Field validation of DNA-based biosensor for rapid detection of ultra-trace mercury(II) in natural waters

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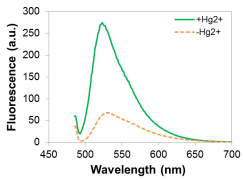
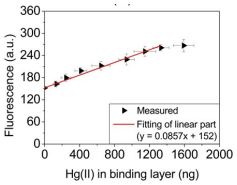
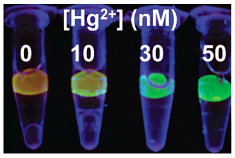
V. How sensitive is the sensor?



Sensor test with (green)/ without (orange) 1 μM Hg^{2+} in pH 8 buffer

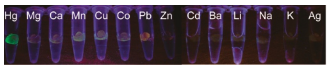


Calibration curve for DNA-DGT sensor



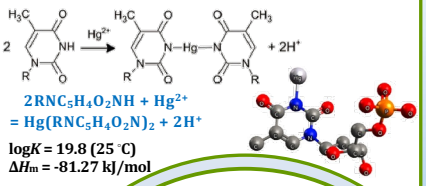
- Integration with DGT device enables very low detection limits, e.g., **0.55 μg/L** after 8 h deployment.
- Good linear calibration curve for Hg^{2+} up to **1400 ng** Hg in the binding layer, enabling wide range of applications.

IV. How selective is the sensor?



Test: 1 μM of various metal ions

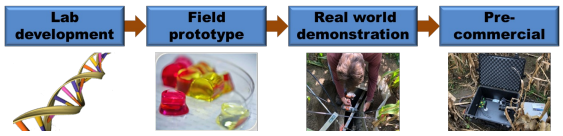
- Only Hg^{2+} produces green fluorescence → **high selectivity** for Hg^{2+}
- Strong affinity of Hg^{2+} complexation by two thymine groups in the customized DNA

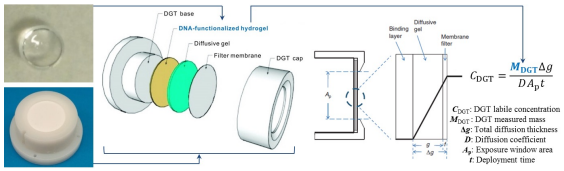


$2RNC_5H_4O_2NH + Hg^{2+} = Hg(RNC_5H_4O_2N)_2 + 2H^+$

log*K* = 19.8 (25 °C)
ΔH_m = -81.27 kJ/mol

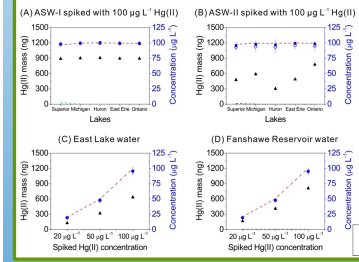
III. Solution: smart sensors for real waters



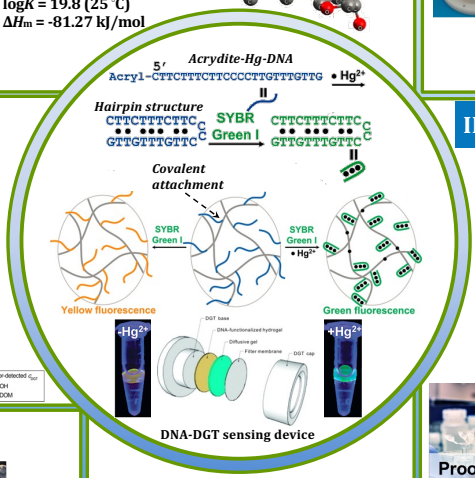


User-oriented value chain:
from lab concept to real-world application

VI. Performance under field conditions?



- **97%** Hg(II) in water, irrespective of speciation, is captured in the sensor's binding layer.
- The remaining **3%** Hg(II) is handled by equilibrium speciation calculations

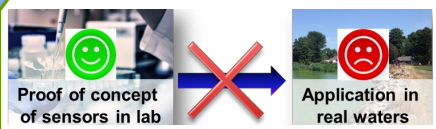


II. Why use DNA for sensing?

- Existing Hg assays are laboratory-based, time-consuming, expensive, and lack flexibility for routine in-field use.
- Conventional methods offer limited outlook for high-resolution monitoring and early warning.
- However, new sensor ideas often don't make it beyond the laboratory proof-of-concept.

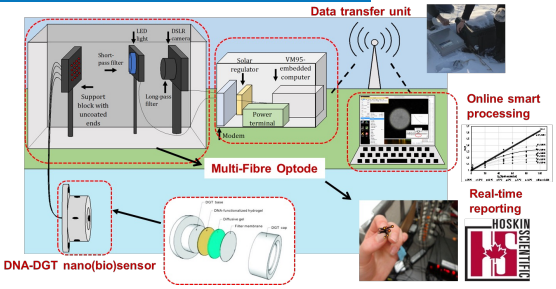
"Conventional" water quality monitoring

Highly expensive
Time consuming | Laborious
Limited accessibility | Offline | Frequent artifacts



Needed: validation of in-situ sensors

VII. Commercialization potential



Smart Water Quality Sensor Systems

- DNA/RNA-based nanosensors can be tailored to detect almost any metal/metalloid in natural waters with high selectivity and sensitivity.
- Combined with speciation models, remote data transfer, and field-proofing, the sensors perform reliably even under harsh field conditions (e.g., winter).
- A 9% mean annual growth rate is expected for global market of water quality sensors and even higher rates for field-deployable sensors.

- **References**: [1] Chumchal *et al.* (2011) *Environ. Toxicol. Chem.* **30**, 1153–1162. [2] Zhou *et al.* (2017) *Chem. Rev.* **117**, 8272-8325. [3] Dave *et al.* (2010) *JACS* **132**, 12668-12673. [4] Pi *et al.* (2020) *J. Hazard. Mater.* **385**, 121572. [5] Pi *et al.* (2020) *ES&T* **54**, 13680-13689. [6] Zhao *et al.* (2022) *TrAC* **153**, 116639.
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I. Hg is a problematic contaminant

- Mercury (Hg) is a highly neurotoxic metal with bioaccumulative potential.
- Hg is a global pollutant in water, soil & air, severely threatening water quality & human health.
- Hg legacies remain a great threat in Canada (e.g., Grassy Narrows) and abroad.
- Routine monitoring of Hg in waters, particularly as oxidized Hg(II), can enhance water and food security around the world.