Global Water Futures 2021 Operations Team Meeting – Project Reporting Template

Instructions: All GWF projects are asked to provide a summary update on their activities and accomplishments in preparation for the upcoming Operations Team meeting. **Please submit these by email to chris.debeer@usask.ca by no later than December 2.** These will be used to help guide discussions and breakout synthesis activities and will be made generally accessible on our website in advance of the meeting.

Project Name:	Sensors and Sensing Systems for water quality monitoring

Our major accomplishments to date are:

Major achievements of sensors and sensing water quality monitoring system are completion of sensors prototyping, lab testing, and their field deployment (in a limiting way, deployment delayed, and impacted by COVID 19). Some of the highlights are:

- A highly sensitive solid state phosphate sensor was developed. A new electrochemical sensing approach to phosphate can allow detection as low as 10^-7 M. Prototype is ready to be field tested. This work has led into a new startup company "Phosphosense".
- A novel pre-concentration approach for sensitive colorimetric monitoring of trace level detection of Copper and Iron has been established using passive aliquoting and cost effective-readily available materials. This method can detect copper at 10 ppb, and experiments are ongoing for low level lead (at 1-10 ppb levels) detection.
- A chemiresistive sensor that utilized exfoliated graphite to form a few-layer graphene (FLG) film is developed to detect trace levels of copper, and silver cations in aqueous solution. Detectable range for silver ions is in range of 3-1000 ppb in solution. When tested in environmental waters (Spencer Creek, Hamilton ON), recovery values were similar to that obtained by ICP-MS. Work is underway to identify suitable ligands detect lead in aqueous solution.
- A working DNAzyme GR5 sensor has been developed for bioavailable fraction of lead sensing. DNA-zymes is found to respond to Pb2+, PbOH+, and PbCl+ species. DNAzyme can be used for understanding the effect of dissolved organic matters (DOMs) on metal binding and sensing.
- LoRa sensors, and enclosures for long-term continuous housing of sensors are designed for continuous monitoring of water quality along rivers and creeks of Six Nations. Biofouling in the lab on sensors is simulated to identify impact of biofouling and establishing ways to eliminate fouling on sensor surfaces.
- Fluorescent sensor to detect low concentration cyanobacteria has been successfully achieved to measure Chl-A and multiple algae species (Spirulina, Chlorella, mixed species) and tested at field site (Buffalo Pound). This has important application for early warning of potential cyanobacterial blooms.
- Efficient communication protocol and Dynamic clustering algorithm for IoT-UAV platform developed and tested at lab. IoT WSN for wide area remote monitoring (WARM), developed full IoT platform with LoRa connectivity; tested at North SK River site; fully deployed and working
- Performance analysis of LWC algorithms for IoT platform; developed and tested at the lab; field trial not possible due to COVID-19.

- A prototype for new and improved portable microwave sensor coupled with microfluidic chip and palm-size signal analyzer has been developed for detection of lead at 1 ppb concentrations in water.
- A fully integrated free chlorine sensing system that include reagent-less operation with reusable sensing electrodes, and complete elimination of pH and temperature calibration has been developed to measure free chlorine with high sensitivity. The free chlorine sensor has also been demonstrated in preliminary fashion in Six Nations to be used in different community locations for measuring free chlorine in drinking water. The validation of the sensor system and training of the use of the sensor system are undergoing right now, which was delayed due to Covid-19 restrictions.
- The development of the field version of the oxygen sensing system has been completed, in partnership with Hoskin Scientific Ltd. The Multi Fiber Optode (MuFO) microsensor, and photo-logging systems were deployed in two agricultural field-controlled lysimeter systems located at University of Guelph's Elora Research Station and the subsurface Oxygen (O2) dynamics together with soil and air temperature, snow, precipitation, moisture content, and pore water geochemistry are monitored over four seasons (October 2018 to August 2019). The analyses of porewater samples from the lysimter experiments is completed in February 2020 using Ion Chromatography (Dionex ICS-5000), Inductively-Coupled Plasma Optical Emission Spectrometry (Thermo iCAP 6200 Duo ICP-OES), and a TOC analyzer (Shimadzu TOC-LCPH/CPN).
- Libelium based network has been deployed in lakes downstream of mining operations in collaboration with Orano (previously Areva Resources, a uranium mine in northern Saskatchewan). Functioning water quality sensors for temperature, dissolved oxygen, pH, ORP, turbidity and conductivity, calibrated in the Aquatic Toxicology Research Facility (ATRF) have been used in this study. Analysis of all samples from 2019 is now completed and analysis of water samples collected from McClean Lake during March 2021 are presently being processed. The outcome of these analysis will help elucidate the research hypotheses of seasonal differences (summer vs winter) in selenium bioaccumulation and trophic transfer.
- The first Phase of the Virtual reality (VR) storytelling experience is completed. The experience utilizes a virtual sensor and water quality station at the knowledge center to train users on water quality analysis. Demos can be viewed on the Ohneganos website.
- The project team has been working with our partners at Mohawk College to develop a local water treatment plant operator training curriculum at Six Nations that incorporates Indigenous and Local Knowledge (ILK) as well as Traditional Ecolocial Knowledge (TEK). A program for high school students has been approved by the Ministry of Environment, Conservation and Parks.

Our current activities are:

- Field testing of some of the sensors prototypes and analysis of pending samples. Some sensors are in the final stages of their development.

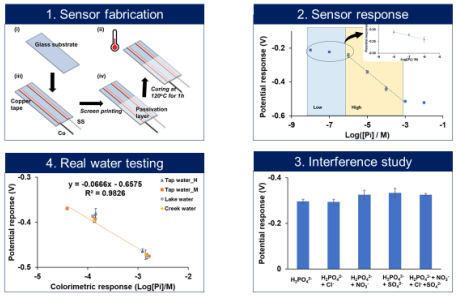
The main accomplishments expected by the end of the project are:

- Completion of all pending projects including field work and sample analysis.

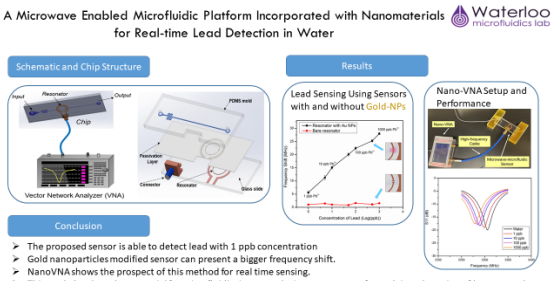
Here is a key visual from the project (figure, photo, table, graph, etc.)

- Phosphosense: Link

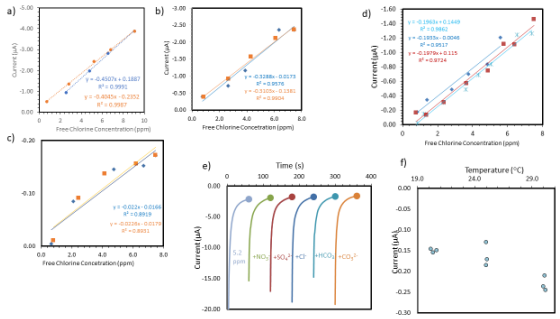
Phosphate sensor:



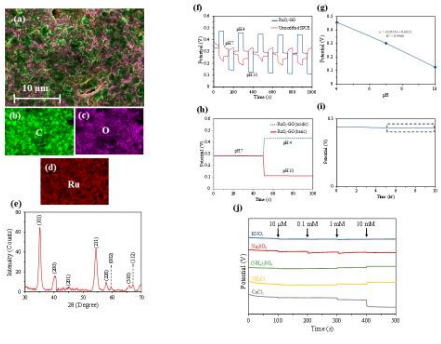
Microwave Sensor

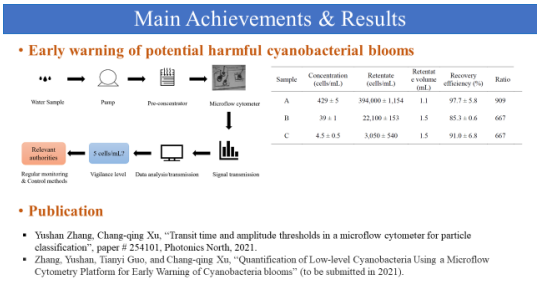


GO-Sensor:



PH-Sensor





Sensors and Sensing Systems for Water Quality Monitoring

Dr. Dawn Martin-Hill (Co-PI)

Main Objectives:

1. Facilitating sensor system installation & training in Six Nations
2. Environmental monitoring capacity building for youth
3. STEAM and TEK training and education

Highlights:

- Facilitating free chlorine sensor testing and validation & training with SNHS.
- Ohneganos Let's Talk Water (Slide 2)
- Virtual Reality Experience (Slide 3)
  - Water testing & sensor training through interactive/experiential learning in cultural setting.
- McMaster Continuing Education Certificates of Completion
  - For GIS mapping, sensor monitoring, VR development, digital stories.
  - Accreditation agreement (i.e., 4 CoC for a post-secondary credit).
- Indigenous students and community members coordinating initiatives.
  - Christopher Martin – Community Mapping Facilitator for digital Indigenous map (Terrastories, MAPEO, community workshops, etc.); Supporting/facilitating Lotka water quality sensor installation in streams.
  - Denise McQueen – Coordinator of Community Engagement for KGPS Haudenosaunee science guidebook; bi-lingual framework developed.
  - Makasa Looking Horse – Community Outreach Officer and Ohneganos Youth Lead. Coordinating external partnerships with Ohneganos initiatives; Let's Talk Water host; Facilitating turtle sensor deployment; author for children's book ('Water Protecting').

Key Partners and Collaborators:

Local Schools: SNP STEAM Academy, Kawennón:no/Gaweni'yo Private School

Institutions/Organizations: Mohawk College, McMaster University (CCE, ISP, etc.), Waterfution, Wellington Water Watchers, SHAD Canada, Carolinian Canada.

Key Outcome

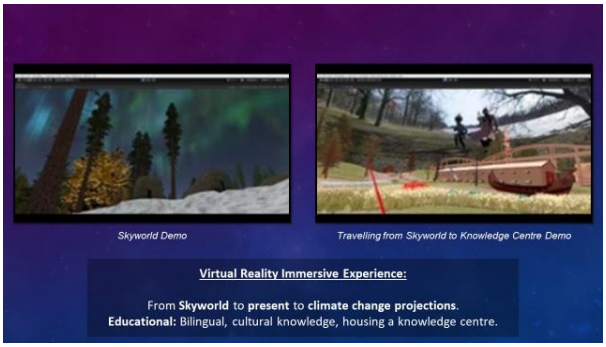
OHNEGANOS: Let's Talk Water

Production Team: Makasa Looking Horse, Kathryn Chen, Hannah Grewal

- Youth-led live video podcast (vodcast)
- Produced 28 episodes as a training, knowledge production, and research dissemination tool.
- Won the David Suzuki Future Ground Prize (People's Choice award)

https://www.ohneganos.com/

https://www.youtube.com/c/OhneganosOhnegahd%C4%99g9



Skyworld Demo

Travelling from Skyworld to Knowledge Centre Demo

Virtual Reality Immersive Experience:

From **Skyworld** to **present** to **climate change projections**.
Educational: Bilingual, cultural knowledge, housing a knowledge centre.

USask-Liber Results

- An autonomous sensor network was deployed downstream from a mining/milling operation in Saskatchewan for 1-2 months during the summers/early fall of 2018-2020.
- Effluent distribution was spatially variable and did not follow an easily predictable pattern across monitoring locations, although conductivity did generally decrease with downstream distance from the discharge point.
- Real-time conductivity data from the sensor network was successfully applied as a surrogate parameter to estimate aqueous selenium and arsenic exposure in a boreal lake downstream from the mining operation.
- The estimated risk for aqueous arsenic toxicity from sensor data was considered low and should not adversely affect aquatic invertebrates in downstream lakes.
- Selenium bioaccumulation potential at the base of the food chain, from sensor-estimated aqueous selenium concentrations, was used to derive a site-specific threshold for selenium in surface waters.
- Selenium concentrations in most benthic macroinvertebrate taxa exceeded published selenium benchmarks at sites with greater effluent exposure. A monitoring approach was proposed to assess selenium bioaccumulation potential in lakes impacted by the mining operation.

Bioavailable Metal Sensing

Bioavailable metal (Pb) sensing using DNAzymnes (GR5)

Figure 1: Secondary structure of DNAzyme GR5 (left). Cleavage site is represented by the arrowhead. Schematic representation of the metal induced cleavage reaction (right). Pb^{2+} is used to induce cleavage. F and Q labels indicate fluorescein amidites - labeled fluorophore and quencher respectively.

$$[Pb^{2+}] = \frac{K_{obs}}{m1 + m2K_{OH}[OH^-] + m3K_{Cl}Cl_T}$$

Equation for the calculation of ionic lead based on measured rate constant of fluorescence signal (Figure 1 see F) and calibration parameters m1 for Pb^{2+} response, m2 for $PbOH^+$ response, m3 for $PbCl^+$ response and thermodynamic binding parameters K_{Cl} and K_{OH} and total chloride (Cl_T).

Figure 3 →
WHAM predicted [Pb^{2+}] compared to measured data, using k_{obs} and best-fit parameters of the 3 most important inorganic species using the multiple linear regression calibration equation. The dashed line represents 1:1 with an r^2 value of 0.883. The different water chemistries and electrolytes are indicated in the legend to the right of the figure.

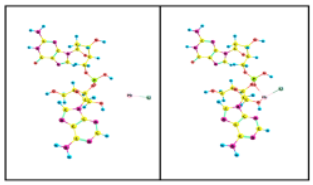


Figure 2: DFT structure showing the interaction between GR5 and $PbCl^+$ at the proposed binding site. The formation energy was found to be -0.075 eV and is thus expected to represent a stable complex.