A Smartphone-Based Colorimetric Sensor for Household Lead Detection

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Background

- Lead poisoning is related with the damage of brain function and nervous system
  - Children are at a greater risk for lead poisoning than the adults
  - There is NO safe level for lead exposure
- A significant source of lead emission to tap water is via pipe corrosion during water distribution
- In Chicago, around 80% of the households are receiving tap water supplied through lead service lines

Materials and Method

Water Sampling

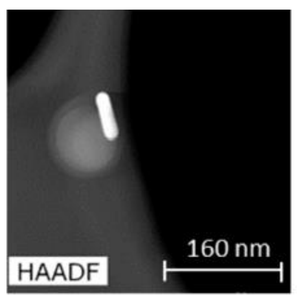
- 22 drinking water samples collected from the *south side of Chicago*
  - First-draw sample: minimum 6 h stagnation time required
  - Flush sample: having the water run for ~3 mins before sample collection

Water Sample Analysis

- Water matrix
  - pH
  - Conductivity
- Instrument analysis for Pb
  - Inductively coupled plasma-tandem mass spectrometry (ICP-MS/MS)

Sensor Development

- Janus gold nanorods (AuJNRs)
  - Gold nanorods partially coated with silica
- Localized surface plasmon resonance (LSPR)
  - Collective oscillation of conduction electrons
  - Basis of plasmonic colorimetry



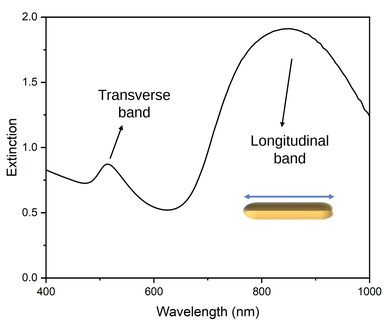
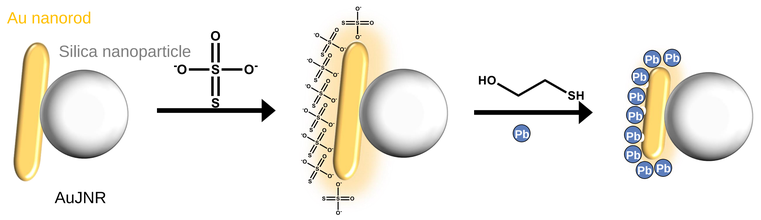


Figure 1. (a) Transmission electron microscopy image of AuJNR; (b) ultraviolet-visible (UV-Vis) spectrum of AuJNR colloid.

Sensing Principles



Scheme 1. Mechanism of colorimetric lead sensor based on gold leaching.

$$4Au^0 + O_2 + 2H_2O + 8S_2O_3^{2-} \rightarrow 4Au(S_2O_3)_2^{3-} + 4OH^-$$

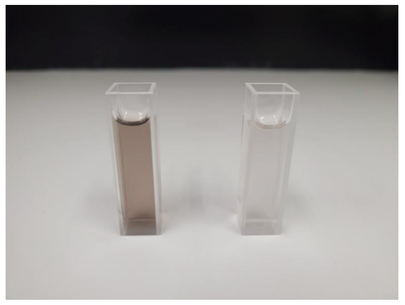


Figure 2. AuJNR colloid before (left) and after (right) leaching induced by lead ions. The color change can be detected by UV-Vis spectroscopy.

Water Sample Characterization

- **pH**: 7.583-8.850
- **Conductivity**: 297-314 µS/cm
- **Lead concentration**: 0.02-10.62 ppb

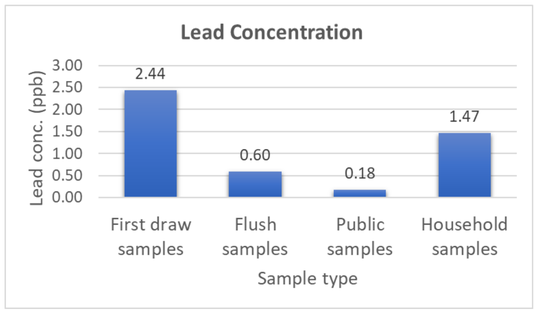


Figure 3. Average lead concentrations of the first-draw vs. flush and public vs. household samples.

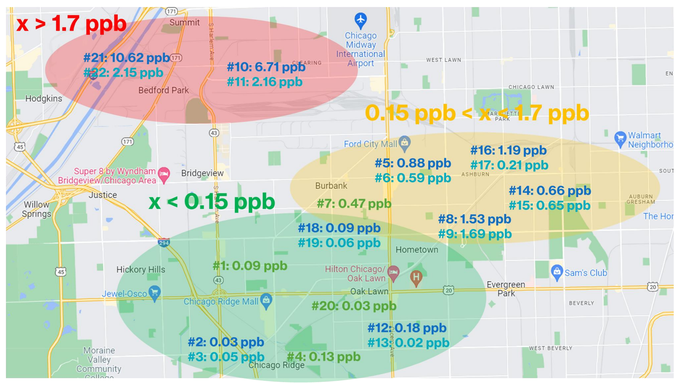


Figure 4. Spatial trend of lead concentration in drinking water collected from the *south side of Chicago*. The sampling sites were clustered into three distinct groups based on the lead concentration of flush samples. The green cluster represents the area with the lowest level, while the red cluster indicates the area with the highest concentration.

Sensor Verification

Stability Test

- In Madison tap water (conductivity = 752 µS/cm)

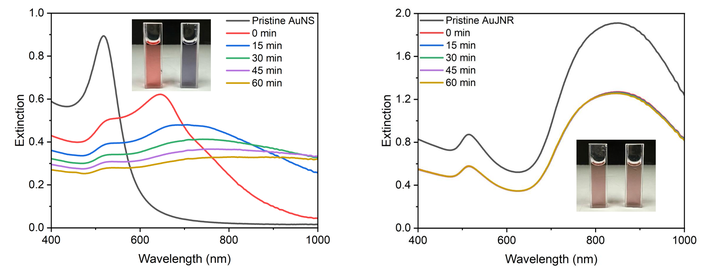


Figure 5. UV-Vis spectra of mixture of (a) gold nanosphere (AuNS) and (b) AuJNR colloid with Madison tap water in 1 h. Inset photos are (a) AuNS and (b) AuJNR colloid before (left) and after (right) mixed with Madison tap water.

Sensitivity Test

- There was a significant decrease in longitudinal band, indicating the shortened length of AuJNRs.

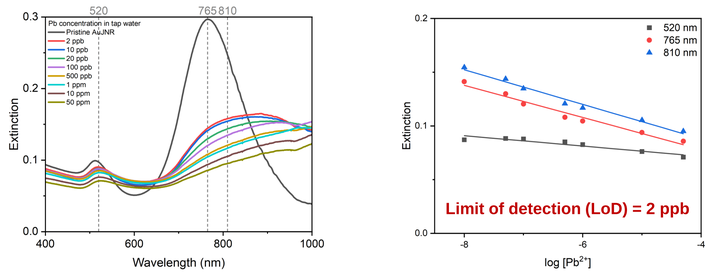


Figure 6. (a) UV-Vis sensing results of Pb-spiked Madison tap water; (c) linear regression of extinction indicators vs. lead concentration.

Future Works

- Further developing the sensor into smartphone-based applications for household detection in virtue of image analysis tools
- Verifying the sensitivity of the current sensors using Chicago tap water samples

Findings

- There was a clear spatial trend of drinking water lead level in the *south side of Chicago*
  - Summit, IL region – a low-income community with relatively high Hispanic population (76.1%), and Black or African American population (8.7%) – was detected with the highest lead concentration in drinking water, which raised concerns about the potential environmental injustice
- The AuJNR-based colorimetric sensor exhibited superior stability at high ionic strength
- The sensor demonstrated high sensitivity towards Pb^{2+} in tap water with a LoD of 2 ppb (EPA Maximum Contaminant Level: 15 ppb)