Application Note: Hach 5500sc AMC vs. SWAN/ Amtax combo

Background

A test of the new Hach 5500sc AMC analyzer was conducted at a large drinking water facility routinely producing about 85MGD. The source water is a river water stored in a large reservoir (artificial freshwater sea), the intake location is ~10 miles away of the plant. The plant adds ammonia to the raw water at the intake, followed by free chlorine (~30 sec after ammonia injection), and prior to addition of coagulant (alum) downstream on site. The water goes through coagulation/flocculation/sedimentation before quick sand filters (sometimes complemented with anthracite and/or PAC for emergencies). The long exposure to chloramines between the intake and coagulant addition allows for better pre-oxidation. Chloramination is controlled at the entrance to the plant (prior to addition of coagulant) and free chlorine is boosted after the filters, to ensure correct chloramination before clear well, and then water undergoes UV treatment prior to entering the distribution system. There is no residual disinfectant online monitoring at the discharge.

The source water is very stable and the plant experiences seasonal manganese issues due to the reservoir turnover and an LDO sensor was recommended for monitoring rising manganese levels. The plant does not monitor pH and turbidity online.

Given the disinfection process setup it was considered to be a benefit for installing an AMC analyzer on chloraminated water intake to compare performance with an existing SWAN and Amtax sc analyzers measuring this sample in parallel. The facility has two Amtax sc instruments measuring free ammonia: one before the filters (pre-oxidation with chloramine before coagulation), and another at two clear wells (a 2-channel analyzer).

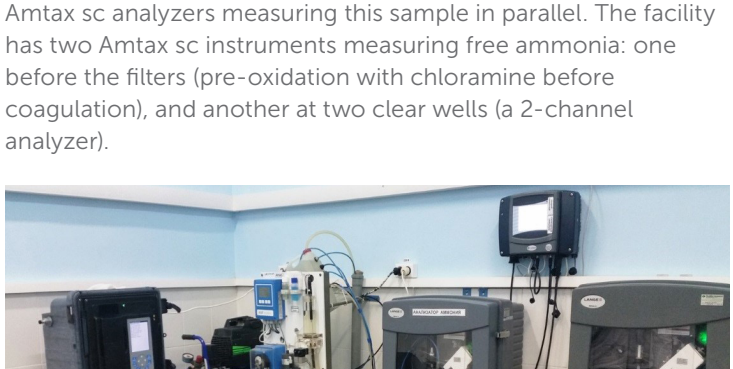

Figure 1 - Setup of the process analyzers at the DW plant. Service was running a verification test on AMTAX units at the time of the visit

There are three SWAN analyzers measuring free and total chlorine at the following sampling points: one after pre-oxidation (before coagulation), and two at each of the two clear wells. The SWAN instruments are set to calculating mono- and dichloramine concentrations. All five instruments cost around $70K. The test setup is shown in Figure 1.

The plant controls chloramination based on total ammonia results that are not directly measured or displayed by the existing process instruments. Calculation of total ammonia from measured free ammonia (Amtax) and monochloramine (SWAN) concentrations is programmed in the sc1000 (Fig. 1), and this value sent to SCADA does not always match with results of grab sample analysis. The lab method is based on indophenol, so no general chemical interference is expected and the disagreement between the process analyzers and lab measurements of total ammonia is one of the plant's personnel main pain points.

During a sales visit in May 2016 a test with SL1000 conducted for Free Chlorine, Total Chlorine (TC), Monochloramine (MCA), and Free Ammonia (FA) reveled some discrepancy between monochloramine (SWAN) and SL1000 results, which was considered to be a potential source of the Total Ammonia (TA) disagreement. It was also discovered that the Amtax measurement interval was set to every 2 hours, therefore it was never guaranteed that the displayed Amtax reading was the same as the grab sample, and therefore may not match the lab results, which was another potential reason for the discrepancy. One more source of potential error was found to be the calibration (scaling) of analog outputs of the online instrumentation, and therefore locally displayed readings may not always match the readings shown on SCADA.

5500sc AMC Demo Test Results and Discussion

The demo test was conducted in summer of 2016 and the data were collected directly from the instruments to minimize any error potential. Before implementation of the 5500sc AMC analyzer, the plant personnel could see 4 data sets (Fig. 2): online monochloramine (MCA) expressed as NH2Cl (SWAN-displayed), lab total chlorine (TC), lab total ammonia (TA), and online free ammonia (FA). Two more lines presented in Figure 2 reflect results calculated from SWAN readings (MCA as Cl2 and MCA as N), and displayed in Figure 2 for comparison purposes only.

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The following observations and reasonable assumptions could be made from the data available prior to the demo test:

- If MCA results (SWAN) are expressed as NH2Cl (Fig. 2, blue line), then it provides a trend for the target disinfectant residual and shows a significant discrepancy with lab TC data, first of all due to the concentration expression units. Once the SWAN monochloramine results are expressed as chlorine (Fig. 2, grey line), the discrepancy becomes smaller, but still present. This is unusual, because concentration of MCA, being the target disinfectant produced in chloramination, should match total chlorine within normal accuracy expectations, unless there is an issue with the treatment process.
- A significant discrepancy between MCA concentration as presented in Figure 2 (SWAN-displayed, blue line) vs. lab total ammonia ("plus" marks, Fig. 2) is expected due to the units of expression for monochloramine. However, the discrepancy is still present when MCA concentration is expressed as N (Fig. 2, green line), which may be attributed to the presence of free ammonia, assuming the process is under control.

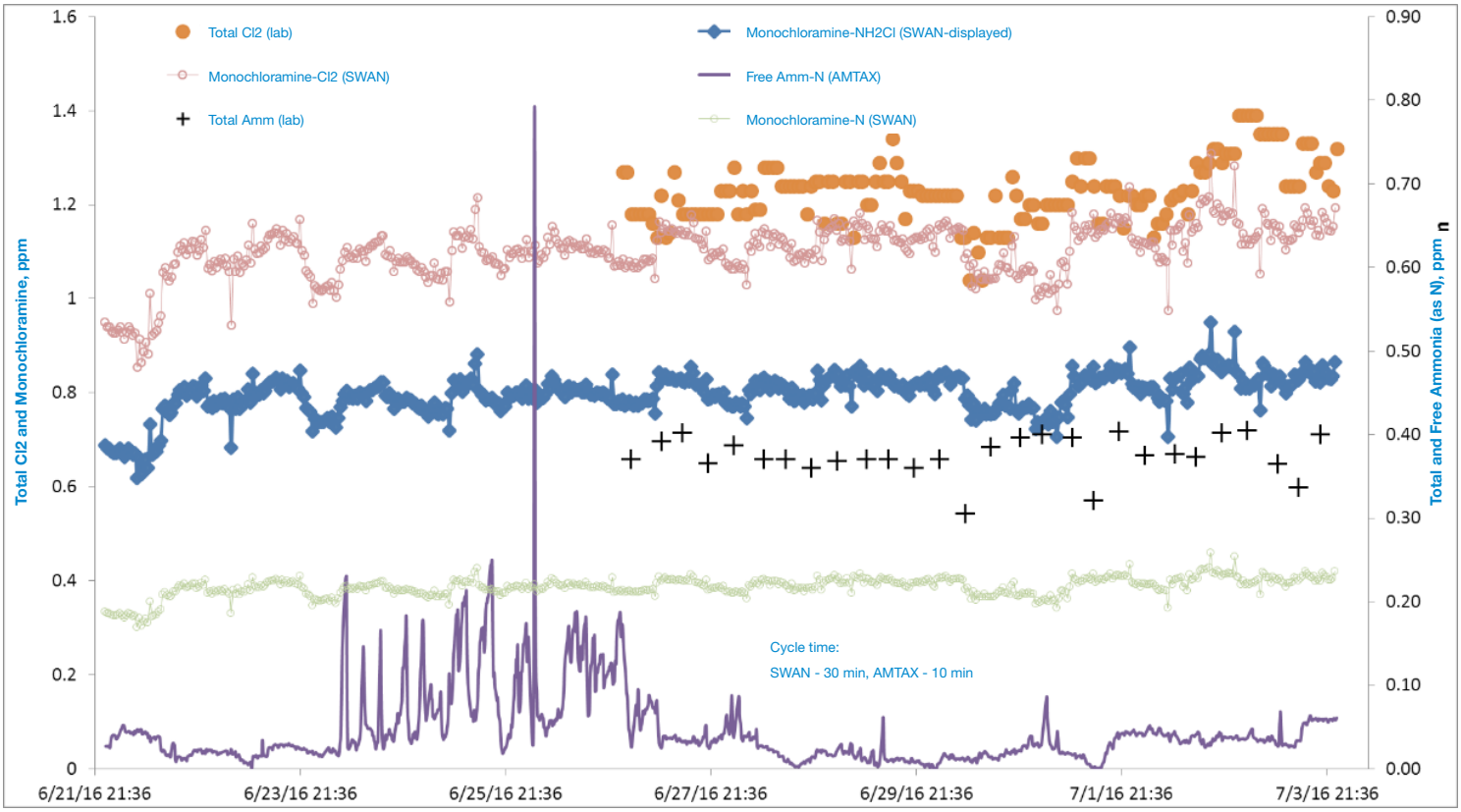

Figure 2 - Date from the process analyzers and laboratory measurements available prior to installation of demo AMC

- The trend analysis between TC and MCA provides some insight about stability of chloramination; however, more accurate understanding of the process can be achieved only with simultaneous analysis of the FA, MCA, and TC.
- The cycle time for SWAN measurements (30 min) was sensibly longer than the Amtax 10-min cycle time, which may result in missing some important data critical to efficient chloramination control.
- The lab TA results provide general trend (the analysis cycle of 5-7 hours is definitely too long for efficient process control), while the numerical values for TA may be used for indirect verification of online instrumentation.
- It is assumed that a sum of MCA (as N) and FA concentrations should give TA, which should match the lab analysis. The customer complained that it was not the case with SWAN/Amtax results and the expression of MCA concentration in mg/l of NH2Cl did not help to understand this issue. Summarizing MCA (as N) readings of SWAN with FA readings of Amtax did not result in matching the sum with lab TA data presented in Figure 3, which also contains all readings recorded by the 5500sc AMC analyzer added to the suite.

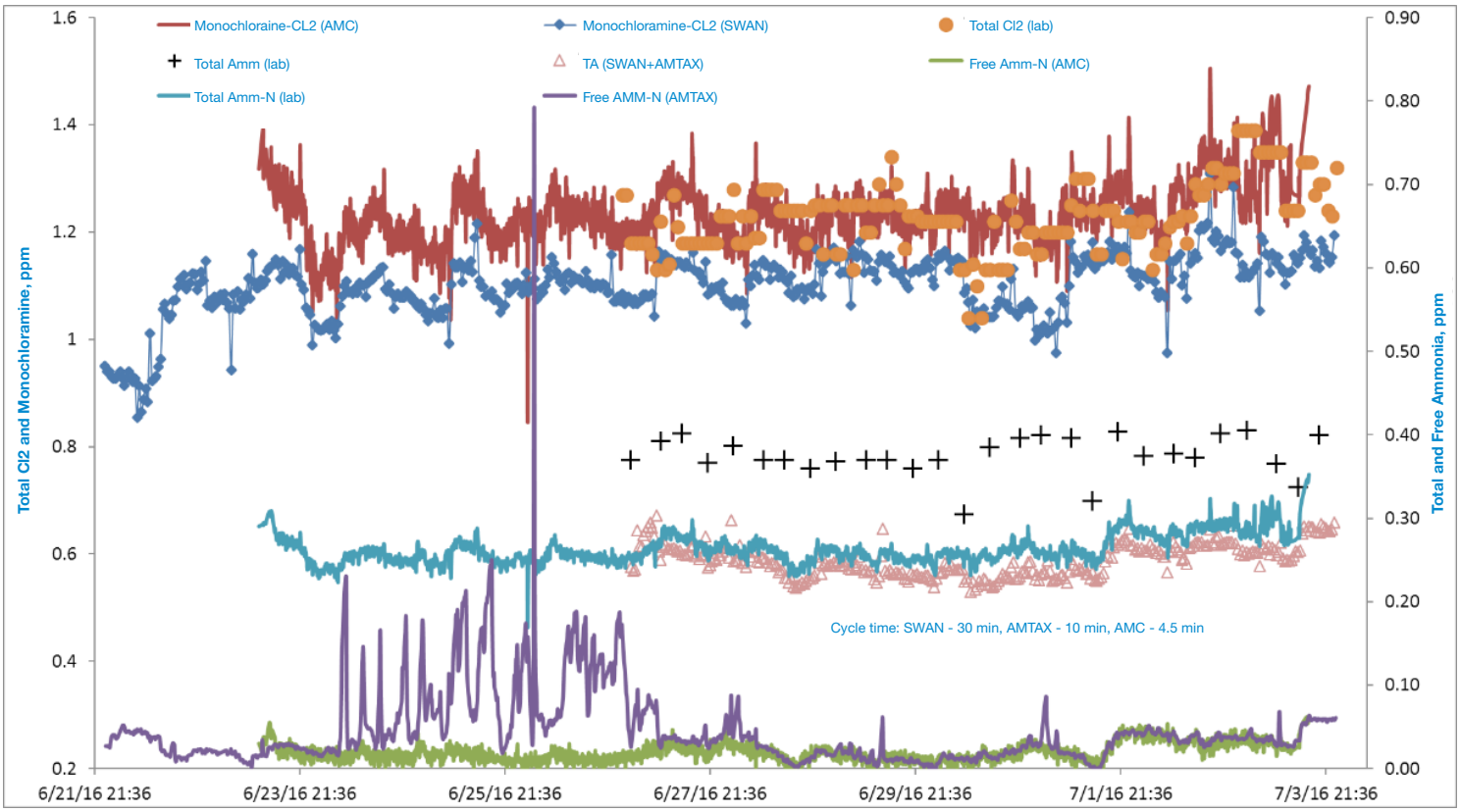

Figure 3 - Graphs representing the readings from 3 online analyzers and corresponding laboratory results

Once the demo AMC unit was installed next to the other two analyzers (Fig. 1) to measure the same sample (basically, raw water after pre-oxidation with monochloramine), the picture became more complete (Fig. 3). The comparison of three online instruments' readings and corresponding lab results allowed for the following summary:

- General trending between AMC (monochloramine) and lab TC data displayed a consistent match and confirmed general stability of the chloramination process and effectiveness of its controls.
- Correlation between FA readings received from AMC and Amtax was very close, beyond the situation with lack of sample to the Amtax analyzer observed between June 24 and 27.
- TA concentration calculated from Amtax (FA) + SWAN (MCA as N) readings showed reasonable correlation with corresponding AMC readings (74% match rate); however, still displayed a significant deviation from the lab TA results (0.13 ppm or 34% difference, based on 27 comparable data points). The AMC readings of TA were numerically closer to the lab results (0.11 ppm or 28% difference); however, the discrepancy was still significant.
- The discrepancy between TA readings from all process and lab measurements is difficult to explain and it casts a suspicion over the lab analysis, pointing to a possible systemic error, because accuracy of the AMC is confirmed by results of two independent analyses (FA and TC, see Fig. 4, 5 discussed below). This discrepancy requires additional investigation to determine the root cause, because deviations beyond 10-15% are considered abnormal and usually point to an error caused by either calibration of the process instrument, quality of reagents, process itself (e.g. instability or chemical interference), or by the human factor usually associated with lab procedures. From this stand point process analyzers have an advantage, especially if equipped with auto-calibration and self-diagnostics functions, as the Hach 5500sc AMC analyzer.

A detailed analysis of comparable readings demonstrated a better correlation between the residual TC (lab) results and AMC monochloramine readings vs. SWAN measurements of monochloramine (Fig. 4).

The 95% correlation rate between AMC (MCA) and lab (TC) demonstrates a good process control by the plant personnel as well as confirms accuracy of the analyzer (Fig. 4, inset). The discrepancy between SWAN (MCA) and lab (TC) being almost at 40% (share of readings outside of the acceptable accuracy, Fig. 4) is most likely caused by deficiencies of the method employed by this process analyzer, involving a large share of calculations based on the reaction rate (kinetics) and pH, although, influence of calibration is also possible. The SWAN instrument measures directly only free and total chlorine; however, these readings were not available,

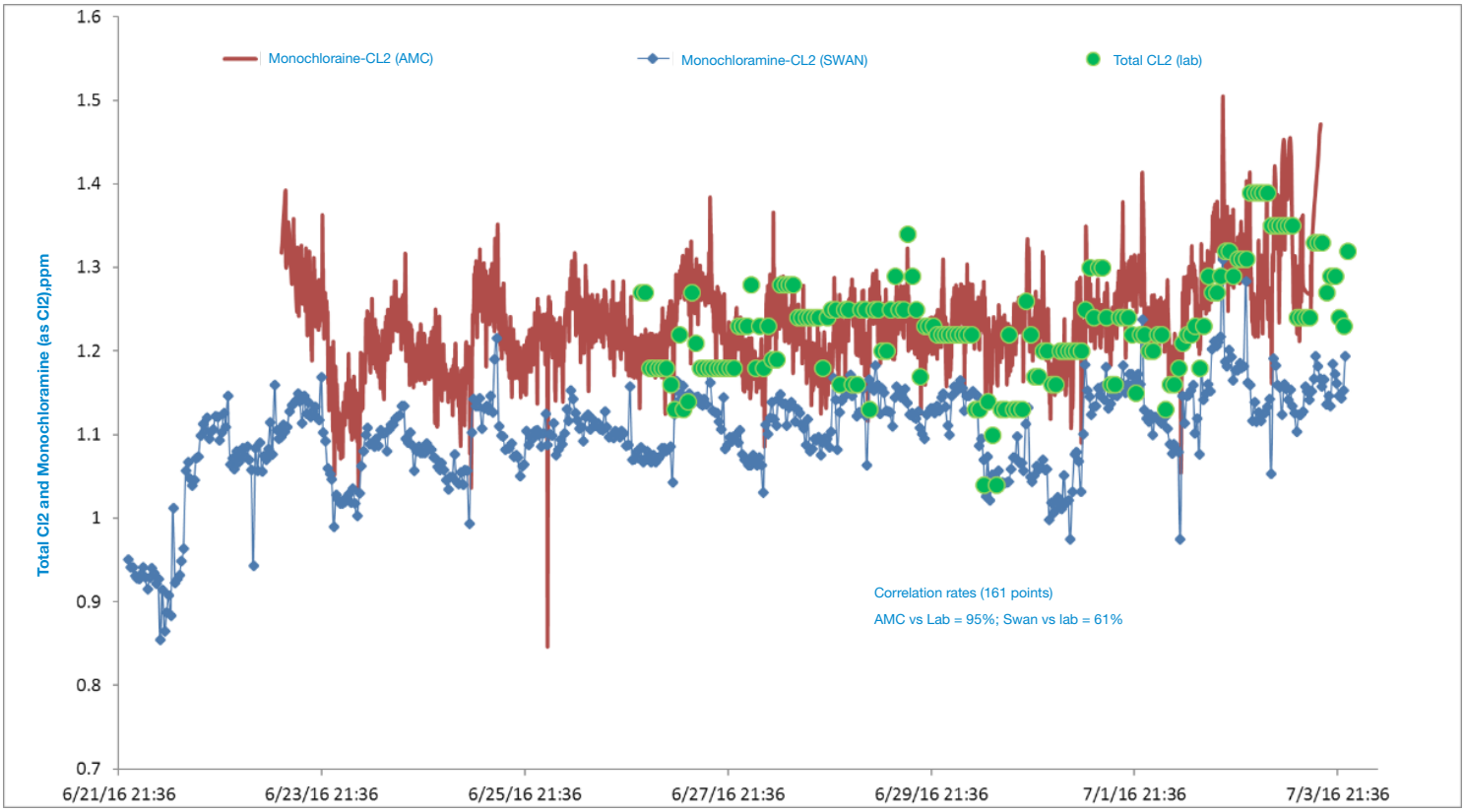

Figure 4 - Comparison of the disinfectant residual concentration measured by lab and process means

unfortunately. It would be interesting to analyze these data to better understand the root cause of the noted discrepancy, though it represents mostly academic interest.

The accuracy of the AMC performance was also confirmed by comparison of its free ammonia results with Amtax (Fig. 5). It is very important, because these instruments employ completely different methods: AMC – calculates the FA as a difference between TA and MCA direct measurements, while Amtax measures FA directly.

A detailed analysis of the AMC and Amtax free ammonia results as presented in Figure 5, showed excellent match between the readings during the time both analyzers functioned properly, thus confirming accurate measurement of this parameter critical for chloramination control. Average discrepancy between these two different methods obtained from comparison of 877 corresponding data points (Fig. 5) was less than the limit of detection specified for the AMC analyzer (0.01 ppm).

The trending and absolute values of FA concentration demonstrated that chloramination was under full control during the demo test and the deviation in Amtax readings (June 24-27) was caused by disruption of sample delivery to the analyzer, as registered in the Event Log. It was also discovered that some deviations in the AMC performance during the demo test happened due to either absence of reagents, excessive sample pressure, or low sample flow (all situations were registered in the Event Log), and were not related to any malfunctioning of the AMC systems. The mentioned mishaps did not allow for a fuller comparison of the results; however, may not affect the conclusions derived from the analysis of all data collected in more than 10 days of observations when all three instruments displayed good performance.

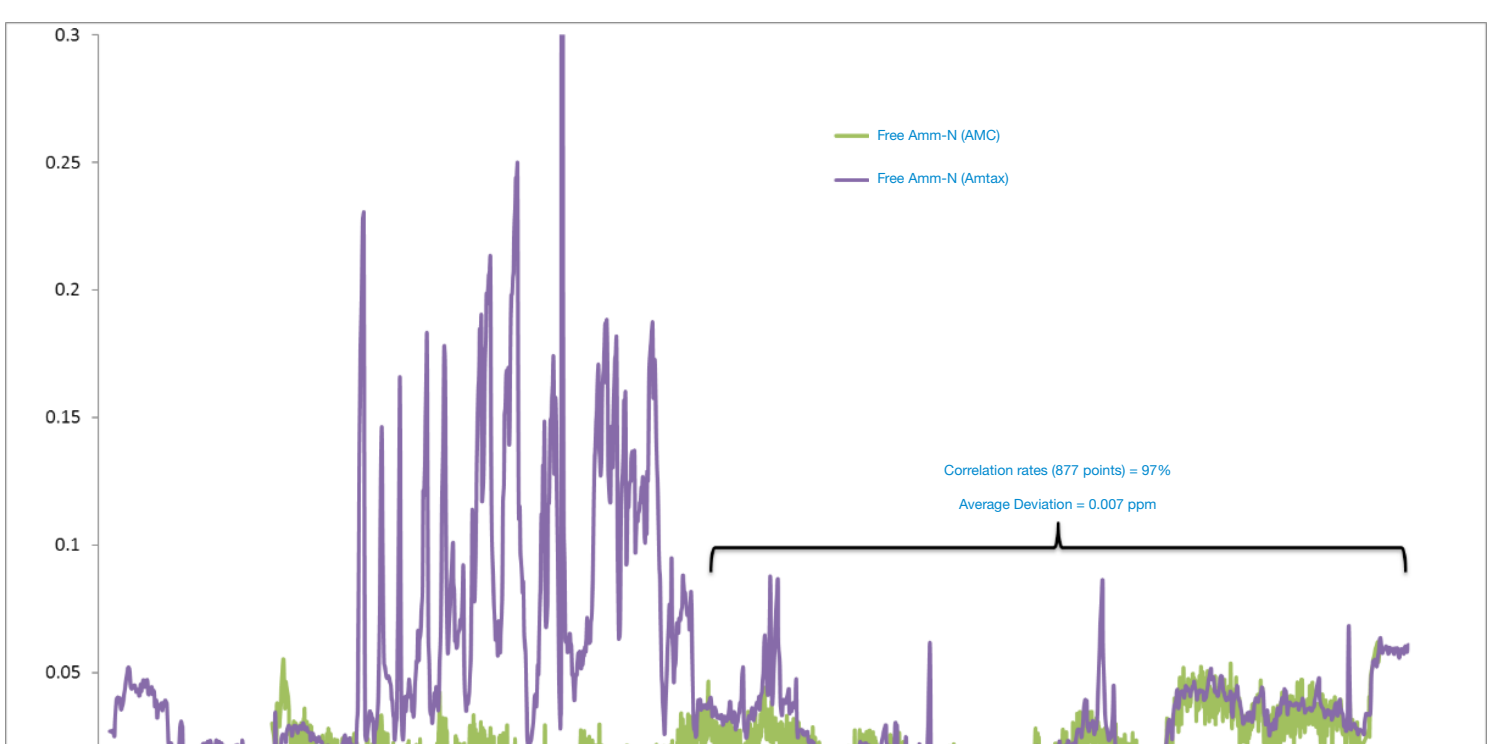

Figure 5 - Comparison between free ammonia readings from two analyzers utilizing completely different measurement methods

Conclusions

- During the demo testing, Hach 5500sc AMC analyzer showed high accuracy of all measurements in comparison with independent methods and instruments.
- High degree of accuracy at significantly shorter cycle time allows for better control of chloramination, especially comparing Hach AMC to laboratory analyses only, and/or online monitoring system employing combination of Hach Amtax and SWAN analyzers.
- Financial analysis shows that one Hach 5500sc AMC analyzer featuring more advanced user interface and self-diagnostics, providing two additional results (Total Ammonia and Cl_2: N mass ratio), and demonstrating higher analysis frequency, can efficiently replace two other online instruments with capital cost savings of over $11000. Overall, two fully equipped 2-channel AMC analyzers (5500.AMC.4.KTO) can replace all five online instruments currently installed at this facility providing cost savings of ~$23000, without accounting for exchange rates, Prognosys software, and consumables.

About the Author

Vadim B. Malkov (PhD Chemistry) joined Hach Company in 2002. Originally Dr. Malkov worked at Hach R&D and then moved over to the business organization. During his tenure at Hach, he led and participated in development of several process analyzers and applications. Vadim Malkov has published many papers in scientific and professional journals and presented results of his work at multiple conferences in the United States and abroad.

Dr. Malkov is currently working at Hach as a Product Applications Manager for Process Solutions Business Unit focused on Drinking Water applications and specifically on disinfection processes and practices.

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