Top Five Parameters - Generate Critical Water Quality Insights

Technological advances in solid state electronics have made a significant impact in the modern world we live in, including how we monitor our environmental water resources. Instead of relying on taking grab samples from the field to the lab for monitoring baseline environmental water quality parameters, solid-state submersible sensors reliably capture, process, and record data on site for instantaneous insights on environmental water quality.

Long-term datasets, consisting of discrete/spot measurements, samples, or time series measurements, help establish baseline ranges for key water quality parameters and capture general trends over time. In turn, these datasets provide insights to help develop water resource management strategies and monitoring programs, as well as a means of tracking their effectiveness over time. In this paper, we will explore how the top 5 water quality parameter measurements help to generate these insights, specifically, the parameters of water temperature, conductivity, dissolved oxygen, pH, and turbidity.

Water Temperature Monitoring

Water temperature sensors are perhaps the most commonly deployed types of submersible probes used in environmental water quality monitoring. These sensors come standard on CTD's (instruments measuring Conductivity, Temperature, and Depth), numerous pressure probes, and multiparameter sondes and they measure the thermal energy of their surroundings. Temperature dictates metabolic function, reproductive timing and duration, and therefore, the life cycle of aquatic organisms. The ubiquity of temperature sensors is both a reflection of the importance of the parameter, as well as of the dependence that other baseline water quality sensors have on this parameter to be able to generate accurate data (i.e. conductivity, dissolved oxygen, pH, etc.).

Having an established baseline range for water temperature and capturing data trends helps water resource managers and aquatic scientists to understand many different processes within lakes, reservoirs, rivers, streams, groundwater, and all other types of aquatic systems.

Rivers, Streams, and Groundwater

- Upstream inputs from melted snow, precipitation, industrial discharge, and other sources can be detected by temperature changes at continuous monitoring stations further down the watershed.

Lakes and Reservoirs

- Seasonal temperature changes can cause lakes to stratify into distinct layers and then de-stratify, causing

Parameter	Trend	Possible Source	May be Caused by
Temperature	Increase	Vegetation removal	Stream bank vegetation provides shade and reduces runoff (turbidity)
		Impoundment	Increased exposure to solar radiation
	Decrease	Cold Water inflow	Groundwater, tributary, springs and reservoir bottom all can be colder than receiving waters
		Depth	Seasonal stratification - mainly in lakes

Table 1. Common reasons for changes in Water Temperature.

the mixing of previously separated layers.

- If there is a stratified bottom layer rich in organic matter and/or anaerobic bacteria, the upwelling of this layer into the upper layer(s) has the potential to stimulate harmful algae blooms (HABs) as well as to harm fish and other aquatic organisms through an increase in biological oxygen demand.

Effects on Aquatic Organisms

- Water temperature has a direct influence on aquatic organisms, such as fish, plankton, and macroinvertebrates as each species has a tolerable temperature range.
- Temperatures above or below tolerable temperature ranges of aquatic organisms is a source of stress which could potentially affect their survival.

Many water quality monitoring programs operate throughout a “field season” spanning the summer when temperatures are the warmest and water bodies are the most biologically active. During this time, temperature may be monitored at a regular interval, for example every two weeks to assess current conditions and determine seasonal trends. To improve temporal resolution and capture water temperature changes as they occur, water quality instruments measuring temperature may be installed at the site and collect continuous time series data.

Conductivity Monitoring

Like water temperature sensors, conductivity sensors are also prevalent with environmental water quality monitoring as they come standard on CTD’s and

Pic. 1 Discrete monitoring of temperature, DO, pH, and Conductivity using HYDROLAB HL4

Parameter	Trend	Possible Source	May be Caused by
Conductivity	Increase	Urban runoff	Chemical de-icers, salts
		Geology	Clay soils dissolve into ionic components
	Decrease	Agricultural runoff	Ions such as nitrate, phosphate, and salts
		Industrial effluent	Oils, alcohols, sugar & hazardous organic compounds

Table 2. Common reasons for changes in Conductivity.

multiparameter sondes. Conductivity sensors measure ions in water and give data for the parameters of conductivity, specific conductance, salinity, and total dissolved solids. Conductivity is also affected by water temperature. The warmer the water, the higher the conductivity.

Measuring conductivity can help inform water resource professionals about potential changes in the water body. Establishing a baseline conductivity range for a water body, enables future measurement comparison potential to detect changes as a result of pollution discharge, surface and groundwater interaction, and similar water mixing events.

Type of Water (EPA, 2012)[1]	**Typical Ranges**
Distilled water	0.5 to 3 µmhos/cm
United States River	50 to 1500 µmhos/cm
Streams supporting good mixed fisheries	150 to 500 µmhos/cm
Industrial waters	As high as 10,000 µmhos/cm

Table 3. Typical conductivity ranges for different types of water.

As there can be significant variation in conductivity levels in different parts of any given watershed at different times, taking infrequent spot samples with these sensors can be limiting in their ability to capture noteworthy water quality change events in the environment. This is especially the case in coastal areas where freshwater and marine water mix together and can also be significant with the confluence of two or more distinct water bodies. Observing conductivity changes with continuous, long-term data can help water resource managers to take management actions that help to preserve environmental water resources.

Stations located throughout the watershed can help to indicate changes in the environment such as from:

- Precipitation
- Drought
- Saltwater intrusion
- Groundwater disruption
- Drawdown from dams
- …just about any type of event that influences water flow within a watershed

Dissolved Oxygen Monitoring

Dissolved oxygen sensors measure the amount of free oxygen dissolved in water from mixing with the atmosphere as well as generated by photosynthetic organisms in the water such as aquatic plants, algae, and phytoplankton. Just as life on land depends on oxygen for cellular respiration, aquatic organisms such as fish, invertebrates, aquatic plants, and aerobic bacteria depend on adequate levels of dissolved oxygen in the water to carry out the same cellular processes.

Healthy aquatic habitats in the environment are typically marked by adequate mixing of the water body with the atmosphere as well as by minimal levels of organic loading. Monitoring dissolved oxygen levels within these environments will typically show a range at or around complete saturation. In a stable body of water with no stratification, dissolved oxygen will remain at 100% air saturation. While it is possible for dissolved oxygen to exceed 100% air saturation in water by biological means, this process can be sped up by aeration.

On the flip side, unhealthy aquatic habitats are typically characterized by inadequate mixing as well as high organic loading that leads to a system with high biological oxygen demand. In these water bodies, long-term monitoring can help water resource managers to establish a baseline for dissolved oxygen levels that they can aim to improve with different management techniques such as with supplemental aeration in smaller lakes and reservoirs, or with watershed management strategies to help curb eutrophication.

The actual amount of dissolved oxygen (in mg/L) in water will vary depending on temperature, pressure and salinity.

- Solubility of oxygen decreases as temperature increases.
- Surface water requires less dissolved oxygen to reach 100% air saturation as does deeper, colder water (refer to Table 4).
- Dissolved oxygen will increase as pressure increases. This is true of both atmospheric and hydrostatic pressures.
- Water at lower altitudes can hold more dissolved oxygen than water at higher altitudes.
- Dissolved oxygen decreases exponentially as salt levels increase.
- At the same pressure and temperature, saltwater holds about 20% less dissolved oxygen than freshwater

Water Temperature	Dissolved Oxygen
4° C (39° F)	10.92 mg/L
21° C (70° F)	8.68 mg/L

Table 4. Temperature influence on amount of dissolved oxygen to reach 100% saturation at sea level (760 mm Hg).

Parameter	Trend	Possible Source	May be Caused by
Dissolved Oxygen	Increase	Aeration	Rapids and turbines add oxygen
		Photosynthesis	Plants give off oxygen
	Decrease	Decomposition	Plants & microorganism consume oxygen
		Turbidity	Blocks sunlight from plants, decreasing photosynthesis
			Causes water temperature to rise by increasing absorption of solar radiation
		Nutrients	Fuel overgrowth of algae, which die and decompose

Table 5. Common reasons for changes in Dissolved Oxygen.

pH Monitoring

Similar to the parameter of dissolved oxygen, pH is an environmental water quality parameter that is commonly associated with habitat suitability for aquatic organisms. pH sensors measure how acidic or how basic a body of water is, with pH 7 being neutral. Different types of aquatic organisms have different ranges that are suitable for them to inhabit and environmental changes that affect pH can have an adverse effect on their health and survival. For example, during plant growth, carbonic acid is removed from water and the pH increases. As aquatic plants respire, and bacteria consume decomposing matter, they release carbon dioxide that reacts with the water to form carbonic acid. Therefore, at night while plants are respiring, the pH decreases with the increase in carbonic acid. These diurnal changes in pH are measurable but are not significant enough to affect the health of aquatic life.

However, acid precipitation can be very detrimental to crops as optimal pH conditioning is necessary to attain high yields. Rain is typically around 5.6 pH but, in some areas, it can increase to harmful levels between 4.0 and 5.0 pH due to atmospheric pollutants. Also, acid snow can accumulate over the winter, and then potentially release a toxic dose of acidic runoff in the spring. Heavily industrialized areas of the US have been historically targeted by various environmental agencies to minimize the pollutants that cause acid rain. The burning of fossil fuels, such as coal, releases gases into the upper atmosphere that, when combined with the naturally acidic rainwater (below 7.0 pH), change composition and cause the rain water to become more acidic.

In general, most aquatic organisms survive in waters between a pH of 5 to 9. Beyond this range, the diversity and abundance of species decreases, as pH fluctuations affects solubility of metals and nutrients. For at risk

Parameter	Trend	Possible Source	May be Caused by
pH	Increase	Photosynthesis	Plants use carbon dioxide, which reacts with water to form carbonic acid
		Mining operations	Acid mine drainage
	Decrease	Respiration	Plants give off carbon dioxide, which reacts with water to form carbonic acid
		Vegetation	Pine needles are slightly acidic (bogs, marshes, and pine forests)
			Decaying vegetation produces organic acids
		Burning fossil fuels	Emissions react with the atmosphere to form acid precipitation

Table 6. Common reasons for changes in pH.

aquatic environments such as ones downstream of mining activities long-term monitoring of pH can give baseline ranges and capture trending data that can help water resource managers to monitor environmental pollution risks.

Turbidity Monitoring

Turbidity sensors are optical instruments that use a light source and a detector to measure the light scattering of particles in water. The amount of dispersed suspended solids in natural water bodies is an important indicator of water quality. These solids that often include silt, clay, algae, organic matter, and other minute particles, obstruct the transmittance of light through the water and impart a qualitative characteristic known as turbidity. Turbidity is often closely correlated to climatological or surface water conditions and changes in in turbidity are therefore indicators of changes in environmental conditions.

Turbidity can be interpreted as a measure of the relative clarity of water. It is not a direct measure of suspended particles in water but, instead, a measure of the scattering and attenuation effects these particles have on light. The higher the intensity of the scattered or attenuated light, the higher the value of turbidity. Human activities such as logging, mining, road building, and commercial construction can often lead to chronic levels of suspended solids in lakes, rivers, and streams. High levels of suspended sediment often create negative effects on aquatic life. For example, suspended sediment can interfere with photosynthesis by blocking light from reaching submerged aquatic plants. This not only directly damages vegetation but also results in reduced levels of dissolved oxygen because of the reduced rates of photosynthesis.

Parameter	Trend	Possible Source	May be Caused by
Turbidity	Increase	Erosion	Agriculture, construction activities
		Nutrients	Increased algal growth
		Urban runoff	Salts, fertilizers, sediment
	Decrease	Erosion prevention	Stream-bank vegetation - BMP for agriculture, construction

Table 7. Common reasons for changes in Turbidity.

Moreover, waters with high levels of suspended solids absorb more sunlight and can therefore cause an increase in water temperature that can cause dissolved oxygen levels to drop even further. Low dissolved oxygen then stresses aerobic aquatic organisms and could ultimately lead to fish kills.

"Turbidity data can be used as a surrogate measurement because it is strongly correlated with sediment, nutrients and bacteria, and can be measured in-stream on a continuous basis."

Turbidity can be used as a surrogate measurement for many environmental influencers, such as for:

- Monitoring the impact of humans on natural water bodies.
- Monitoring pathogens in water, such as E. coli in stormwater runoff from cattle pastures.
- Monitoring sediments to track erosion and landscape change.
- Monitoring natural streams below mining and dredging operations.

When there are minimal change events occurring, turbidity levels can remain relatively consistent. Without knowing when environmental change events are going to occur, continuous water quality monitoring with turbidity sensors can help to take the guesswork out of when to spot sample by automatically capturing baseline conditions and environmental change events as they occur. With information available, water resource managers can be more proactive with managing our water resources.

Pic 2. Continuous long-term monitoring

Conclusion

Although the parameters of water temperature, conductivity, dissolved oxygen, pH, and turbidity are each unique components of water quality, they all share the distinction of being able to monitor environmental change. Through the generation of long term datasets, these changes can be captured and analyzed to help tell the story as to what is going on within a specific water body location at any given time. In turn, these stories help water management professionals and aquatic scientists to develop and benchmark environmental water quality monitoring programs.

[1]"5.9 Conductivity." EPA, Environmental Protection Agency, 6 Mar. 2012, archive.epa.gov/water/archive/web/html/vms59.html#area.

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