Advances in Online Colorimetric Analyzer Technology

Until now, accurate and reliable total phosphorus analysis was practical only in the lab. Recent technological developments now enable high accuracy total phosphorus measurement in near real-time, on-line, that reliably matches lab results.

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As total phosphorus and other nutrient limits are driven lower, managers of Wastewater Treatment Plants (WWTP) are struggling to operate plants within permitted limits, while also trying to control operational costs. One significant cost is excessive flocculant dosing used for phosphorus removal. Many factors impact total phosphorus load and removal efficiency making it necessary, especially during the warmer months of the year, to run frequent grab-sample tests to ensure compliance. In addition to biological removal, many plants are dosing flocculant for phosphorus removal. But, flocculant is frequently overdosed to avoid exceeding discharge limits. This overdosing leads to a significant increase in operating costs. The time and expense of frequent grab-sample testing make optimizing flocculant dosing nearly unachievable and very frustrating because process phosphorus levels can be hard to predict. To help address this issue, Endress+Hauser developed the Liquiline System CA80TP Total Phosphorus analyzer, a member of the Liquiline System CA80 platform of analyzers.

Figure 1: Mountain View Wastewater Treatment Facility, Township of Wayne, NJ.

Until the release of the Liquiline System CA80 colorimeter platform from Endress+Hauser, featuring onboard experience-based predictive diagnostics, colorimeters required frequent operator intervention and inspection to avoid costly and time-consuming instrument failures. When maintenance intensive analyzers are complicated, the devices are all too often abandoned altogether. In the case of total phosphorus removal applications, this results in plants choosing to base Poly Aluminum Chloride (PAC) dosing on flow and grab-sample results. The consequences are the labor time to take and analyze grab-samples; the additional cost of lab testing; the increased cost of PAC to ensure compliance as process conditions change between grab-samples; and an increase in sludge production. All these factors add up to significant, unnecessary operating expenses/costs.

The solution to the problem of unsatisfactory performance, low reliability and expensive operation of the phosphorus measurement lies with key improvements in new-generation analyzer. Critical improvements in analyzer design include onboard predictive diagnostics, fault detection/alarming, well designed and simpler sample collection and components that are simpler to access and maintain. Most importantly, with clear and concise guidance as to what needs attention within the analyzer, new generation analyzers can be maintained by plant personnel with minimal outside assistance. The Endress+Hauser Liquiline System CA80TP Total Phosphorus analyzer uses robust components that are easily accessible for maintenance and integrates diagnostics that ensure the analyzer is functioning properly. Diagnostics detect sample dosing volume to ensure proper sample flow to the analyzer and other parameters such as digester temperature and reagent usage. By making components easily accessible and

designing diagnostic capabilities into the unit, intimate knowledge of the analyzer is not required to determine if the unit is operating properly and operational issues can be corrected with very little training and experience.

With the Endress+Hauser Liquiline System CA80TP Total Phosphorus analyzer accurate and reliable online total phosphorus analysis is a reality. When quality analysis is combined with EtherNet/IP or other network based digital fieldbuses, operators will be informed of critical predictive and corrective diagnostic warnings before plant performance is adversely affected. Because the analyzer is digital, in-depth troubleshooting can be done remotely via a network connection to the IP addressable onboard webserver.

Sample Preparation and Collection Requirements

Analyzers in a wastewater plant that are used to monitor compliance parameters must extract a representative sample from the process and use that sample in precise volumes for analysis. In the case of total phosphorus, this means the sample must contain dissolved orthophosphate, phosphorus rich biomass (organic phosphorus) and suspended solids which could have both soluble and insoluble phosphate attached. Solids pose a challenge for analyzer designers since solids can interfere with the detection method and cause maintenance problems within the analyzer sample pumping, metering and tubing. Unlike other colorimetric analyzers, ultra-filtration cannot be employed for total phosphorus measurement since all but the dissolved orthophosphate is removed by filtration.

To obtain a representative sample for total phosphorus measurement, Endress+Hauser developed a “Y” strainer (Figure 2) with 0.8 mm ID suction tube for sample extraction. With the Y strainer the small sample suction tube is suspended in the strainer flow stream in the direction of the flow. With this innovative design, larger solids pass by the sample inlet tube with only smaller particles drawn up into the tube for analysis. Prior to sample extraction the sample line is purged by the analyzer sample pump to ensure the line is free of any obstructions. Following the purge, the sample is drawn into the analyzer via a peristaltic sample pump and into an optical dosing chamber. The optical dosing chamber precisely measures the sample volume prior to being pushed into the reaction chamber/digester via a linear driven syringe pump. Once in the digestion chamber the sample is dosed with a precise volume of persulfate, via the linear driven syringe, and heated to 120°C, which converts all phosphorus to orthophosphate. Because the digestion chamber operates at a high temperature, Endress+Hauser implemented a patented mechanical safety interlocked cover that only allows access to the chamber when it is safely at a cool temperature. After digestion, the sample cools and is dosed with precise volumes of reagents for colorimetric analysis for orthophosphate that represents the total phosphorus concentration in the sample. By the time the reaction is complete and the color change has occurred, the solids have precipitated and dropped out of the path of the integral photometer allowing the analysis to proceed unaffected by the solids. All components are monitored by the processor through each step of the operation with time/date stamped warnings generated if a step fails to complete satisfactorily. Warnings are in straightforward with clear guidance given as to probable cause(s) and a few solutions proposed where appropriate.

Figure 2: Y Strainer Provides “inertial filtration” of larger solids while allowing a representative process sample to enter the analyzer for digestion and analysis for an accurate, online, total phosphorus analysis. Automatically back washed before every measurement cycle and manually cleaned only when necessary (when a dosing fault is detected).

Figure 3: Heated/ventilated analyzer shelter with 3/4" hose in from submersible pump with bypass back to process. Y strainer, under analyzer, with 3/4" hose inlet/outlet and analyzer connection. Optional integrated reagent cooling module extends reagent life to maximum while also eliminating the need for air conditioning for ambient temperatures up to 104°F (40°C).

About the Township of Wayne, New Jersey (Figure 1):
The Division of Water and Sewer operates and maintains the drinking water and sanitary sewer systems throughout the Township to provide residents with clean drinking water and sanitary facilities. This Division operates and maintains the 13.5 million gallons per day Mountain View Wastewater

Treatment Facility on Dey Road. This facility treats all sanitary wastes and includes primary settling tanks, equalization basins, aeration tanks, final settling tanks, chlorination/de-chlorination facilities, sludge pumping and storage, and sludge truck loading facilities for off-site disposal. The plant has a complete laboratory for testing and monitoring the treatment process.

During the warmer months, the township must maintain its total phosphorus discharge to less than 0.76 mg/L. After trying several orthophosphate analyzers with varying results, and often little or no correlation with lab total phosphorus results, the plant nearly gave up on on-line monitoring altogether. Conventional orthophosphate analyzers use ultrafiltration to filter the sample and do not digest the bound phosphorus leading to poor correlation with lab total phosphorus tests. They also found that the orthophosphate analyzers tested required very frequent inspection and maintenance to detect and correct analyzer malfunctions such as plugged sample tubing and low reagents.

Challenge

The Township of Wayne, NJ, like all municipal wastewater plants, has regulations, standards, permits and budgets they must adhere to, including regulations regarding total phosphorus levels. In the fall of 2017, the regulations, especially for total phosphorus, grew even more stringent for the township. While biological treatment is an option for total phosphorus removal, this method alone was not practical due to increased nitrate levels and the physical limitations of the facility. PAC dosing was the only practical way to comply with the low total phosphorus limit. Optimizing the process is difficult without near real-time data and overfeeding PAC to stay in compliance as process conditions change was costly.

“Our normal phosphorus discharge runs 2.5 to 3 mg/L at peak turnover,” said Howard Breder, Laboratory Manager for the Township of Wayne. “In October, our phosphorus level was 3.1 mg/L. New regulations and permit limits that have been enforced now require our phosphorus discharge to be 0.76 mg/L or lower. This is extremely low for us, given the way we are running the plant today.”

The municipality was using biological phosphorus that resulted in 50% removal. This approach was insufficient to meet the new and more stringent total phosphorus limit. Additionally, the biological removal process increases nitrate which is another strictly regulated nutrient. Given these challenges, the municipality made the decision to switch to chemical removal using PAC.

Breder added, “Using chemicals becomes more expensive, but if we kept biologically removing phosphorus out of the wastewater we would have had to expand the plant to be able to hit the new limit of <0.76 mg/L. We would need more tankage and the expansion would cost millions of dollars.”

Realization

The Township of Wayne tried multiple analyzers and experienced serious challenges with each instrument making it impossible to get away from frequent grab sampling. In addition to the challenge of meeting a strict limit of <0.76 mg/L, the municipality experienced a lack of accuracy, poor reliability and insufficient lab correlation with the analyzers they tested. The municipality knew it needed a more accurate and dependable total phosphorus analyzer that would provide reliable analysis with close agreement to laboratory results. The Township of Wayne knew that an accurate and reliable analyzer would provide the trending data they needed for insight and visibility into the effectiveness of the phosphorus removal process in near real-time.

“We were looking for an analyzer that would be able to provide accurate data and wouldn’t break down every week,” said Mark Schwind, Superintendent of Operations. “We have limited time to manually maintain it. The analyzer we were using was providing us data, but when something went wrong with the analyzer, we had no warning.”

“The previous analyzer would continue to run when it was clogged and produce inaccurate data and it messed up the entire sampling process,” Breder said. “The analyzer kept adding chemicals without a current process sample and we didn’t know that we were overdosing chemicals, which was a large expense.”

Schwind and Breder would come into work in the morning and check the data from the old analyzer and the numbers would seem miscalculated. The two would have to perform their own calibrations weekly if the numbers weren’t correct and make the necessary adjustments.

“We are dealing with wastewater - there are solids when it comes through the system and a lot of times it gets clogged. The weak point in all the analyzers we have tested so far is getting the sample in the machine for measurement,” said Schwind.

Solution

Endress+Hauser representatives met with the Township of Wayne to demonstrate the Liquiline System CA80TP Total Phosphorus analyzer.

The municipality had tested multiple orthophosphate analyzers with poor results and had originally intended to try Endress+Hauser’s Liquiline System CA80PH Orthophosphate analyzer. However, the plant’s main goal had always been to find an analyzer that would agree with lab total phosphorus data. After being introduced to Endress+Hauser’s new Liquiline System CA80TP Total Phosphorus technology, Breder and Schwind decided they would try this unique, true total phosphorus analyzer.

Solution Details

The Township of Wayne decided to purchase and install the Liquiline System CA80TP Total Phosphorus analyzer based in part on assurances that the system would provide results consistent with the lab method.

"The Liquiline System CA80TP was easy to install compared to some of the other analyzers we tested," said Breder. "The samples are taken automatically every 45 minutes and because of the unique Y strainer (Figure 2) sampling approach large solids are automatically filtered out and doesn't result in the clogging challenges we were experiencing prior."

The Y strainer provides inertial filtration by allowing most particles to pass by the inlet tube while allowing only very small particles and dissolved compounds to enter the analyzer without filtering out the phosphorus rich solids. Ultrafiltration is often used in wastewater process analyzers to remove all undissolved solids from the sample. Unfortunately, most phosphorus except for the dissolved orthophosphate is removed via ultrafiltration and this is one reason why most of the previous analyzers tested rarely agreed with the lab results. Sample handling and conditioning is the most critical feature of any online wastewater colorimetric analyzer.

Results

The Liquiline System CA80TP Total Phosphorus analyzer was installed in August 2017 and the Township of Wayne is pleased with results thus far. During the first four months of operation, process conditions did lead to plugging of the sample tube which was quickly detected by the system and resolved by maintenance personnel almost immediately. This quick recovery was the result of the straightforward alarm messaging provided by the analyzer. Empty reagent bottles were also detected by the system and corrected by operators with only a minor interruption of the measurement. The plant is now able to rely on the measurement, adjust the PAC dosing in near real-time, and see total phosphorus trends which are in close agreement with laboratory grab-sample analysis. None of these benefits were achieved with the previous analyzers they evaluated. The Township of Wayne is now confident that the analyzer will provide useful predictive alarms to warn of low reagent conditions and when faults are present they can be resolved quickly, resulting in minimal loss of measurement time.

	Influent TNT TP mg/L	Effluent TNT TP mg/L (Lab)	PAC Added	Effluent TP mg/L (CA80TP)
10/2/2017	4.66	1.49	350	1.073
10/3/2017	4.65	0.98	350	0.933
10/4/2017	4.48	1.18	400	1.222
10/5/2017	5.47	1.12	450	1.05
10/6/2017	4.07	1.23	650	1.284
10/10/2017	4.46	0.77	680	0.57
10/11/2017	4.32	0.53	730	0.78
10/12/2017	4.73	1	675	1.075
10/16/2017	4.53	0.57	675	0.56
10/17/2017	4.15	0.48	675	0.384

Figure 4: Grab-sample lab data vs. Liquiline System CA80TP Total Phosphorus analyzer data.

"When the phosphorus level is starting to rise, we can see that trend in near real-time because the samples are taken automatically every 45 minutes," said Breder. "We go in and make the adjustment right then. These samples yield accurate data and quality results on-site. You basically have real data that agrees with results that are completed in the lab, which take days to process." (Figure 4)

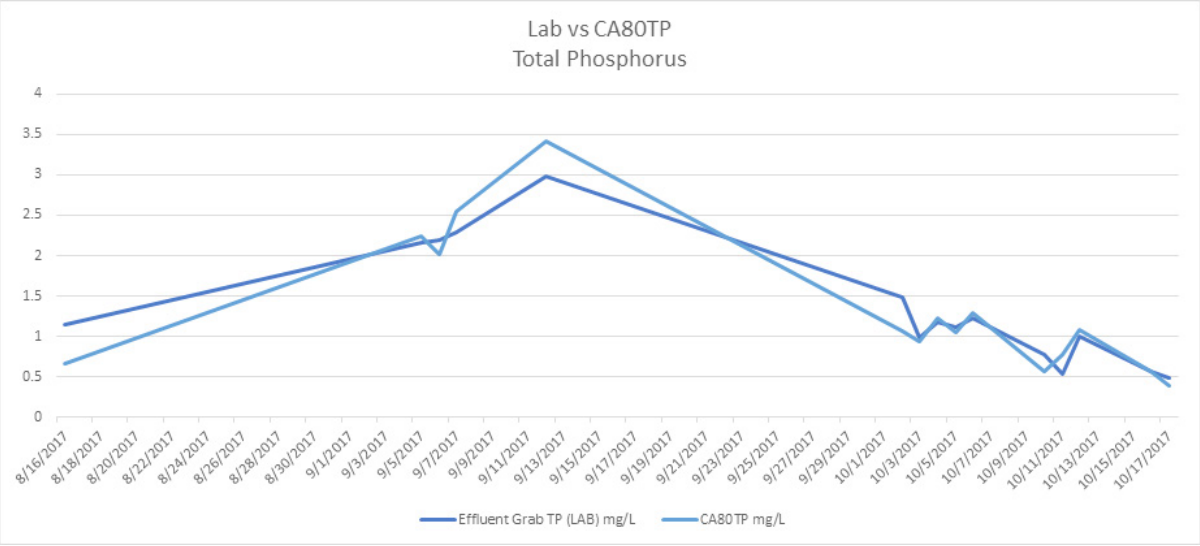

Figure 5: CA80TP Total Phosphorus system process data trend (four months).

The municipality is already discussing plans to implement digital communications using Modbus TCP or EtherNet/IP to take advantage of the extensive predictive diagnostics from the Liquiline System CA80TP Total Phosphorus analyzer (Figure 6) in real-time over the plant network. Once implemented, important current and historical variables such as low reagent warnings, preventative maintenance warnings, overall instrument health, historical and current calibration data will be available via the IP addressable webserver. User-friendly descriptive warnings can be configured to pop up on the SCADA HMI to give immediate indication of analyzer performance issues without the need to go out in the field to the view the instrument display.

"We eventually want to see this data (Figure 4 & 5) right from our desktop and not have to manually adjust," said Schwind. "Eventually our computers will do that for us. The ability to run diagnostics remotely from our desk and know that it is going to run properly will be beneficial. As we start and continue to upgrade, the alarms we were receiving are becoming less and less."

"The end goal is a [total phosphorus] number that you can hang your hat on," added Breder. "You need good numbers and maximum up-time on the instrument and before using the Endress+Hauser system we weren't getting superior, reliable and consistent results. If your instrument is not running or your data isn't accurate, then there is no use."

Figure 6: Endress+Hauser CA80TP Total Phosphorus analyzer.

Conclusion

The issues Township of Wayne experienced for control of phosphorus discharge are not unique. Wastewater treatment plants across the United States are seeing tighter permit levels for total phosphorus discharge. These limits no longer allow for control over phosphorus removal solely relying on manual sampling and lab testing. Orthophosphate analyzers do not produce a correct result, given the fact that sample preparation systems used with orthophosphate analyzers remove a portion of the total phosphorus you are trying to measure. The Township of Wayne found that the Endress+Hauser Liquiline System CA80TP Total Phosphorus analyzer measures true total phosphorus using a unique sampling system that provides a truly representative sample, and complete sample digestion, resulting in highly correlated lab quality results. With onboard diagnostics they also found the analyzer allowed them to maximize process uptime. With future plans to upgrade to digital fieldbus communications with a webserver, the Township of Wayne will further enhance its ability to manage its phosphorus removal process and easily comply with tighter permit requirements.

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