactory water quality.
- Water quality assessment is most accurate when all relevant parameters are analyzed. Reservoir water in areas with different kinds of landuse should be monitored to better understand the effect of landuse on water quality.
- Water in reservoirs may not be suitable for all possible uses because different levels of quality are required for different uses.

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Key Reference

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