

ChemScan[®] Process Analyzer

PROJECT REPORT AND DATA SUMMARY

EVALUATION OF ON-LINE AMMONIA, NITRITE AND NITRATE
ANALYSIS FOR PROCESS CONTROL AND ENERGY MANAGEMENT

Gainesville Regional Utilities
Kanapaha Water Reclamation Facility
Gainesville, FL

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ChemScan Demonstration and Evaluation Report

1. Background

A. GRU Kanapaha WRF

The Kanapaha Water Reclamation Facility was constructed by Gainesville Regional Utilities (GRU) in 1975 and expanded to a 10 MGD facility in 1984. The treatment process includes two anoxic basins preceding two aeration basins, each equipped with four surface aerators. The first and third aerator in each basin is a dual speed unit, 125 hp at high speed and 75 hp at low speed. The second and fourth aerator in each basin is maximum 200 hp variable speed unit.

Thus, a variety of aeration profiles can be achieved in each basin. One treatment objective is to nitrify and partially denitrify the wastewater during the treatment process to achieve a target total nitrogen concentration. This is achieved through the recycle of a fraction of the secondary effluent back to the anoxic tank for denitrification and through the management of aeration rates in the secondary aeration basins. Because of the variable speeds available in the surface aerators, substantial energy savings can be achieved by matching the actual amount of aeration required to achieve the required reduction of BOD during secondary treatment plus achieve the desired transformation in nitrogen cycle species from nitrite and nitrate to nitrogen gas and from ammonia to nitrite and nitrate as the mixed liquor travels through the secondary aeration basins.

The operations staff at Kanapaha investigated several possible control strategies including the use of on-line Oxidation Reduction Potential (ORP), on-line Alkalinity and on-line process chemistry monitoring systems to help manage this process. It appeared to the staff that on-line (automatic and immediate) monitoring of the process chemistry from strategically selected sample points in the aeration basins could provide a means to directly observe the process status, particularly if ammonia and nitrate could be detected by the analyzer. For this to be feasible, the analyzer system would need to function automatically, be a reliable source of process information, be economical to operate and not require substantial efforts to operate and maintain.

The operations staff was aware of several other wastewater facilities in Florida who were successfully using the ChemScan Process Analyzer system, manufactured by Applied Spectrometry Associates, Inc. (ASA) for automatic analysis of ammonia, nitrate and/or nitrite. Most of these other facilities were using ChemScan for analysis in wastewater effluent, where mixed liquor suspended solids had already been removed at an earlier stage in the treatment process. One facility, City of Orlando Conserv II, was using an advanced version of the ChemScan system for analysis of ammonia, nitrate and nitrite in samples obtained directly from their activated sludge process basins. Following a visit to the Orlando facility, ASA was requested to furnish a ChemScan system for a short term demonstration at Kanapaha.

B. ChemScan Process Analyzer System

The ChemScan Process Analyzer is designed to detect multiple chemical parameters in samples pumped from multiple sample points within a treatment facility. This is a significant improvement over conventional analyzers which can detect only one parameter in a single analyzer.

ChemScan systems use multiple wavelength ultraviolet-visible light absorbance measurements for analysis. This technique makes it possible to analyze a sample for one or more specific chemicals without sample alteration or the use of reagents. ChemScan detects 256 wavelengths and uses 15 to 30 wavelengths of information for each analytical procedure. The ChemScan

analyzer uses a branch of mathematics known as chemometrics to process the multiple wavelength data and calculate the concentrations of specific chemicals based on this information.

The combination of multiple wavelength detection and chemometric analysis makes it possible for ChemScan to process a single absorbance signature from a sample and calculate the concentration of closely related chemicals such as nitrate (NO₃) and nitrite (NO₂), mathematically compensate for the presence of other chemical constituents in the sample, and greatly simplify reagent assisted techniques for analysis of parameters like ammonia.

2. Demonstration Results

A. Installation and Operation

A demonstration ChemScan system was installed at Kanapaha in mid November 1997. The system consisted of a ChemScan Process Analyzer set up for analysis of ammonia, nitrite, nitrate and percent transmittance; a ChemScan on-line ultrafilter system and sample accumulator; an off-line filter cleaning system; and a 3 hp double cavity positive displacement sample pump. The analyzer, filter and cleaning system were furnished by ASA and the sample pump was furnished by Penn Valley Pump Company. Installation was performed by the Kanapaha operations and maintenance personnel, under the supervision of an ASA engineer.

Sample Lines

Two sample points were selected for the demonstration, both in aeration basin Number 1. The first sample point was immediately after the second aerator and the second sample point was just before the fourth aerator. Sample lines consisted of three inch plastic pipe extending 48 inches into the aeration tank, connected with an elbow to a header running along the top of the tank wall and held in place with brackets. Both headers terminate at ground level at a point near the sample pump. A common feed line is connected to the vacuum side of the pump and then connects with the sample line headers at the tank wall. Manual ball valves were used during the demonstration to select either the upstream or downstream sample point for analysis. (A permanent system would use motor operated ball valves and an automatic sample controller to cycle between multiple sample points.)

Sample Pump

The sample pump was installed on a small concrete pad at ground level, adjacent to the aeration basin. Power was supplied to the pump through a starter, located on a spare panel in the motor control room. A local off switch was installed to interrupt pump operation, but restart was initiated using a switch on the control panel. The pump is intended to be continuously operated, with a 30 gpm flow of sample from a selected sample point through the cross flow ultrafilter system and returned to the aeration basin through a 1.5 inch diameter plastic pipe connected to the exit side of the ultrafilter system.

Ultrafilter

The ultrafilter system consists of a bank of four 0.1 micron pore size filter membrane elements, connected in series. Each filter element contributes a continuous flow of filtrate to a sample accumulation vessel, mounted in the center of the filter bank. In theory, the high flow of sample through the center of the filter elements is intended to keep the inner surface of the membrane adequately scoured and free from accumulated debris. A 30 psi pressure at the filter inlet and a 10 psi pressure drop across the filter bank is designed to induce sample filtrate, including dissolved chemicals, to flow through the filter pores, while solids in the sample are rejected at the filter surface and carried away with the main flow through the filter assembly. The system is configured such that a U shaped subassembly consisting of two of the membrane elements can be

bypassed and removed from the filter bank, while the remaining two membrane elements continue to contribute sample to the accumulator. Each of the two U shaped subassemblies contains a rotometer to measure the flow rate of the filtrate being delivered to the accumulator. The filter also contains pressure gages at the filter inlet and outlet to monitor the incoming and outgoing pressure, hand operated ball valves to allow adjustment of sample flow and back pressure through the filter. Ball valves are also provided to allow either of the filter subassemblies to be bypassed or bypass of the entire filter bank.

Filter Cleaning System

The filter cleaning system consists of a polyethylene stand containing a 5 gallon chamber for cleaning solution. A hand operated ball valve at the bottom of the chamber allows used cleaning solution to be drained to waste. A small submersible pump is located within the chamber and is plumbed to circulate solution from the chamber through a U shaped filter assembly mounted at the top of the cleaning stand. The top of the stand contains female threaded coupling connections, designed to accept the filter assembly. Each end of the U shaped filter assembly terminates in a male coupling preceded by a ball valve at the end of each membrane element, so that any liquid within the filter assembly will remain intact during transfer of the filter to and from the cleaning stand. Once mounted on the stand, the ball valves are opened and cleaning solution (a weak bleach solution at a controlled pH) is allowed to circulate through the filter for a fixed period of time, controlled by a timer. The submersible pump causes the cleaning solution to become warm during the circulation period. After the cleaning period, the bleach solution is drained and replaced by tap water used for rinsing. After a rinse period, the ball valves are closed and the clean filter is stored on the stand until needed to replace an assembly experiencing diminished output.

Accumulator

The sample accumulator consists of a clear plastic 1 gallon chamber, with a sample drain at the bottom and an overflow drain at the top. A three way valve controlled by the ChemScan analyzer is installed at the sample drain. When an analysis cycle is initiated, based on a pre-set time interval, filtered sample is allowed to drain to waste for a fixed period of time to assure that the sample flow is fresh and representative of the sample point to be analyzed. After the drain time has expired, the sample drain valve closes and the sample accumulator starts to fill with sample. During accumulation, excess sample is drained to waste through the overflow drain. After a short accumulation period, the sample supply valve opens to allow the accumulated sample to flow to the ChemScan analyzer for analysis. During the analysis cycle, sample continues to be accumulated, and flow from the accumulator to the analyzer, under the direct control of the analyzer. After the analysis cycle is completed the sample drain valve opens, allowing the filtered sample to drain to waste until the next sample interval is initiated or a new sample point is selected.

ChemScan Analyzer

A ChemScan Model UV-6100 was supplied for the demonstration. This analyzer consists of an electronics and optics enclosure containing the detection system and associated circuitry plus the main power connection; a flow cell enclosure containing a cell where a beam of light is transmitted through the sample; an external sample conditioning unit where reagents for ammonia analysis are added to the sample; a manifold and PLC control assembly that directs the flow of sample, zero solution or cleaning solution through the analyzer and also initiates control signals for other analyzer system functions; a fractional hp peristaltic pump to move sample from the accumulator through the analyzer and a mounting stand to support these modules. Four plastic containers, one each for zero solution (deionized water), cleaning solution (dilute muriatic acid),

pH sample conditioning (hydroxide and EDTA), and ammonia reagent (bleach) are located beneath the analyzer and are connected to the analyzer with plastic tubes.

When an analysis is initiated based on a preset time interval, sample is accumulated as described earlier. Following accumulation, fresh sample is allowed to flow through the analyzer for a period of time selected to assure a complete sample flush. The sample flow is then stopped and light absorbance measurements are used to calculate the concentration of nitrate, nitrite and percent transmittance. No reagents are used during this portion of the analysis. Following these measurements the sample flow is resumed and used to flush the sample conditioning unit. Following this flush, a small mixing chamber fills with sample, reagents are injected and allowed to react, and the reacted sample then pumped to the flow cell for analysis. Light is transmitted through the reacted sample and the ammonia concentration is calculated. Following the calculation of ammonia results, additional sample is flushed through the analyzer system for a short period. The flow is then stopped and the analyzer counts down to the start of the next analysis interval. During the demonstration period, a sample was analyzed every 15 minutes. (The permanent system will analyze a sample every 5 minutes using an improved version of this technology which eliminates the external sample conditioning unit, speeds reaction time, greatly reduces flush time and minimizes the required sample volume.) Analysis results are shown on a liquid crystal display located on the front of the analyzer. The ChemScan analyzer also provides a serial output to communicate the updated measurement information for each parameter directly to a PC used for data logging. In addition, a 4-20 mA connection is provided for each of the four measured parameters, with updated information displayed directly to the plant computer following analysis. The plant computer used a software program known as Wonderware to continuously display a graph showing the current measurements for ammonia, nitrate and nitrite together with prior measurements for each parameter, so that operators could easily identify process chemistry trends and take appropriate action to optimize the treatment process and/or conserve energy.

B. Maintenance Requirements and System Reliability

In general, the ChemScan System performed reliably with only modest efforts required for routine maintenance during four months of operation from mid November 1997 to mid March 1998. Routine maintenance included replenishment of analyzer reagents, extraction and analysis of samples to verify analyzer calibrations and filter cleaning. Reagents were replenished approximately once every other week. During each interval, one hour of an operator's time was required to mix reagents and refill chemical containers. (The permanent system will require only once per month replenishment due to greatly reduced reagent use for each analysis.) Excluding samples obtained to verify the accuracy of the analyzer, which would not be routinely required for operation of the system, only a few samples each month would be required for calibration adjustment. Little or no adjustment was required for the nitrate and the nitrite calibrations. Ammonia did require some adjustment, although all parameters tracked well with process events and were in agreement with the results for comparison samples. (See accuracy discussion below.) Initially, filters required attention approximately once every two weeks, but as operators gained more experience with filter operation and after adjustment of cleaning procedures, filter runs increased to three weeks or more. Each filter cleaning required fifteen to thirty minutes of direct operator attention. The demonstration system provided reliable operation with routine maintenance of six hours or less per month.

Pump Maintenance

The Penn Valley Pump operated reliably throughout the demonstration period, with one exception. A positive displacement pump is not designed to push against a closed line. Either an

obstruction in the line or an inadvertently closed valve caused a failure in both trunions within the pump. This failure was discovered during a visit by the pump representative and the ChemScan engineer to evaluate the reason for an apparent decline in filter output. It was discovered that the pump should have been installed with a pressure switch on the output side of the pump. This switch automatically cuts power to the pump when a set pressure is exceeded, preventing damage to the trunions. Spare trunions and a pressure switch were sent from the factory overnight and the pump was returned to service within 24 hours after discovery of the failure. The pump operated without incident after installation of the pressure switch. (The permanent installation will have a pressure switch on both the vacuum and outlet side of the pump.)

Filter

In general, the filter performed well during the demonstration, producing a continuous filtrate volume sufficient to supply enough sample to maintain the intended 15 minute analysis interval without an unacceptable amount of regular maintenance. This occurred even though one filter subassembly, probably overstressed when the return line was closed, was not able to recover a normal output even after extensive cleaning.

Cleaning

The off-line cleaning system was easy to operate and, except as noted above, effective at recovering a high filtrate flow rate after cleaning a filter subassembly. Adjustments were made to increase the recirculation time originally recommended by ASA, but, since this is automatically controlled, the adjustments had no effect on operator maintenance effort.

Analyzer

The ChemScan UV-6100 system provided reliable performance throughout the demonstration period.

C. Accuracy

The relative accuracy of the ChemScan system was continuously monitored by operations personnel during a period from the end of November 1997 through mid March 1998. During this period, operations personnel developed trust in the analytical measurements being made by ChemScan through direct comparisons with laboratory results and through close observation of ChemScan responses to changes in plant operating conditions. By the end of the evaluation period, operations personnel were routinely using ChemScan information to fine tune aeration rates.

During this period numerous split samples were obtained for analysis by ChemScan and by the operations laboratory and the plant laboratory. The operations laboratory is equipped with ion probes for analysis of nitrate and ammonia. The plant laboratory uses a flow injection type analyzer for these parameters.

Although plant personnel did not initially believe that a detectable level of nitrite would be found in the aeration basin samples, experiments were conducted to verify whether or not nitrite was present. It was found that when samples were analyzed promptly (within 48 hours) and not acidified but only preserved at 4°C, up to 0.6 ppm of nitrite-nitrogen was present. This was consistent with the results being reported by the ChemScan analyzer. Because nitrite is an intermediate step in the conversion of ammonia to nitrate (nitrification) and in the conversion of nitrate to nitrogen gas (denitrification), a real-time measurement of nitrite is an important aspect of process control.

D. Observations and Usefulness

The ChemScan Process Analyzer was closely observed for a period of nearly four month at Kanapaha. Throughout this period, the analyzer did not require recalibration for any of the parameters being monitored. Some offset (intercept) adjustments were made for ammonia, but these adjustments were minor and were not difficult to perform. In any event, all parameters proved to be a reliable indicator of process trends and responded as expected when sample points and/or process conditions were altered. Maintenance requirements for the analyzer, filter and sample pump were less than expected. Graphic presentations of trend data for each parameter provide a very clear indication of process status and provide operators with current process chemistry data to guide their adjustment of aeration rates or other process variables. (See Figure 1.)