Continuous, Real-Time TSS Monitoring Verifies Effluent Quality and Coal Ash Management Performance While Reducing Compliance Costs

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ABSTRACT

Reducing the cost and compliance burden associated with meeting final remediation effluent requirements continues to be a key driver to technical innovation. As many power plants continue to struggle with the critical last step in their coal ash remediation processes – the final testing phase – some plants have successfully adopted the use of recently advanced sensor technology to measure real-time total suspended solids (TSS) to verify their discharge water is meeting specified requirements. Accurate on-line TSS monitoring helps ensure and verify the remediation process is performing as intended at all times, regardless of variability in upstream influent. The sensing probe uses optical methods that detect the intensity of scattered light and digitally reports TSS concentrations in mg/L, which is effective and useful for calculating mass balances, a critical component of upstream treatment process control. Power plants traditionally rely on laboratories (including mobile labs) for TSS analysis, and testing often requires extensive manpower for attaining samples in remote locations, sometimes multiple times a day. On-line TSS monitoring significantly reduces this effort. The sensor's two measurement methods provide TSS readings that are accurate at extremely low concentrations (0.1 mg/L), with repeatability of <0.015% or >0.0006 FNU. Having the ability to monitor TSS real time, and obtain accurate results that are repeatable and verifiable with random lab tests, allows for users to automate functions such as controlling pumps transporting effluent, or start and stop pretreatment processes designed to keep effluent within permit guidelines.

INTRODUCTION

The regulatory perspective regarding the safe disposal of coal ash from coal-fired power plants is being driven by comprehensive permit requirements. As these requirements become more stringent, many plants are struggling with the critical last step in their remediation process – the final testing phase that determines if their final effluent complies with current requirements.

Total Suspended Solids (TSS) is the major parameter for verifying effluent quality in regulatory discharge permits for coal ash remediation[1]. The necessity to consistently meet TSS discharge limits and avoid fines and other potential liabilities today requires significant organizational structuring involving field data collection, verification, documenting and reporting.

TESTING LAG-TIME = RISK

Most coal combustion residuals (CCR) operations today either retain or release plant effluent based on laboratory TSS test results that require at least a day to complete, but typically take much longer (2-3 days, or more). The existing TSS testing method for compliance verification is a time-consuming laboratory test that cannot currently be completed in the field, unless by mobile certified field labs[2]. This inherent lag-time between sampling and verification brings unknowns to the remediation process, often necessitating more field sampling and testing (erring on the side of over-compliance) than a plant's permit requires. It also raises the potential for risky bottlenecks in overall remediation operations.

As part of their permit specifications, most plants have maximum allowable discharge flow rates -- only a certain number of gallons can be discharged in any 24-hour period[3]. The permitted discharge volume depends primarily upon the regulatory designation of the receiving stream and the characteristics of the plant's wastewater effluent. Once a plant has met its allowable discharge for the day, pumps must be turned off until the next day.

These discharge permits typically contain both a daily limit and a monthly limit for TSS, and most remediation operations have established their own internal limit, or "daily high," that is set far enough below the regulatory permit limit to provide a margin of protection against violations. Again, plants also typically sample and test multiple times more than required by their permit, to further limit risk.

A VICIOUS CYCLE

The inherent lag-time between gathering field samples and final laboratory TSS analysis has necessitated this expensive and burdensome "over compliance" strategy at many facilities. It can also bring significant bottlenecks to operations. For example: A lab result from a sample pulled two days earlier shows TSS levels above the facility's internally-established limit or, worse, its permit limit. At this point, operations will stop discharging for an extended period of time (dictated by subsequent lab test results) to compensate. Because TSS monthly regulatory reporting is based on a time-weighted average, the plant receives "zeros" for TSS discharge reporting for those days pumps were off, thereby averaging out daily TSS levels to meet the monthly permit requirement.

However, when the facility is in a position where it needs to discharge but can't, the retaining basin or pond is still filling up with more water that must be pumped. Due to its daily maximum allowable discharge limit, a plant cannot get those zero days back by increasing the pump schedule other days to make up the difference. It is a vicious cycle. Critically, excessive zero days can lead to high containment levels that can further exacerbate the potential for very serious issues such as a pond breach during hurricanes and other severe weather events.

Depending upon their permits, some locations test TSS levels several times per day. Other locations test several times a week. In either case, this testing requires manpower to pull samples. Plus, the facility must either continually rely on an outside laboratory or perform the test in-house, which requires having a certified lab. To shave off a portion of this lag-time, some facility owners contract mobile certified labs to remain on site full time to handle effluent testing. Regardless of how lab tests are run, it is generally an expensive and manpower-consuming process.

PROBE-BASED, REAL-TIME TSS MEASUREMENT

Reducing this high cost and compliance burden associated with challenging wastewater operations has served as a key driver to technical innovation in recent years. Some coal-fired power plants have successfully adopted the use of recently advanced sensor technology to measure real-time TSS to verify their discharge water is meeting specified requirements.

TSS is a physical laboratory measurement; it defines the actual weight of suspended material in a given volume of water. The measurement derived from the optical sensor is not an absolute unit. However, TSS has a linear relationship with the scattering and backscattering coefficients of light[4]. Light scattering technology differentiates samples based on refractive index, size, shape, and composition. Backscattering is a method of light scattering measurement that correlates with TSS. The field probe reads the light measurements as a suspended solids value based on the calibration against laboratory grab sample analysis.

Some coal-fired power plants have begun using this optical-based sensor to measure real-time TSS levels to verify that discharge water is continually meeting regulatory requirements. Scheduled laboratory TSS testing continues to be performed to meet permit requirements (and periodically to verify the calibration of the on-line instrument), but real-time, probe-based TSS monitoring eliminates the need for frequent extra sampling and laboratory testing. Through rapid and consistent in-the-field TSS monitoring, these facilities are reducing compliance risks and costs. They are also consistently preventing costly project delays resulting from lengthy lab analysis procedures.

OPTIMIZING PERFORMANCE

TSS in water can be detected by a number of optical sensing techniques, and it has been understood for many years that TSS and the backscattering coefficient correlate well[5]. However, attempts to use early instruments using this method met with limited success in harsh environments like coal ash remediation. It is important to note that these early poor performances were due to shortfalls in electronics, light source and other materials of construction, and control algorithm. Also contributing to sensing limitations of early units was a severe difficulty keeping the sensor's lens clean while operating in harsh, real world environments.

The pressures faced by both industries and municipalities to meet new, increasingly stringent limits prompted YSI, a Xylem brand, to emphasize its research and development efforts towards further improving and stabilizing the backscatter method for TSS prediction and protecting the probe against interferences brought by severe operating conditions. By eliminating and compensating for the most common sources of instability, through the use of light scatter and backscatter measurement methods, advancements in light-emitting diode (LED) technology, the development of a comprehensive algorithm to determine the relationship between measured TSS and predicted TSS, and an advanced sonic lens cleaning system, the IQ SensorNet ViSolid® Suspended Solids Probe is now being used in harsh wastewater streams to consistently and accurately measure TSS in real time with a repeatability of <0.015% or >0.0006 FNU (per DIN ISO 5725 or DIN 1319).

CURRENT USE, AND BEYOND

The optical-based probe is calibrated to a SiO_2 standard solution, which has a known TSS value as measured by laboratory standard methods. Two standard calibration curves have been determined by measurements of typical activated and return slurries (Matrix Type 1) and measurements of typical decaying slurries (Matrix Type 2). The correlation between the standard solution and known TSS value with these two matrix types are shown in Figures 1 and 2. The process variation coefficient is <2% for matrix type 1 applications and <4% for matrix type 2 applications. This standard calibration can be adjusted with a user calibration to fine-tune the measurement for site-specific conditions.

Below the smallest value, the calibration curves are extended to the zero point and, above the largest value, they are extended to the end of the measuring range.

Value pairs	1	2	3	4	5	6	7	8	9	10
Total suspended solids [1000 mg/l] TSS	17.57	15.55	11.62	8.80	6.21	4.42	3.39	2.40	0.77	0.25
SiO2 value [1000 mg/l] SiO2	7.16	7.05	6.52	5.85	4.86	3.91	3.22	2.60	1.37	0.61

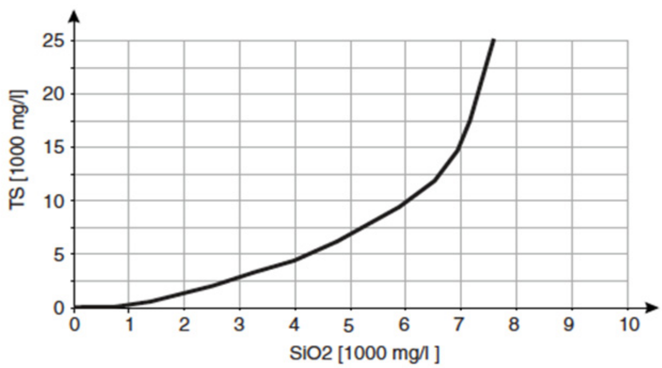

Figure 1. *Default calibration for matrix type 1 application*

Value pairs	1	2	3	4	5	6	7	8	9	10
Total suspended solids [1000 mg/l] TSS	100	59.40	32.00	20.70	14.90	9.97	5.26	2.37	1.48	0.41
SiO2 value [1000 mg/l] SiO2	7.62	7.16	6.26	5.60	5.00	4.28	3.19	1.73	1.13	0.32

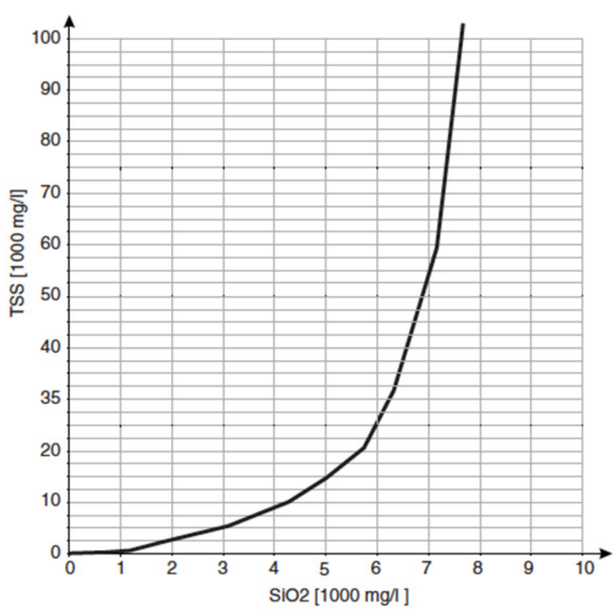

Figure 2. *Default calibration for matrix type 2 application.*

The TSS probe is typically located at less than a right angle to the measurement area, to capture more light which is reflected back in the direction of the light source (Figure 3.). This allows monitoring of higher concentrations of solids. Accuracy is calibrated and verified with gravimetric analysis of grab samples collected near the sensor. The sensor's non-mechanical, ultrasonic clean technology prevents biofouling and its ultrasound source is integrated in the sensor to generate high-frequency vibrations of the optical windows to ensure reliable measured values during continuous operation (Figures 4 and 5.). The sensor also has a quick check system that detects optic contamination or failure of the cleaning system, for early malfunction alert.

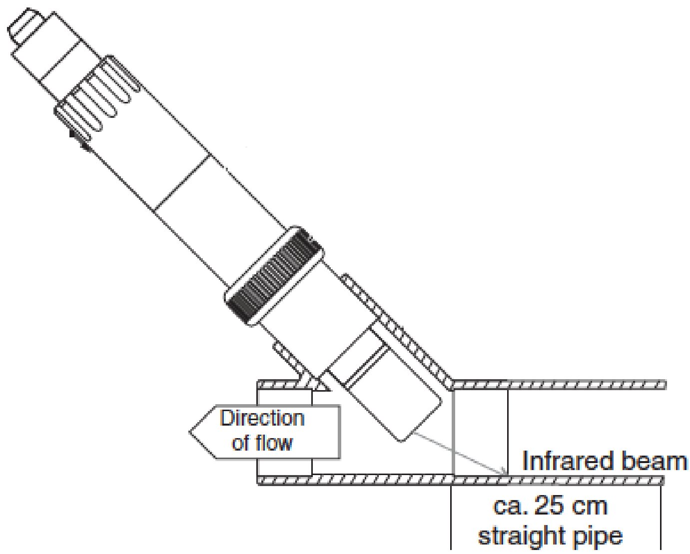

Figure 3. *Example of TSS probe location relative to infrared beam and direction of effluent flow.*

Figures 4 & 5. *Ultrasonic clean technology prevents biofouling. Standard prob (left) and IQ SensorNet ViSolid TSS sensor after 30 days in the same service.*

The sensing probe uses optical methods that detect the intensity of scattered light and digitally reports TSS concentrations in mg/L, which is effective and useful for calculating mass balances, a critical component of upstream treatment process control. The sensor's two measurement methods provide TSS readings that are accurate at extremely low concentrations (0.1 mg/L), with repeatability of <0.015% or >0.0006 FNU. An auto range function selects the optimum resolution for the respective measured value. The majority of plants currently using the optical sensor in their coal ash remediation operations have their systems set up to automatically shut down the discharge pump if TSS is out of specification. Other facilities have set up their systems to simply provide a wireless alert in the event of an excursion.

Figure 6. Provides a weekly comparison of TSS test results and real-time probe readings at an ongoing coal ash remediation project in the Mid South, U.S. The field probe readings were recorded at the same time the grab samples were taken for lab analysis. This site had a daily permit limit of 100 mg/L and a monthly average of 50 mg/L

Because the sensor measures TSS concentrations in real time with consistent accuracy close to that of laboratory analysis, some operators have modified upstream processes, such as flocculent dosing, for higher treatment and remediation efficiencies. The long-term reliability of the measurement is also important for automation. Having the ability to monitor TSS real time, and obtain accurate results that are repeatable and verifiable with random lab tests, allows CCR remediation facilities to automate functions such as controlling pumps transporting effluent, or starting and stopping pretreatment processes designed to keep effluent within permit guidelines.

Coal Ash TSS Field results vs Lab results

Date Grab Sample	Field Reading	Lab Results	Difference
11/29/18	5.8	5.1	0.7
12/6/18	5.8	5.4	0.4
12/13/18	6	5.7	0.3
12/20/18	5.7	5.2	0.5
12/27/18	6.3	6	0.3
1/3/19	6.8	6.3	0.5
1/10/19	6.3	5.9	0.4
1/17/19	7	6.7	0.3
1/24/19	7.6	7.2	0.4
1/31/19	8	7.4	0.6

All units in mg/L

Figure 6. *A weekly comparison of TSS test results and real-time probe readings at an ongoing coal ash remediation project in the Mid South, U.S. This site had a daily permit limit of 100 mg/L and a monthly average of 50 mg/L.*

AUTOMATING FUNCTIONS

Real-time TSS measurement, for example, can allow for automated polymer dosage control based on the probe's continuous TSS measurements. If effluent TSS levels get too high, systems have been designed using the probe to automatically stop the transfer pump and instead recirculate the flow within the retaining pond while automatically dosing a flocculent, thereby making the solids further accumulate and drop out of solution (Figure 7.). The same control system serving the TSS probe can also simultaneously measure pH (by adding a pH probe). If effluent pH is too high or too low, the controller can be programmed to turn on a small pump to add acid or base for pH adjustment to ensure upper and lower pH permit limits are being met. The system's cellular or satellite communication allows operators to log in remotely for monitoring or troubleshooting purposes and can remotely text and email alarms operations personnel.

Figure 7. *Real-time TSS monitoring coupled with automation allows for less staff to be on site.*

Many coal ash remediation sites have been decommissioned and are now costing owners, with much of this cost being in manpower requirements. Real-time TSS monitoring coupled with automation allows for less staff to be on site. In addition to the reduction in sample gathering and laboratory testing, manpower isn't needed to go out and turn a pump on or off, or open and close a valve. Real-time TSS measurement allows these functions to be automated, providing owners the necessary oversight without having to be physically present on site. To further support site operations, a system can also be established to notify operating personnel when a chemical storage tank or chemical tote is running low on supply.

AN "OPTICAL FINGERPRINT"

In 2015, the EPA finalized national regulations to provide a comprehensive set of requirements for the safe disposal of coal ash from coal-fired power plants. These requirements have many owners today asking how to best monitor and comply, especially with the critical last step– the final testing phase. Accurate on-line, optical sensor-based TSS monitoring provides a real-time measurement of effluent TSS that can be used as an operation and management parameter for complying with regulatory requirements.

Continuous TSS measurement can also provide plant owners the potential for significant operational efficiencies and cost reductions. Sampling and laboratory testing exceeding the number of random samples required to meet permit are no longer necessary, freeing up manpower and laboratory costs. The long-term reliability of the measurement also allows for the automation of certain functions such as to control transport pumps and valves, and to start and stop chemical pretreatment processes.

Importantly, real-time TSS monitoring can provide ongoing backup documentation, an "optical fingerprint" providing a real-time effluent discharge record that can substantiate compliance reporting and defend against potential legal action. It can also be used to demonstrate a plant's good faith in exceeding its permit requirements – demonstrating the plant is being a good steward of the environment.

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