Quality Assurance and Quality Control

Introduction

Useable data is the lifeblood of any water monitoring program and variation in measurement processes impairs the quality of the data that water resource professionals work so hard to obtain. Differences in operators, equipment, materials, calibration procedures, test methods, environmental conditions, and other factors can contribute to discrepancies between measurement results – whether comparisons are from time to time, site to site, instrument to instrument, or operator to operator. Metrologists understand that the true value of a measurement result can never be 100 percent certain. Consequently, savvy practitioners focus less on absolute accuracy and strive to minimize variation in the measurement process by undertaking activities to assure and control their data quality.

The primary activities taken to assure and control data quality are aptly called quality assurance and quality control. Quality assurance (QA) refers to planned and systematic processes that provide confidence in a measurement process' ability to achieve its intended outcome. Examples of QA activities include methodology development and standards validation. Quality control (QC) activities, such as testing and inspection, aim to find defects in specific elements of the measurement process. The differences between QA and QC activities can be subtle, which is why they are often seen combined as simply "QA/QC."

Many people do not realize the presence of QA/QC programs in their everyday lives. For products sold by weight or volume, the devices used to measure these products have to be tested and validated on a regular basis. For example, automobile filling stations must have their gasoline pumps validated by a government agency to deliver the correct volume of fuel. Similarly, grocers must have certified scales to weigh meat or fish that is sold by mass. These instances from commerce have a supporting QA/QC program in place. But generally there is no reason for most people to question the measurement results or the QA/QC program supporting them. Just as in commerce, a reliable and controlled measurement system is valuable for water monitoring programs.

The "True Value" – An Elusive Pipe Dream

Determining the "true value" of a measurement is an important fundamental of any QA/QC program. To determine the true value, many professionals choose another means of measuring the parameter of interest, such as another instrument that is kept serviced and calibrated just for quality control purposes or a grab sample that is evaluated using a trusted laboratory technique. Calibration standards may also be used as a reference.

By definition, the true value is the value of a water characteristic obtained by an ideal and perfect measurement system. However, because an ideal and perfect measurement system is nonexistent, the true value used in a QA/QC program is really a surrogate – a value very close to the true value and accepted as such on faith. This surrogate true value is sometimes referred to as an assigned value, best estimate, conventional value, accepted value, or reference value.

Once the basis of a true value is determined, calibration procedures that ensure the integrity of the measuring equipment need to be established. The calibration procedure recommended by the manufacturer is a great starting point. However, in most cases, the manufacturer's recommendation is not a calibration in the purest sense, but a process to set the sensor's output to a particular scale based on known standards. More should be done than just the basic manufacturer's recommendations to truly confirm proper instrument performance. Sensible activities might include checking the sensor's reading in a different standard, either immediately or after some time. An alternative option is setting up various baths with different temperatures and make-ups to check performance over time. Regardless, good QA/QC programs require robust calibration procedures that ultimately provide valuable information about, and confidence in, the instrument's performance.

QA/QC Program Fundamentals

An important part of a QA/QC program is supporting or verifying the measurements taken with the instrument – whether for real-time, grab, or profile sampling. To eliminate variations caused by differences in time or sample location, the QA/QC measurement or sample should be from the same place and time as the field instrument's measurement. For example, if an instrument is scheduled to take a measurement at 10:00, the QA/QC measurement or sample needs to be taken in the water as close the field instrument's temperature sensor as possible at 10:00, not at 10:15 or 10:30, and not several feet or meters away from the field instrument.

Eliminating all sources of variation in measurement processes and proving data accuracy can quickly become impractical and cost prohibitive. Furthermore, as the amount of experience with instrumentation grows, whether through general use or rigorous data collection and analysis, it becomes clear that each instrument is slightly different and that calibration cannot be the sole measure of performance. Ultimately, reasonable acceptance criteria need to be established that can be used to evaluate measurement results. Understanding thoroughly the variables that affect measurement results, minimizing the variations in the measurement process, and executing thoughtful QA/QC strategies will allow instrumentation users to establish acceptance criteria confidently and get the most useful water resource data from their equipment.

For most surface water sampling projects, spending a minimum of 10% effort for QA/QC is a good rule-of-thumb. This means that one in ten samples should be a duplicate sample, laboratory blank, bottle blank, calibration check, or something similar. In a typical real-time water quality monitoring program, generally two QA/QC measurements are taken per month (one just before deployment and a second 30 days later at the end of the deployment) at each site. If hourly readings are taken (24 per day) over 30 days between visits (720 total readings), this comes to only 0.28% effort in QA/QC. While this level of QA/QC effort is common and may be justified based on the circumstances, 0.28% is probably not enough effort to ensure equipment is performing properly and that all measurement results are acceptable.

Whether profiling ponds, lakes, or reservoirs or grab sampling in small streams or rivers, the same 10% effort for QA/QC should be applied. In common profiling applications, measurements are taken once per meter from just below the water surface to just above the bottom. So over the course of a 10 meter depth profile, a Van Dorn or Kemmerer sampler should be used at one of the 10 depths measured with the instrument and then analyzed separately for the parameters of interest. For grab sampling in small streams or rivers it may not be possible to sample ten sites in one day, but at least one sample should be taken per field day to be analyzed separately for the parameters of interest for QA/QC purposes.

Field Methods for QA/QC

When real time or remote instruments are first placed into the field, accompanying measurements should be taken with a handheld water quality instrument or by some other means. These field measurements – which are sometimes paired samples taken for laboratory analyses – serve as QC points. These independent field measurements are extremely important as they are the only check of the accuracy and performance of the real time or remote water quality measurement. Each time an instrument is removed and/or replaced another complete set of field measurements should be collected.

Field measurements should be obtained as frequently as budgets and practicality allow to verify performance of the instruments between changeovers or to verify unusual occurrences. Once the previously deployed instrument is returned to the laboratory, field measurement QC points are used to determine if post-calibrations are required or to verify or reject suspicious data. Also, by the end of the monitoring season, each site's data sets have regular field QC measurements to support data validity.

Field QC measurements identify when sensor drift begins affect data quality. Usually dependent on the productivity of the water, fouling or sensor drift could start to affect the performance of the sensors in as little as a few days to as much as a few weeks. Analysis of historic data from QA/QC programs allows water resource professionals to set strict acceptance criteria for the data collected. These will not be limits set by the manufacturer, which are generally conceived on a laboratory workbench, but limits that are based on actual field performance, which is affected by countless site-specific variables.

Years of experience with various monitoring programs has established some basic acceptance criteria that are generally easily obtainable in the field (Table 1). Data collected from the real-time or remote instrument can be within these user-set acceptance limits, initially or by post-calibration, and could even be accepted by the courts if required. With rigorous execution of QA/QC programs, little of the data collected is rejected for failing to meet the acceptance criteria. If workloads or other problems restrict water resource professionals from visiting sites at an ideal frequency, these limits could be doubled and the collected data could still be useable.

Parameter	Temperature	pH	Conductivity	Dissolved Oxygen (DO)	Turbidity
Field Accuracy Guideline	±0.3 ºC	±0.5 units	±10% of reading	±0.3 mg/L from a paired Winkler	±10% of range

Table 1: Electronic Water Quality Data Acceptance Criteria

Laboratory Methods for QA/QC

As more multi-parameter water quality instruments are being used for water monitoring programs, the need for an efficient method of testing each instrument's performance becomes evident. Tank testing can be used to analyze the precision and performance of each instrument as it relates to a group of instruments. This mass-testing approach helps demonstrate that unit A is measuring the same as unit B, as is unit C, and so on.

Tank testing can be accomplished in a 600 liter water tank with a submersible pump inside to circulate the water. Up to 10 multi-parameter water quality instruments can be tested simultaneously in a tank this size to determine their performance as a group. Each unit is prepared, as it would be to go into the field, and is allowed to stabilize in the test tank for a few hours before the test begins. Measurements are recorded for all parameters by each unit every five minutes for the 12 to 24 hours test duration. Data from each instrument are retrieved and graphed by parameter to show variation. Graphs for each parameter from each group of instruments should show a difference in variation less than the parameter’s acceptance criteria. Users can set acceptance criteria with sophisticated statistical comparisons or choose simple pass/fail rules.

Individual units that appear to be outside the group or are obviously malfunctioning would need to be repaired and then retested in the same manner. Depending on the nature of the problem, some repairs are basic and can be done by the user while others are more complex and require changing a sensor or a circuit board. More complicated repairs should be left to a trained professional.

Summary/Conclusion

As the old adage goes, one gets out what one puts in. Today’s water quality instrumentation is capable of producing high-quality data for many applications. In the end, the level of commitment that water resource professionals devote to a QA/QC program dictates the quality of data that is generated. To collect the most and best data possible, field staff must maintain equipment whenever required and take regular field samples to be used for quality checks. If, because of other commitments, instrumentation is only maintained on an occasional basis and only minimal field QC measurements are made, then lower quality and less accurate data must be accepted.