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Determination of Trace Lead, Cadmium, and Arsenic (III) in Municipal Wastewater by Anodic Stripping Voltammetry

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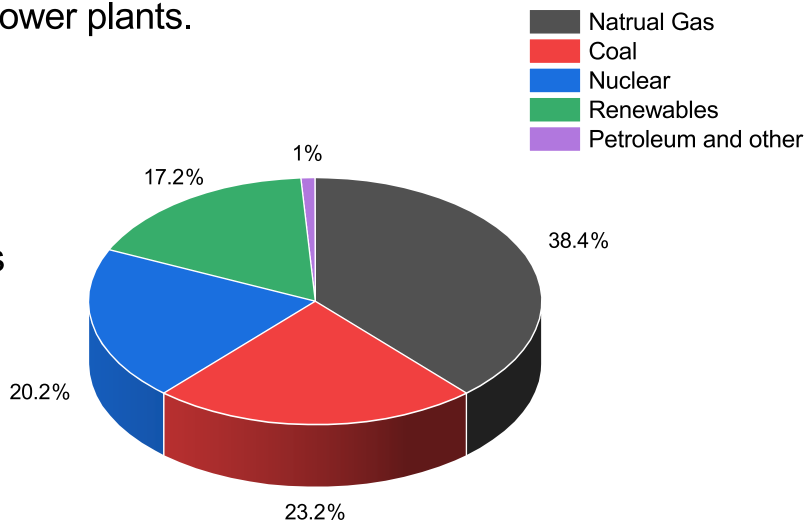
Outline

- Introduction
- Methods
- Results & Discussion
- Conclusion

Water-Energy Nexus

- 83% of electricity in the USA is produced by thermoelectric power plants.
  - Fossil-fuel power plant
  - Nuclear power plant
- Water is a critical component of thermoelectrical plants
  - Electricity generation
  - Cooling

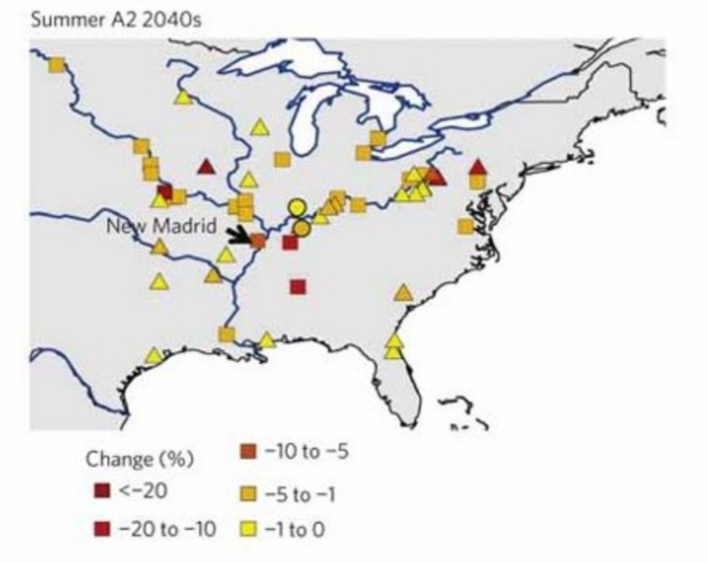


U.S. Electricity generation by major energy source (2019)

Source: The U.S. Energy Information Administration (EIA)

Alternative Water Resource

- Water scarcity
  - Related to Climate change
  - Caused a drop in electricity production
- Municipal wastewater (MWW)
  - Widespread availability
  - Relatively uniform quality



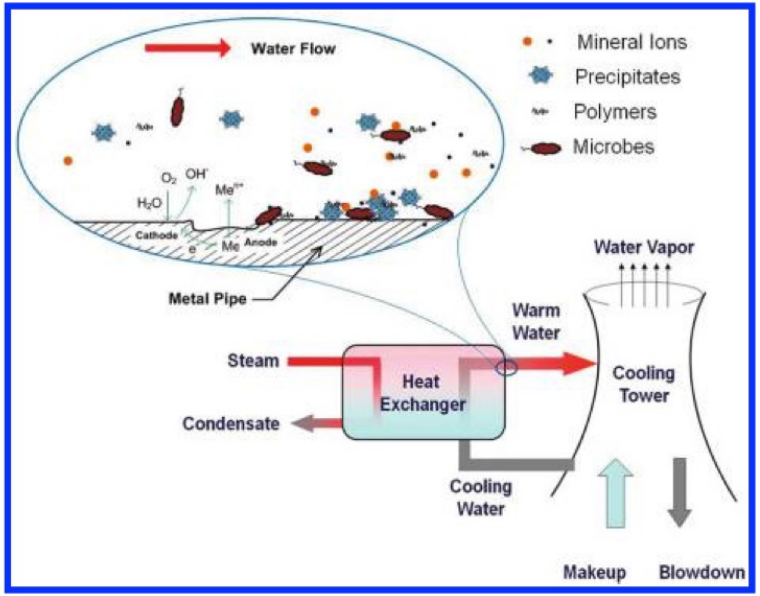
Projected decreased water resources for thermoelectrical plants

(Van Vliet et al., 2012)

Challenges with MWW

- Metal Pollutions in Cooling water
  - Metals introduced from pipe corrosion
  - Metals existing in MWW

There is a strong imperative to frequently monitor heavy metals.

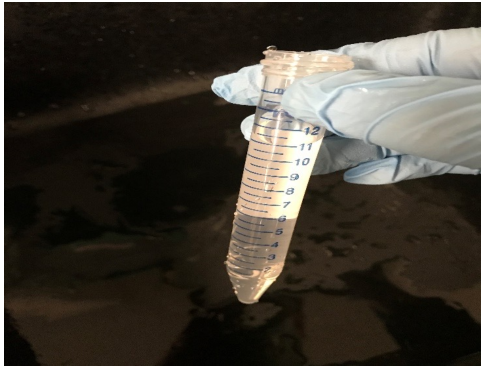


Metal pollutions introduced from the pipes

(Li, Chien, Hsieh, Dzombak, & Vidic, 2011)

Challenges with Metal Detection

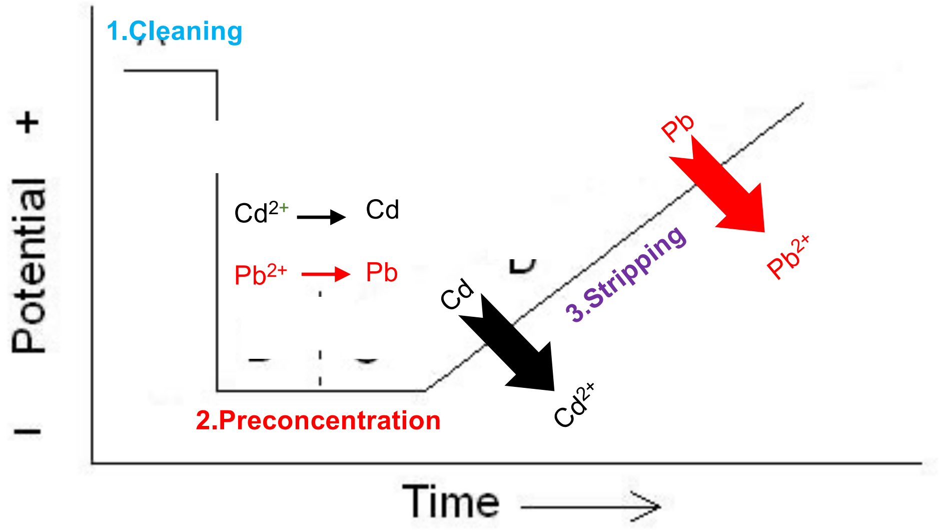
- Limitations of mature metal detection techniques
  - Expensive
  - Dedicated staff required
  - Grab-sampling required
  - Lengthy processing



The device that could autonomously conduct metal measurements is desirable.

Anodic Stripping Voltammetry (ASV)

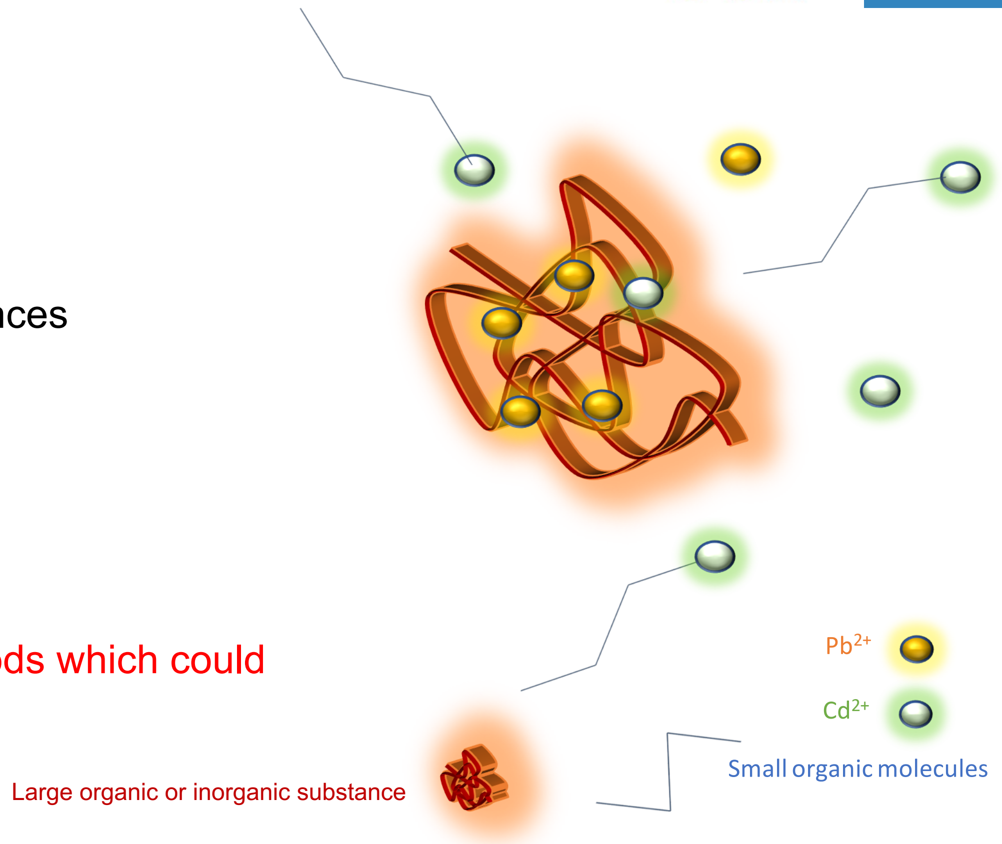
- Advantages
  - Low-cost
  - High sensitivity
  - Easy to be miniaturized
  - Easy to be automated
- Limitation
  - Only ionic metals are ready for ASV detections



Metals in MWW

- Complex with natural organic substances
- Bind with inorganic substances
- Absorbed by various components

Important to develop pre-treatment methods which could release metal ions

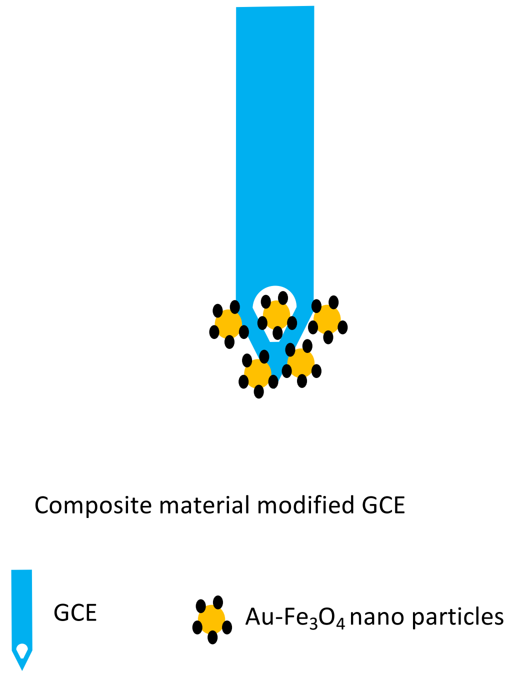


Methods

- Electrode synthesis
- Pretreatment Method Investigations

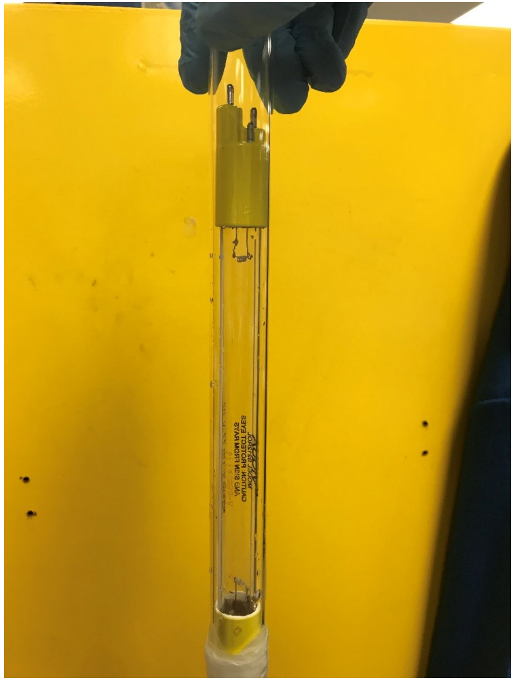
Electrode Fabrication

- Arsenic detection
  - Au-Fe_3O_4 modified glassy carbon electrode (GCE)
    - Increase conductivity and arsenic sorption ability
- Pb and Cd detection
  - $(BiO)_2CO_3$-rGO-Nafion modified GCE
    - $(BiO)_2CO_3$ facilitates the preconcentration of Pb and Cd
    - rGO increases the conductivity
    - Nafion enhances structural stability



Pretreatment

- Acidification
  - Dissolve inorganic substances
  - Precipitate humic acid
- Ultraviolet (UV)/H_2O_2
  - Produce hydroxyl radicals (*OH)



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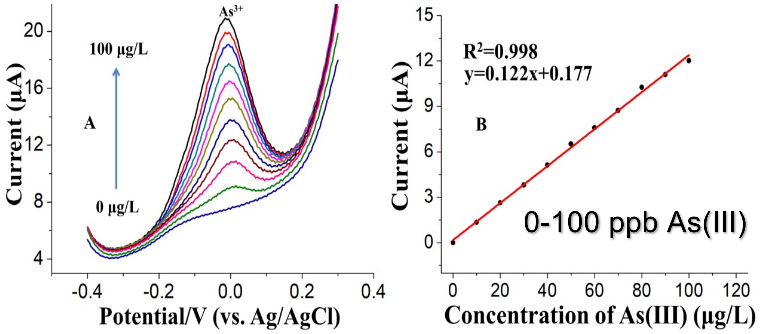
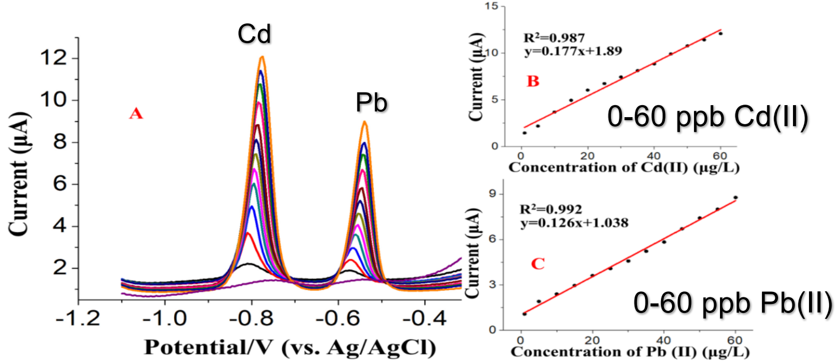
Results & Discussion

- Performances of electrode
- Automation

ASV Performances in DI water

- The response peaks increased linearly with increasing concentrations, with well-defined stripping peaks observed.
- The limit of detection is very low (i.e., we could achieve a high sensitivity)
  - Pb: 0.24 ppb << (Discharge limit: 2.5 ppb)
  - Cd:0.16 ppb << (Discharge limit: 0.7 ppb)
  - As: 0.22 ppb << (Discharge limit: 150 ppb)

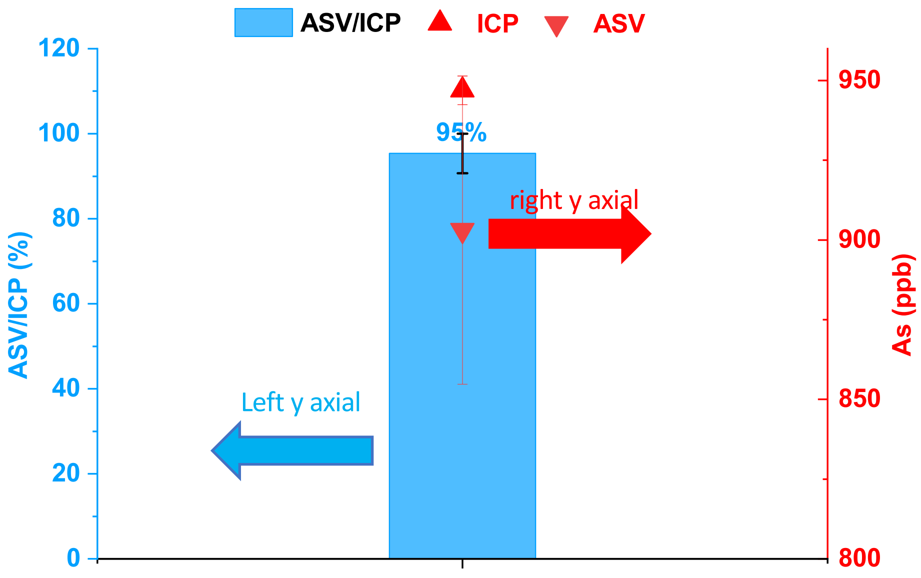




ASV Performances in MWW

As detections

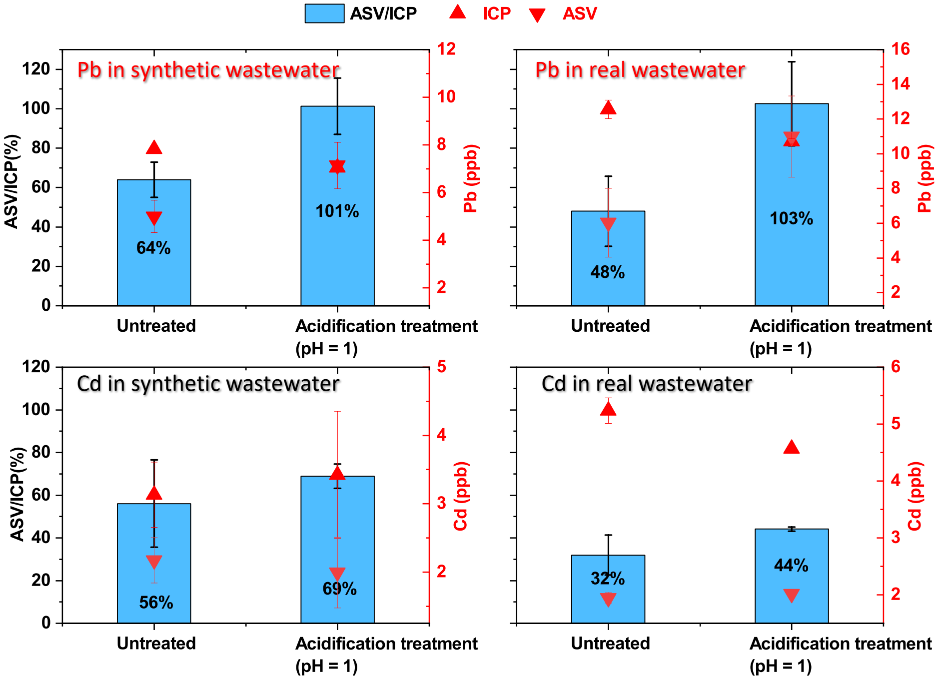
- ASV could directly detect ~900 ppb As(III) in MWW without any pretreatment
    - As(III) has a high pKa (9.23), which makes it very mobile.



ASV Performances in MWW

Acidification for Pb detections

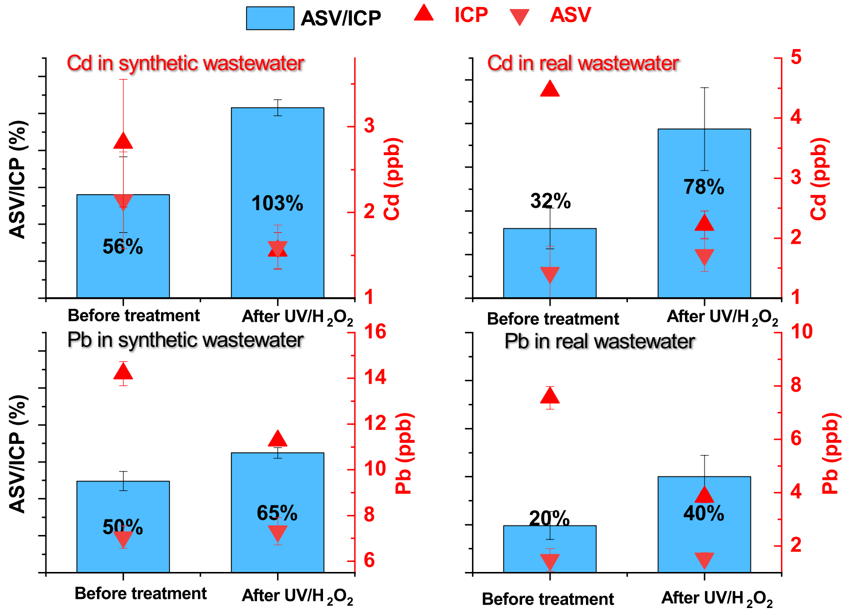
- Acidification treatment enabled 12.5 ppb Pb in MWW detected by ASV, while acidification failed to make Cd detectable.



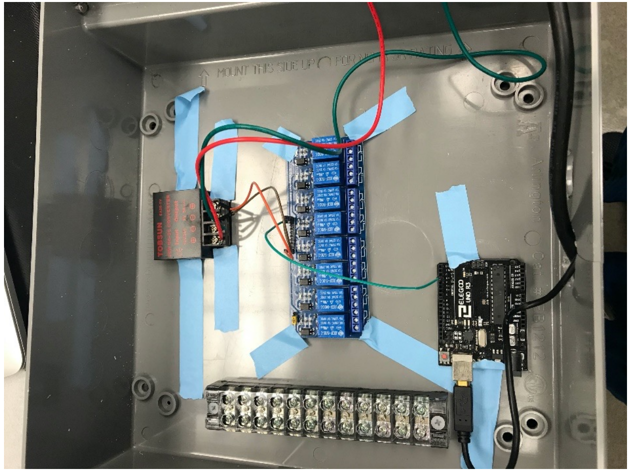
ASV Performances in MWW

UV/H_2O_2 for Cd detection

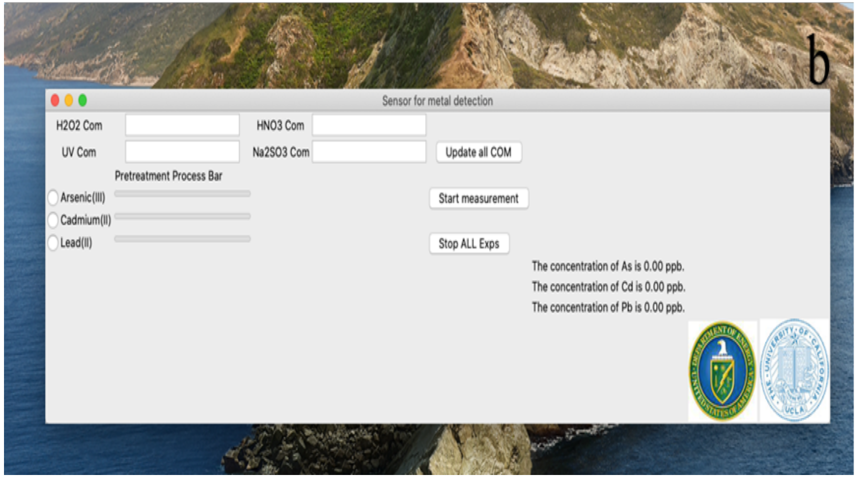
- UV/H_2O_2 treatment made ASV successfully detect most of 3.5 ppb Cd, while it failed to make 12.5 ppb Pb detectable.



Automation



Arduino-based hardwater



Python-based software

Conclusions

1.Our nano-material based ASV methods successfully detected all trace As(III) (i.e., ~900 ppb) in wastewater without pretreatment.

2. Acidification (i.e., adjust pH to 1) pre-treatment methods enabled the detection of trace Pb (~12.5 ppb) by ASV in wastewater.

3.A UV/H_2O_2 pre-treatment process enabled the detection of trace Cd (~3.5 ppb) by ASV in synthetic wastewater. However, ASV only measured 78% of Cd in real wastewater, and a systematic error was observed. We will solve it via using glass reactors.

4.The whole process could be automated by integration of open-source software (Python) and open-source hardware (Arduino).

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Questions?

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