Nutrient Sensor Action Challenge

Submitted by

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Nutrient Sensor Challenge Plan of Action

A. Nutrient Issue

The fate of nitrogen in streams resulting from the discharges of wastewater treatment plants is not well documented. Previous studies have focused on grab samples in streams and composite samples in wastewater treatment plant effluents. The grab samples are snapshots in time, often far and few in between. Wastewater treatment plant samples are generally 24-hour composite samples that obscure the true nitrogen picture by smoothing out the peaks and valleys into a single daily number, an “average” concentration in the effluent. Neither characterize the fate of the nitrogen component (ammonium and nitrate) in the receiving stream or are particularly representative of the varying nature of wastewater treatment plant effluent.

With advent of affordable nutrient sensors that can be deployed in wastewater treatment processes, a new picture of the dynamic nature of ammonia and nitrate in treated wastewater effluents has been revealed. Deploying the Xylem/YSI IQ SensorNet VARiON sensors in wastewater treatment plants has provided high resolution datalogging of ammonium and nitrate concentrations in flow equalization basins, anoxic tanks, aeration tanks, and final effluents. Typically, the datalogging capabilities of the instrument’s controller allows for setting the sampling intervals from as short as one minute up to one hour with datalogging capability up to 150 days. In past deployments, our group set the controller to log at 10-minute intervals for 30-60 days so as not to be overwhelmed with data in any one download.

We have also successfully deployed the IQ SensorNet VARiON (along with IQ SensorNet components Sensolyte (pH electrode) and FDO (optical dissolved oxygen sensor)) in streams, using four deep cycle 12 VDC marine batteries configured to provide 24 VDC. Thus, the IQ SensorNet controller can be deployed remotely with a 24 V power supply, where no 110 V electricity is available. Simultaneous deployment of these low-cost continuous sensors during trials by our team in monitoring operations at small activated sludge wastewater treatment plants and their receiving streams allowed determination of ammonium and nitrate nitrogen concentrations on a seasonal basis, and comparison to compliance with water quality standards. We believe the systematic use of the IQ SensorNet VARiON in the treatment train and in-stream in tandem not only allows for optimization of existing treatment processes, and hence, determination of a plant’s potential to remove nitrogen, but also a mechanism for identifying the vulnerability of receiving streams to ammonium and nitrate nitrogen and enabling improved decision-making regarding these nitrogen components.

B. Team

Our Nutrient Sensor Challenge Team is experienced in all aspects required of this challenge, can consist of the following staff and their affiliations:

Member	Affiliation	Role	Expertise	Responsibility
Jon van Dommelen, P.E.	Ohio Environmental Protection Agency, Division of Environmental and Financial Assistance, Compliance Assistance Unit	Team Leader	Water Quality Monitoring (wastewater treatment), Data management, Communication, Data analysis, Continuous nutrient sensors	Nutrient Sensor deployment, calibration, maintenance, data management, data analysis, presentation development, primary contact
Tyler Linton, Ph.D.	Great Lakes Environmental Center, Inc., Principal Research Scientist	Co-Leader	Water Quality Monitoring (natural surface waters), Data management, Communication, Data analysis	Data analysis, presentation development, secondary contact
Craig Voros, M.Sc.	Great Lakes Environmental Center, Inc., Research Scientist	Technical support	Water Quality Monitoring (natural surface waters), Data management and Information technology, Data analytics	Nutrient sensor deployment, field sampling, data analysis, presentation development
Eric Saas	Ohio Environmental Protection Agency, Division of Surface Water, Central District	Technical support	Water Quality Monitoring (natural surface waters), Data management, Data analytics	Nutrient sensor deployment, field sampling, data analysis, presentation development

C. Current Monitoring

Our group teamed up in 2016 to conduct a study to determine whether small wastewater treatment plants in Ohio could meet the new ammonia criteria being proposed for the protection of freshwater animals, particularly ammonia-sensitive unionid mussels. We deployed Xylem/YSI VARiON ammonium/nitrate electrodes in the effluent of four randomly selected wastewater treatment plants in Central Ohio. We also deployed another Xylem/YSI VARiON instrument in the mixing zone of the receiving stream. This permitted our group to determine the ammonium and nitrate concentrations discharged from the WWTP and characterize the stream's response to this loading. The mixing zone was determined using the conductivity signature from the WWTP effluents as measured in-stream below the plant outfall and downstream until completely mixed with ambient water. The instruments were deployed at each of the WWTPs for one week, in the cold weather of January and February and again later in hot weather of July and August of 2016. Both instruments were datalogging at intervals of 10 minutes, 24 hour/day, for the entire week. The results of this study will be presented in Chicago at WEFTEC 2017 on October 1, 2017.

In addition, Team Leader Jon van Dommelen has extensive experience with the VARiON instruments as well as the other IQ SensorNet instruments. He uses them to troubleshoot non-compliant wastewater treatment plants and to assist the Ohio communities which they serve to return to compliance. He has deployed, maintained, and analyzed the collected data from these instruments for 5 years at WWTPs from 1500 gallon per day up to 15 million gallons per day systems in over 30 different treatment plants in Ohio.

D. Sensors and Monitoring

The team proposes to expand on its novel use of the low-cost, continuous sensors from its earlier work by deploying 3 or 4 VARiON instruments at a single site for long term monitoring of approximately 60 days. For a 3-instrument deployment, we propose to place one instrument in the effluent of the selected wastewater treatment plant. A second VARiON will be placed in the mixing zone in the receiving stream, as determined via the effluent conductivity signature as described above. The third instrument will be deployed far down stream to determine the ultimate fate of the nutrients in the discharge of the wastewater treatment plant. If a fourth instrument can be procured, our intent is to place it upstream of the WWTP discharge to determine the background concentration of ammonium and nitrate. The VARiON in the wastewater treatment plant will be powered by 110 VAC at the plant. Each remote VARiON unit will be powered with four deep cycle 12V marine batteries configured to provide 24 VDC to power the VARiONs (a capability already acquired and validated via use in previous trials). The in-stream VARiONs will be placed in an instrument holder that will keep it submerged in the stream but off the bottom of the stream bed. The cables connecting the instruments to the controller will be weighted and run across the stream bed to the controller and the batteries on the shore. In addition to the VARiONs, it may be possible to add up to two more instruments to each site: a pH probe and either an optical dissolved oxygen probe or a conductivity probe, budget allowing. Temperature is datalogged with the instrument as well as a time stamp for each data point.

To calibrate the ammonium and nitrate electrodes on the VARiON instrument, the manufacturer's procedure is to immerse the instrument in the liquid in which it will be datalogging, and telling the controller to record the millivolt reading at that moment. A sample of the liquid is obtained and then it is analyzed for ammonium, nitrate, potassium and chloride. The potassium concentration is used to compensate for an electrode interference by potassium at low ammonium concentrations. Likewise, the chloride concentration is used to compensate for an electrode interference at low nitrate concentrations. The VARiONs will have a compensating electrode for either potassium or chloride that will automatically compensate the ammonium or nitrate electrode, which ever one is expected to be at a low concentration (usually less than 1 mg/L). This procedure is referred to by the manufacturer as a "matrix adjustment." Matrix adjustments will be performed at a minimum of once per week for the duration of the study. A Hach DR900 Colorimeter will be used for the matrix adjustments. Reagents for the Hach DR900 are the salicylate method for ammonium, the chromotropic method for nitrate, a low-level potassium method, and silver nitrate method for chloride analysis. pH and conductivity or dissolved oxygen calibrations will be conducted per the manufacturer's recommended procedure.

The detection limits for the ammonium and nitrate nitrogen sensor on the VARiON are 0.10 and 100 mg NH_4-N/L, respectively. The detection limits for ammonium and nitrate nitrogen measured colorimetrically are 0.10 and 100 mg NO_3-N/L.

In addition to the concentrations logged by the controller, we anticipate taking grab samples next to the deployed instruments to be analyzed by the Ohio EPA Laboratory or GLEC laboratory on a biweekly basis to confirm accuracy of readings. Use of grab samples in this manner provides an independent check on the matrix adjustment and ensures that that instruments and calibration are within the range necessary for a true duplicate. (Note: this methodology was employed in our previous work with the sensors and with the exception of only a couple of outliers, the samples came back from the lab as true duplicates).

E. Data

1. Solution Architecture

Figure 1 Deployment Schematic

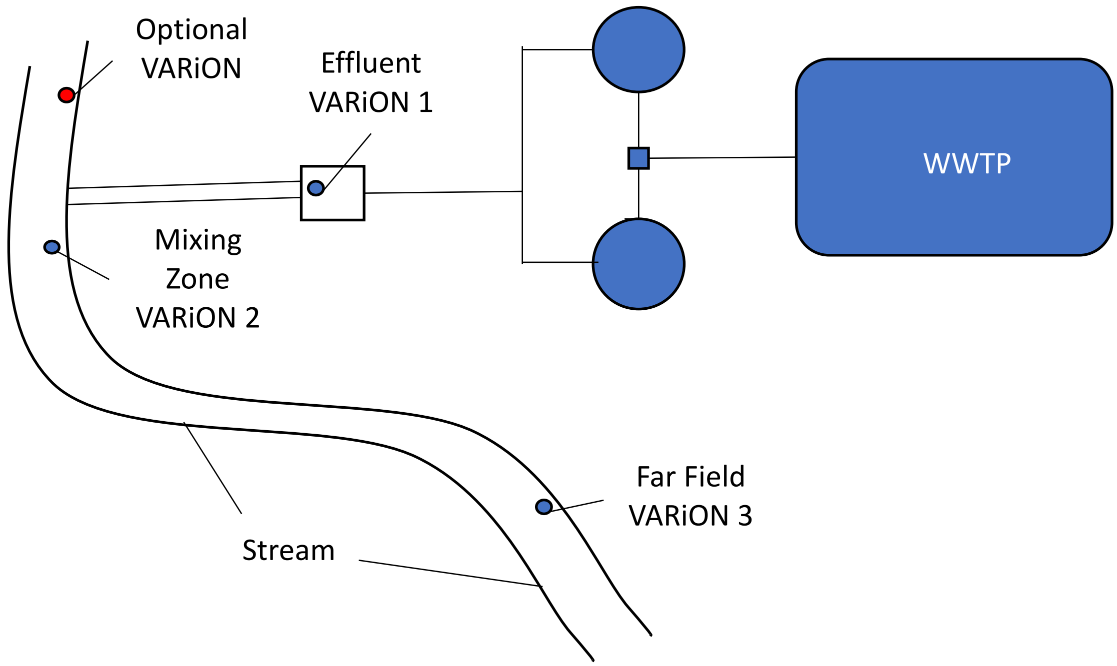


Figure 2: Controller and Instrument Configuration

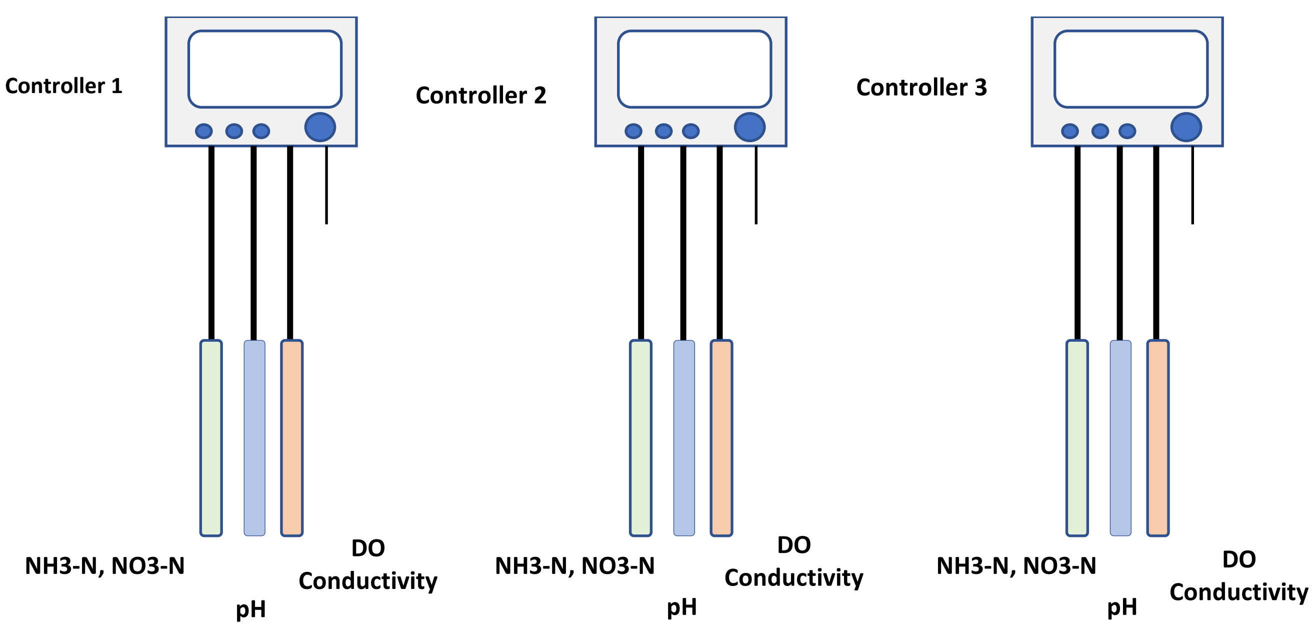
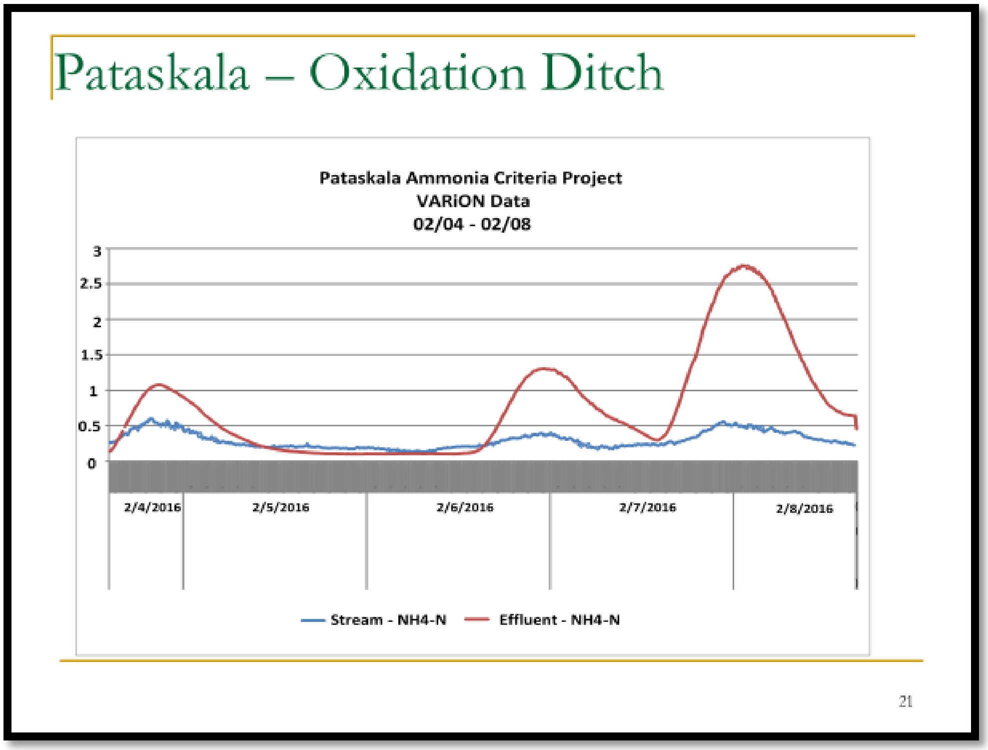


Figure 3: IQ SensorNet Controller in Operation

Figure 4:Battery Configuration for Remote Deployment of IQ SensorNet System

Figure 5: Pivot Table Example of VARiON Ammonium Data



Data that has been logged by the controller can be downloaded from the into a USB memory stick. The downloaded data is formatted as a Microsoft Excel comma separated value (csv) file. This is easily imported into an Excel worksheet (xlsx) on a laptop. We then format the xlsx file so that it can be presented as a Pivot Table and a Pivot Chart for analysis. This workbook containing the Pivot Table and Pivot Chart can then be saved to a shared file such as SharePoint or similar.

2. QA/QC

Per above, we will perform checks with grab samples to confirm the matrix adjustment at a minimum on a weekly basis. The matrix adjustment, the recommended procedure for calibrating the VARiON electrodes, will be analyzed with a Hach DR900 Colorimeter for ammonia, nitrate, potassium and chloride. Additionally, we will run duplicate biweekly grab samples next to each deployed VARiON for analysis by the Ohio EPA Laboratory or the GLEC laboratory. In addition, during the matrix adjustment, standards for ammonium and nitrate will be analyzed as a quality control.

3. Data Sharing

The data that is collected from the VARiON instruments will be formatted and uploaded to a web site that will be accessible for judging. The data will be collected weekly from the various IQ SensorNet controllers associated with each deployed instrument. When the controllers are downloaded the previously downloaded data will be appended, thus ensuring continuity of data for subsequent uploads.

4. Metadata

The IQ SensorNet controller follows a naming convention as indicated below in Table 1:

Table 1: IQ SensorNet Controller Download Format

S04	VARiON	A	13450978	1/6/2016				
Date	Time	Conc Qual	Concentration	Concentration Units	Analyte	Temp Qual	Temp	Temp Units
1/6/2016	13:05	Valid	3.4513	mg/l	NH4-N	Valid	8.86319	°C
1/6/2016	12:55	Valid	3.46332	mg/l	NH4-N	Valid	8.84778	°C
1/6/2016	12:45	Valid	3.48956	mg/l	NH4-N	Valid	8.83881	°C
1/6/2016	12:35	Valid	3.48874	mg/l	NH4-N	Valid	8.82336	°C
1/6/2016	12:25	Valid	3.49355	mg/l	NH4-N	Valid	8.80807	°C

The first row of column headers includes the sensor location in the controller (S04), the ion specific electrode (A for ammonium), the VARiON serial number (13450978) and download date (1/6/2016). The second row contains the column header for the data set. Note that the columns “Conc Qual” and “Temp Qual” have been inserted by the user for data base and Pivot Table use. Additional columns and data headers will be added as necessary to ensure that the NWQMC format is consistent.

Additionally, the team intends to place the data into an Excel Pivot Table for its own use. The team finds that the flexibility of using Pivot Tables and Pivot Charts is particularly useful when analyzing large data sets. In particular with the IQ SensorNet instruments, the Pivot Chart has become the most useful illustrator of the interrelationships between VARiON stations.

F. Analytics and Interpretation

The data from the controller is downloaded as an Excel Comma Separated Value file for each electrode. This data is easily imported into and Excel workbook (xlsx file) and then can be presented in a Pivot Table and Pivot Chart. By plotting the dense data into a Pivot Chart, the relationships between the WWTP effluent VARiON and the two downstream VARiONs will be clearly revealed. Also, because the features of the Pivot Charts allow filtering of the plots for sites, parameters and dates, areas of interest are easily explored and analyzed.

G. Communication and Use

The data that is obtained from the Nutrient Sensor Action Challenge will provide high resolution information regarding the interaction between wastewater treatment plants and receiving streams with regard to the fates of ammonium and nitrate concentrations. This data will be made available to the Water Quality modelers in Ohio as well as other interested states and governmental agencies. The data will likely be presented at State, Regional and even National Conferences as a new approach to water quality data collection as well as the ultimate fates of ammonium and nitrate in streams.

Conclusion

Ohio EPA and Great Lakes Environmental Center, Inc., with project sponsor City of Johnstown, Ohio and its partners, successfully prototyped the deployment of the Xylem/YSI IQ SensorNet system and the VARiON ammonium and nitrate electrodes in natural streams in Ohio on a short-term basis in 2016. Our Nutrient Sensor Action Challenge proposal will take what we have learned during the prototype deployment and will expand the deployment of this monitoring system for a longer period (up to 60 days) to characterize the ammonium and nitrate characterization of a small stream long term.

The ammonia and nitrate data that we collect through our Nutrient Sensor Action Challenge proposal could be useful for more complete characterization of specific nitrogen components in existing platforms such as the Ammonia Toxicity Model (AMMTOX, Version 2a), A Tool for Determining Effluent Ammonia Limits (Lewis, W.M., Jr. et al. 2002, University of Colorado, Center of Limnology) in order to refine the predictive quality of the model. In addition, it may also provide a better nutrient characterization as an input to Ohio’s Stream Nutrient Assessment Procedure (SNAP) process by yielding a higher resolution to the fate of nitrogen in a receiving stream. Finally, the high-resolution data, datalogged continuously every ten minutes, will provide unique insights into the dynamic interaction between wastewater treatment plants and receiving streams with respect to inorganic nitrogen.