Using a Copper-Alloy Based System for Effective Biofouling Deterrence

New Anti-Fouling Methods from YSI Inc. Reduce Impact of Biological Fouling on Water Monitoring Instrumentation

Although biological fouling has always been an issue for water quality data collection, longer deployment times are now more common due to advances in electronics and equipment design. Considering this, manufacturers are actively pursuing anti-fouling methods to reduce the impact of biofouling on the quality of collected data. Researchers with **YSI Incorporated** tested anti-fouling materials for two years at six different sites. This paper examines data from two of these sites. Deployments indicate that anti-fouling hardware on water quality sondes effectively provides viable data for extended deployments of more than 40 days. In contrast, biofouling more rapidly affected the control instruments used in these experiments.

Battling Biofouling

Collecting viable water quality data always has challenges. Water and weather conditions, as well as site location and access are some of the difficulties faced when trying to collect high quality data. On the technology side, improved sensor stability, longer battery life and lower power consumption allow for longer sensor deployment times at lower operating costs. These factors create new questions about sensor maintenance intervals due to biofouling; the longer an instrument stays in the field, the greater the risk for biofouling. For our purposes, biofouling is defined as the accumulation of microorganisms, plants, algae and small animals on water monitoring equipment. Biofouling impacts data quality as the biological growth on sensing components interferes with readings and often causes false positives, increased noise and sensor failure. For example, optical turbidity sensors emit infrared light and then measure the scatter of light caused by particles in the water. Biological growth on the optics also causes light scatter, creating artificially high turbidity values. With this knowledge, water managers must consider biofouling rates at specific sites and seasons in order to plan site maintenance visits. Typical site visits require multiple employees and vehicle usage as well as the time and resources to travel to the site(s), equipment preparation, equipment cleaning, readings verification and instrument redeployment. Therefore, more frequent site visits require more resources and ultimately more money spent to collect quality data for a given site.

The Alliance for Coastal Technologies estimates that maintenance costs due to biofouling consume 50% of operational budgets. Over the years, methods for combating biofouling on submerged sensors have evolved from the use of toxic chemicals and pumps to more mechanical systems that use wipers or shutters to combination systems that use mechanical systems and technologies such as ultrasonic or chlorine generation systems. The latter systems are often more effective and typically do not have a negative impact on the environment. Copper-containing paints have been used as a biofouling countermeasure but there are significant limitations when applying to sensors since the paint interferes with sensing technologies, pollutes the environment, and must be re-applied on a regular basis. However, copper-based alloys are being use as a good alternative; many alloys have low dissolution rates and little impact on the environment, and they can last for long periods of time. Materials with anti-fouling properties are increasingly being coupled with mechanical systems that physically wipe or guard the sensing element between sampling intervals to provide optimal protection.

Generally, marine biofouling presents a greater challenge than freshwater biofouling due to presence of hard fouling organisms such as barnacles and mussels. Also, when considering marine applications, the speed of settlement and aggressive growth of organisms on submerged surfaces are key factors. Soft fouling organisms typically characterize freshwater systems and are often more easily controlled by mechanical wipers. It should be noted that hard fouling can completely cover the optics on probes, thus completely corrupting data and potentially damaging the sensing element.

Figure 1. Water quality sonde with soft fouling

Figure 2. Water quality sonde with hard fouling

Anti-Fouling Experiments

Researchers chose six sites throughout the United States for long-term field tests on a variety of prototype anti-fouling systems, which were used in conjunction with the sensor wipers and brushes employed on YSI's 6-Series Multiparameter Sondes. Each site, two freshwater and four marine, represented a challenging field condition. Over 18 months, the research team tested and refined the anti-fouling components, selecting specific materials that provided optimal durability and anti-fouling properties.

South Florida Test Site

The University of South Florida collaborated with YSI at a deployment site in St. Petersburg Harbor. Deployments were to a depth of 0.5 meters with sondes configured to collect data every 15 minutes. A sonde-mounting apparatus and test platform used in the study allowed researchers to deploy multiple sondes in close proximity at the same depth to expose the sondes to the same conditions. The platform allowed easy access to the sondes for biofouling checks and instrument servicing. Visual inspection, photographic documentation and data downloads were completed on a weekly basis.

Figure 3. Test platform in St. Petersburg Harbor used for anti-fouling testing

For the experiment, the following three anti-fouling treatments were deployed: Control; Copper-alloy components; and Copper-alloy components + Copper mesh. The control sonde did not utilize any anti-fouling hardware other than standard wipers, while the copper-alloy sondes utilized copper-alloy sensor guards plus copper-alloy sensor housings or copper tape on the housings. The copper-alloy + mesh sondes utilized the same hardware as the copper-alloy sondes, but also included a copper wire mesh on the inside of the sensor guard. The mesh was used to minimize the entry of potentially colonizing marine plants and animals into the sensor area.

The temperature data from all three configurations did not exhibit biofouling effects and accurately represented site conditions. The sonde temperature-compensates all data; therefore it is important to always ensure that fouling does not corrupt temperature readings. Specific conductance data indicated that biofouling affected the conductivity sensor on the control sonde. All sondes exhibited similar specific conductivity trends for the first 22 days; after which, the control sonde began to deviate from the two anti-fouling sondes.

YSI's conductivity sensor houses four nickel electrodes inside the sensor body with channels that allow water to flow freely through two boreholes along the sensor's axis. The internal location of the electrodes presented an anti-fouling challenge. The solution was a combination of treatments. Copper tape treated the outside of the sensor housing. While initial testing of copper paint provided protection to the inlet and outlet portions of the sensor, it cannot be used on the electrodes as it insulated the sensor from the measurement environment and biased the data. In the end, a small copper-mesh screen was used around the probe to prevent the settlement of biofouling organisms. In addition, the electrodes were treated with C-Spray, a nanopolymer coating used to inhibit the attachment of fouling organisms. These treatments did not impact the conductivity signal and extended deployment times from weeks to months.

Figure 4. Anti-fouling copper "sock" used for conductivity sensors

Data from a second marine site in Marion, Massachusetts, indicated the effectiveness of a conductivity/temperature probe with this anti-fouling protection. When first deployed, the probe did not have the copper mesh screen. During a 46-day deployment in mid-summer, biofouling impacted the unprotected conductivity sensor after 18 days. After cleaning the sensor, researchers installed the copper mesh "sock" and treated the conductivity electrodes with C-Spray. In late summer the sondes were redeployed. The data indicated that the treated conductivity sensor resulted in 93 days of maintenance-free, accurate data.

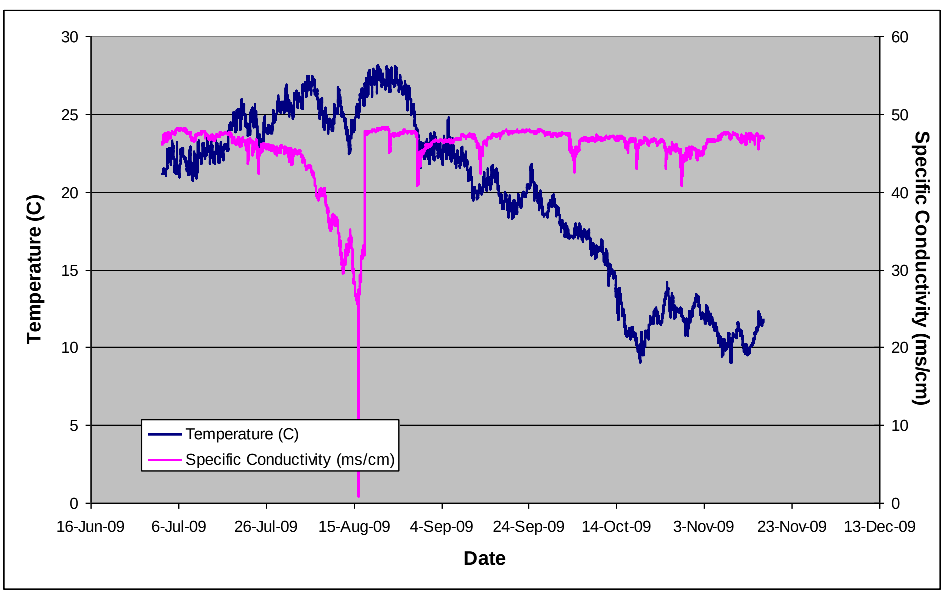

Figure 5. Anti-fouling data from sonde using copper mesh screen and C-Spray

Optical water quality sensors are susceptible to biofouling due to the exposed optical surface and the sensitivity to particles in the light path or covering the membrane. In addition, multiple potential growth surfaces (sonde guard and wiper assemblies) surround the optical sensors and provide opportunity for fouling to impact these surfaces and affect readings. Optical dissolved oxygen data from the test site in Florida indicated that both anti-fouling sondes performed well over the 40-day deployment, while the control sonde diverged from the norm 11 days after deployment.

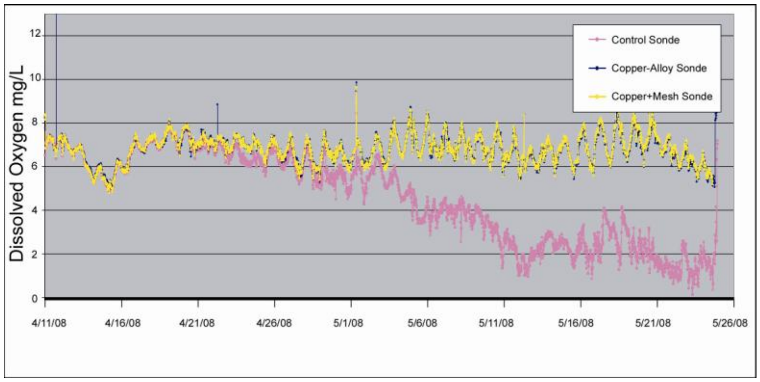

Figure 6. Optical Dissolved Oxygen data from Florida test site. The control sonde showed evidence of fouling after 11 days of deployment, while the anti-fouling sondes were not affected by fouling for 40 days.

Like dissolved oxygen, turbidity data was similarly compromised. The data indicated that the control sonde began to deviate from the anti-fouling sondes after only nine days. However, the anti-fouling sondes collected good data throughout the 40-day deployment. The anti-fouling sondes showed evidence of biofouling on the mounting apparatus, but sensor surfaces, wiper bodies and brushes were free of biological growth. In contrast, the control sonde displayed fouling on sensor surfaces as well as wiper and brush bodies that ultimately affected the quality of data collected.

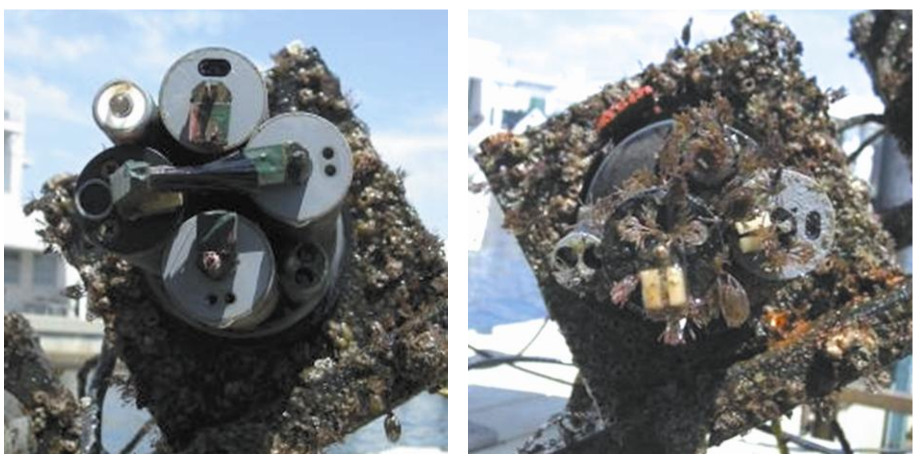

*Figure **7**. Anti-fouling Sonde vs. Control Sonde, with evident biofouling after 18 days*

Gulf of Mexico Test Site

The Louisiana Universities Marine Consortium (LUMCON) provides coastal laboratory facilities to Louisiana universities and conducts research and educational programs in the marine sciences. LUMCON compared data from sondes without anti-fouling protection to data from sondes that applied an anti-fouling sensor guard as well as copper tape on sensor bodies and wiper/brush bodies. Data are from separate deployments at the same site in the Gulf of Mexico, 30 miles offshore and deployed to a depth of 1 meter. The control sonde (no anti-fouling measures) collected data in the lower-fouling winter environment and the anti-fouling sondes collected data in the higher-fouling summer environment.

Turbidity data from the control sondes show low NTU levels until day 45 of the deployment, when the NTU levels steadily rise. High turbidity readings and the high frequency of spikes in the data suggest that the optical sensor is covered by biofouling. Similar trends appeared in the chlorophyll data. In the first 32 days, spikes in the data may have resulted from algae or other chlorophyll-containing material in the water column. However, after 32 days the increase in spike frequency in the data indicates that biofouling impacted the functionality of the sensor.

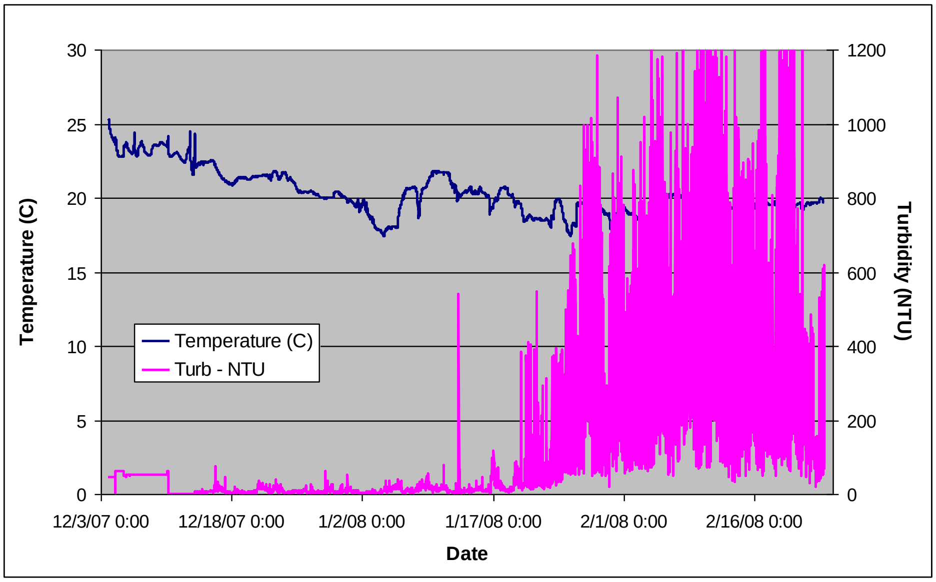

Figure 83. Turbidity data from control sonde at Gulf of Mexico test site. Note biofouling effect after 45 days

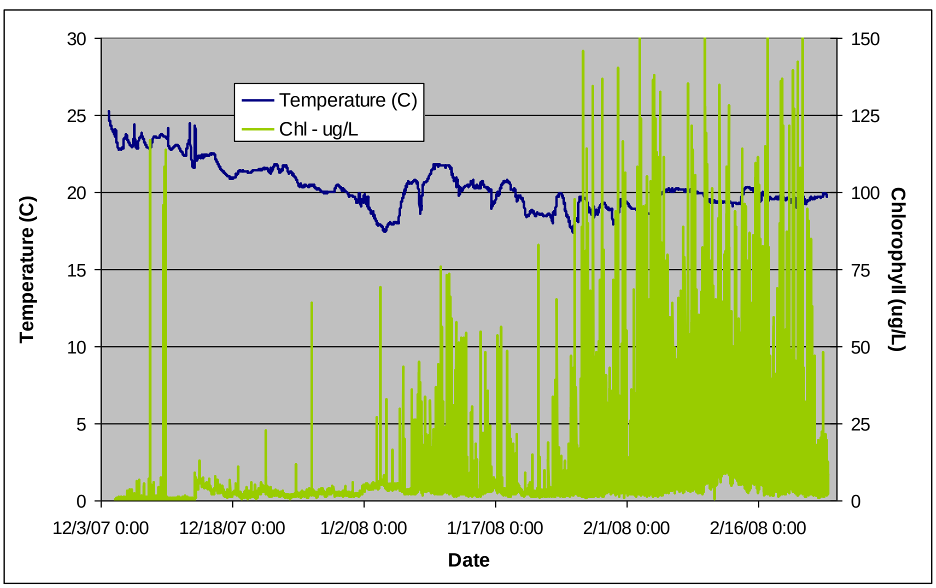

Figure 9. Chlorophyll data from control sonde at Gulf of Mexico test site. Note biofouling effect after 32 days

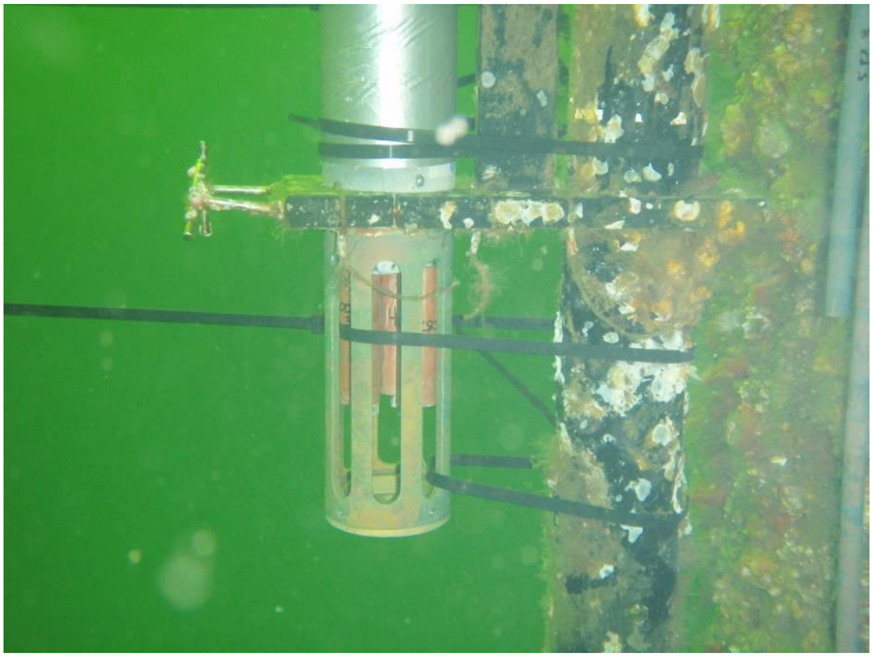

Figure 10. Sonde deployed with anti-fouling kit in Gulf of Mexico. Copper-alloy parts are extremely resistant to fouling, often going 10 months before cleaning is required.

Unlike the turbidity data collected with the control sondes, data collected by the anti-fouling sondes are clean and accurate. Note that the spikes progress in a natural upward trend and are short in duration. This suggests that the spikes were event-driven rather than an effect of biofouling. Researchers observed similar trends in the chlorophyll data; peaks progress in a gradual upward trend. Overall, the anti-fouling measures applied in this high-fouling environment were effective for the 35-day deployment.

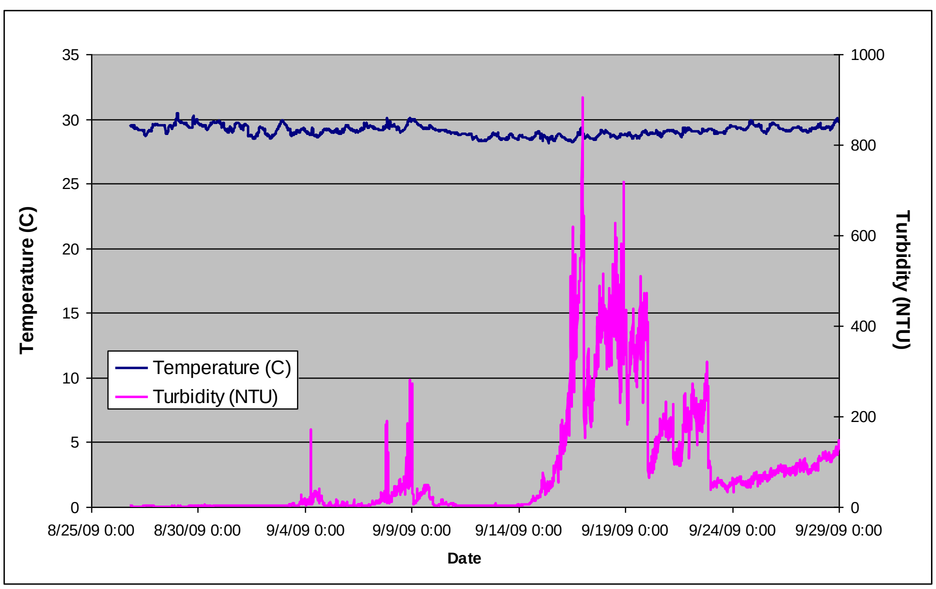

Figure 4. Anti-fouling turbidity data from Gulf of Mexico test site

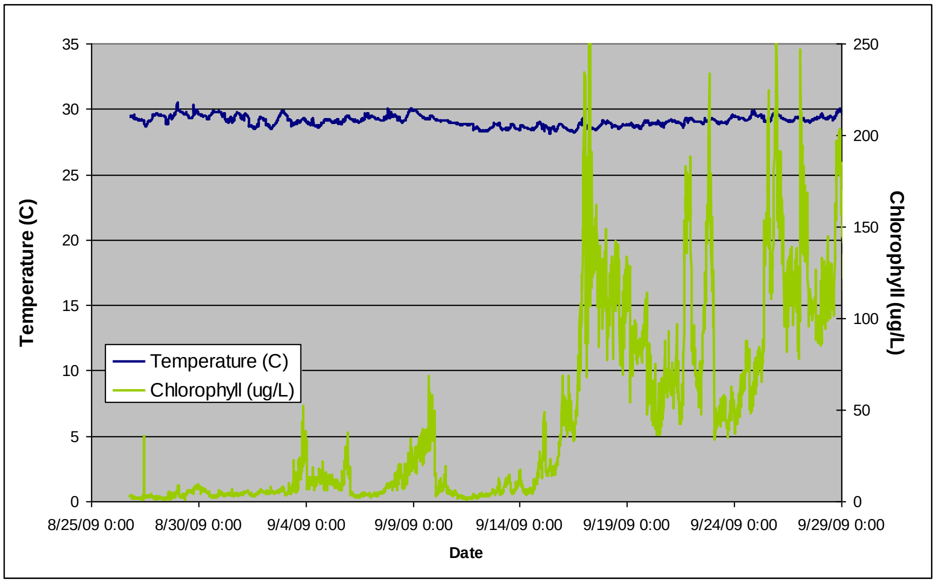

Figure 5. Anti-fouling chlorophyll data from Gulf of Mexico test site. Rise in chlorophyll concentrations is from natural event, not biofoluing

Anti-Fouling Solutions

YSI has designed and successfully employed a combination of anti-fouling measures that significantly lower the cost of maintenance by protecting multiparameter water quality systems in long-term deployments. All YSI optical sensors already utilize mechanical wipers and brushes. Wipers keep optical sensors clean and free of debris; brushes remove debris from the wipers and non-optical sensors. Both wiping mechanisms mount to a central wiping shaft; when the shaft rotates, the wiper/brush moves in a circular motion, removing the debris. Wiping precedes all sampling intervals. Wipers and brushes have provided adequate biofouling protection in moderately productive environments; however, systems require additional protection in highly productive environments and to prolong deployment intervals in all environments.

Through extensive field trials, YSI found that treating all surfaces near the sensing elements was critical. Otherwise, biofouling organisms could attach to any unprotected surface, such as the foam wiper pad or sensor guard, and grow many inches from that point and potentially interfere with the sensing elements. Therefore, YSI developed a complete copper-alloy anti-fouling system that complements existing wipers and brushes. This Anti-fouling System includes the following components:

- Copper-alloy optical wipers, which clean the entire surface of the sensor, not only the optical portion. This prevents biofouling organisms from colonizing the edge of the probe and migrating towards the sensing element.
- Sonde guards made from a durable copper-alloy
- Optical sensors with copper-alloy housings that are rated for submersion to 200 meters
- Copper-alloy ROX™ optical DO membrane caps
- Copper-alloy locking nuts and port plugs
- Copper mesh screen around the conductivity/temperature probe
- C-Spray solution, which creates a slippery surface on the internal conductivity electrodes

*Figure **13**. YSI water quality probes with copper-alloy housings and wipers. The conductivity/temperature probe has been treated with C-Spray coating and copper screen*

Conclusion

As in-situ sensor technology advances, biofouling is the principal limiting factor of long-term deployments and prevents further reduction in costs by environmental monitoring programs. Biofouling isolates water quality sensors from the measuring environment or interferes with light transmission and thereby compromises data. As a result, water managers must carefully plan site maintenance visits in order to obtain high quality data; data can be compromised due to poor planning or the inability to reach sites. YSI tested anti-fouling materials for two years at six freshwater and marine sites. Data from deployments indicated that anti-fouling hardware effectively provided viable data for deployments longer than 40 days. Without anti-fouling hardware, sensors were affected by fouling in as few as nine days. By using anti-fouling components, the monitoring program in St. Petersburg Harbor decreased its maintenance visits by 66% and saved $10,000. Overall, anti-fouling components for water quality instruments very effectively extend deployment times and collect high quality data for water managers.

References

Alliance for Coastal Technologies. Biofouling Prevention Technologies for Coastal Sensors/Sensor Platforms. Workshop Proceedings, 2003. No. ACT-03-05.