

Palladium-Based Bimetallic Catalysis and Applications in Groundwater Remediation

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Overview

- Problem Statement
- Current Methods and Solutions
- Summary of Research Novelty and Use
- Screening Test
- Previous Batch Results
- Future Goals

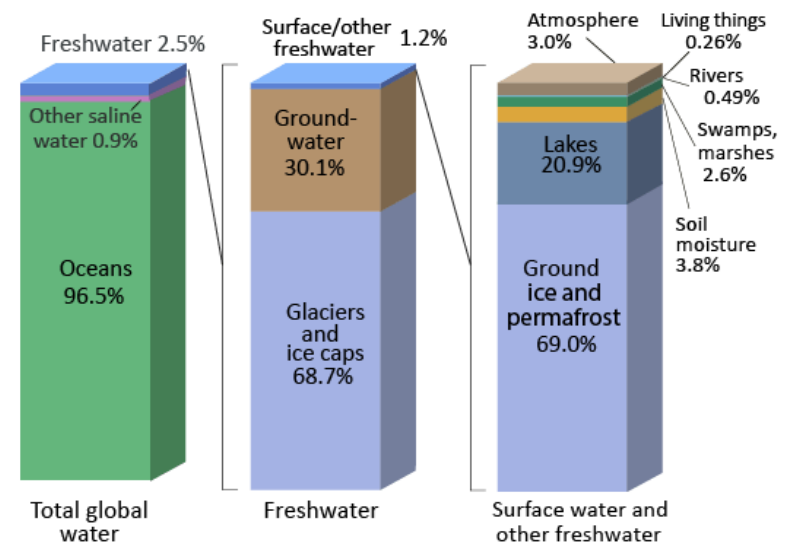
71% of Earth's Surface

...Water!

The following:

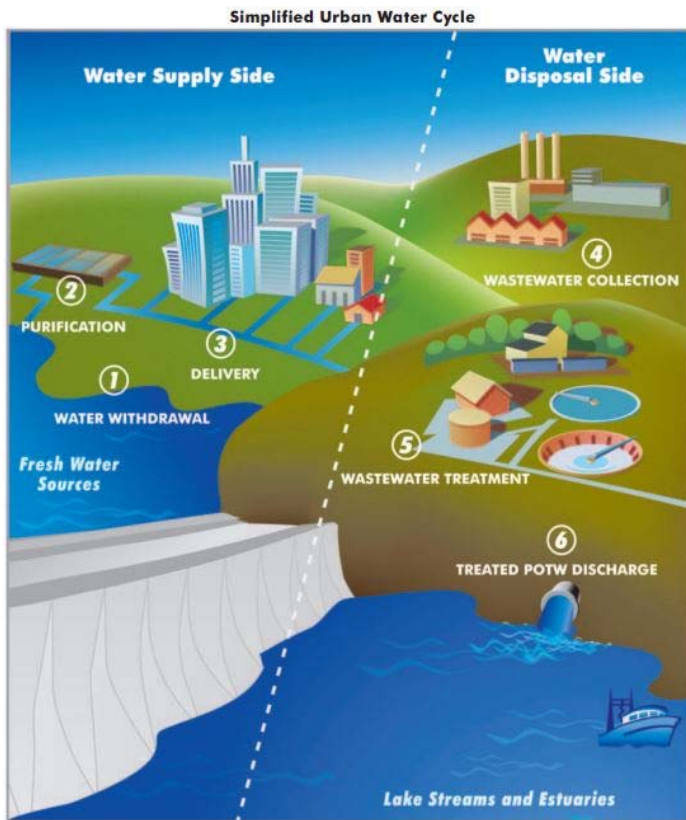
- Freshwater Rivers,
 - Swamps/Marshes,
 - Lakes
- ... only make up 0.0072% of all of Earth's water! [1]

Where is Earth's Water?

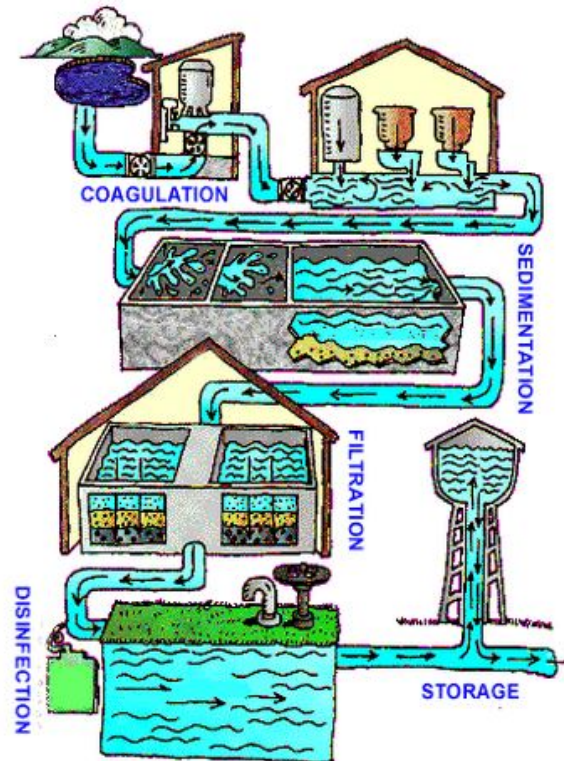


Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, *Water in Crisis: A Guide to the World's Fresh Water Resources*.
NOTE: Numbers are rounded, so percent summations may not add to 100.

Current Treatment Methods



Source: [2]



Source: [2]

- Many methods
- Waste treatment is the big problem
- Still not enough water!

Groundwater Contaminants

Groundwater makes up about 20% of total yearly water withdrawals [3]

However, it must be remediated!

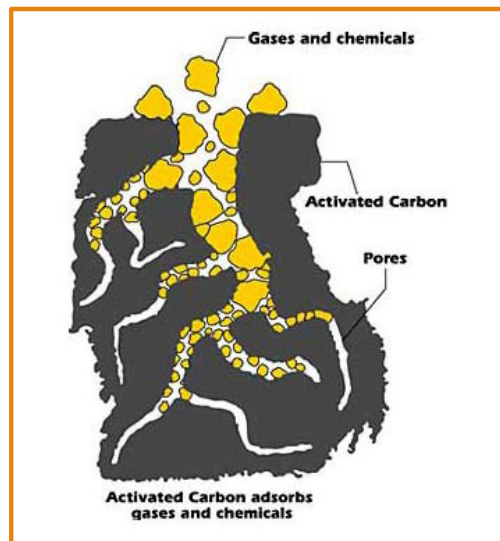
Volatile Organic Compounds (VOCs) can't be handled conventionally

Common means of remediation:

- Physical Methods
- Chemical Methods

Physical Methods v.s. Chemical Methods

PHYSICAL METHODS



Source: [4]

- Carbon Adsorption
- Air Stripping

CHEMICAL METHODS

- Catalytic Remediation
 - Degrades the VOCs to simpler compounds
 - Can be highly effective
 - However, catalyst can be fouled, and lose effectiveness.

Our Solution: Combine the Two!

Granular Activated Carbon (GAC):

- Commonly used in water filters, the high porosity and surface area is ideal for physisorption of influent
- This is the support for our catalyst

Palladium as the catalyst

- High catalytic capabilities
- Affordable
- However, low resistance to fouling



Source: [5]

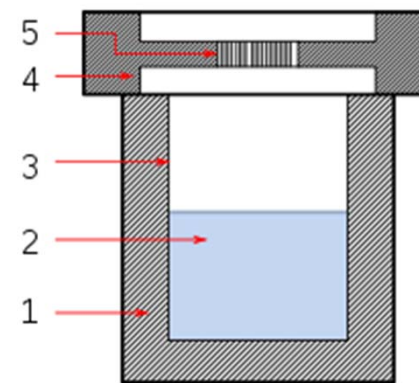
Granular Activated Carbon-Supported Bimetallic Catalysis

- Promoter Metals (Au, Cu, In, etc.) are thought to improve electronic structure of the catalyst.
- Currently, we are using Gold as a promoter, as it has shown that Pd-on-Au has higher fouling resistance. [6]

Synthesis

• Solvothermal Method

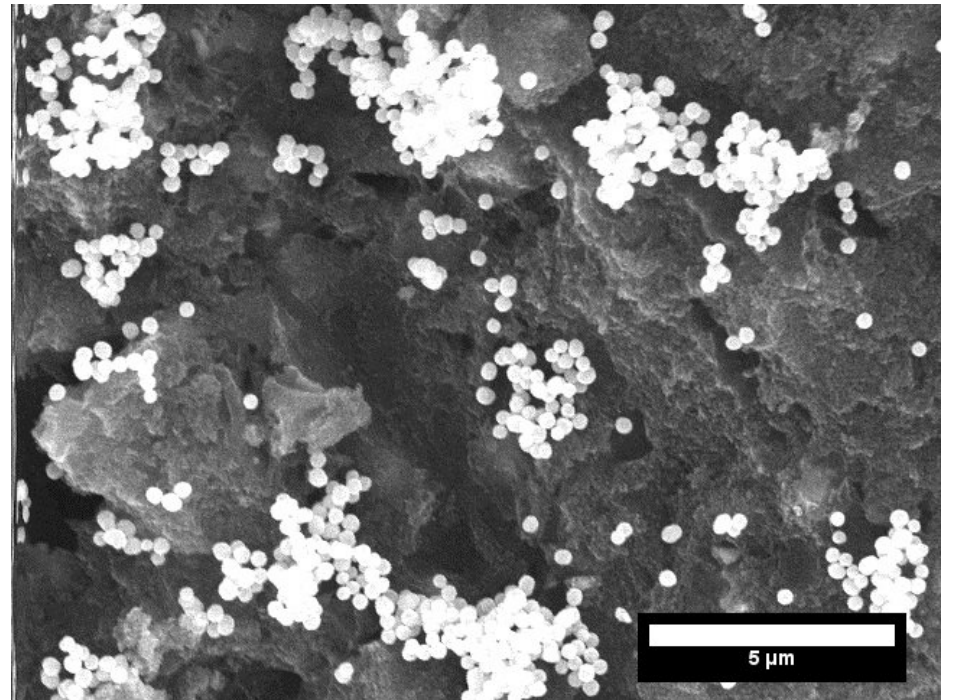
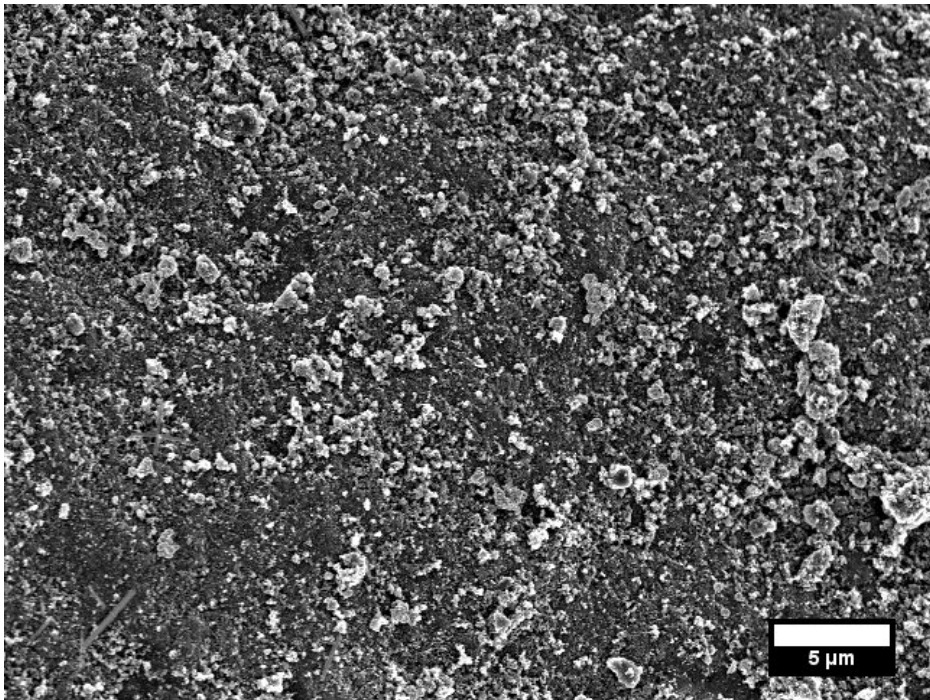
- Temperature and pressure maintained
- Contents synthesized in a solvent
- Based on molar ratios of Au and Pd
- Patent-pending method by former Post-doc researcher, Dr. Wen Qian, from Dr. Jun Jiao's lab group



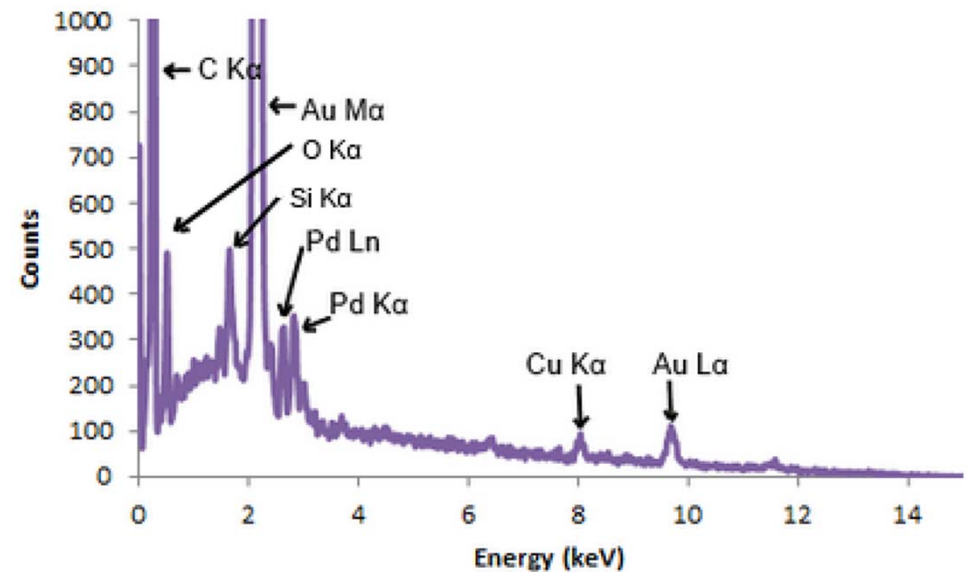
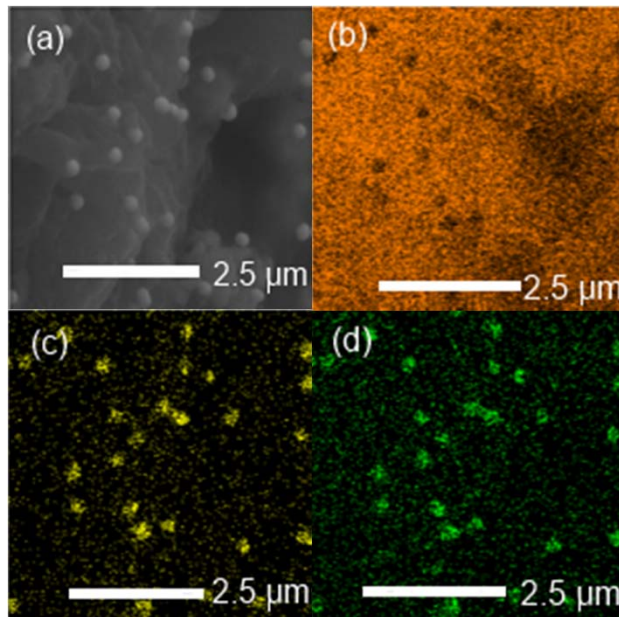
Source [7]

1. Stainless steel shell
2. Solvent, with precursors
3. Teflon Liner
4. Stainless steel lid
5. Spring

Characterization: SEM Images



Characterization – SEM/EDX



(a) image, (b) C K α , (c) Au M α , and (d) Pd L α

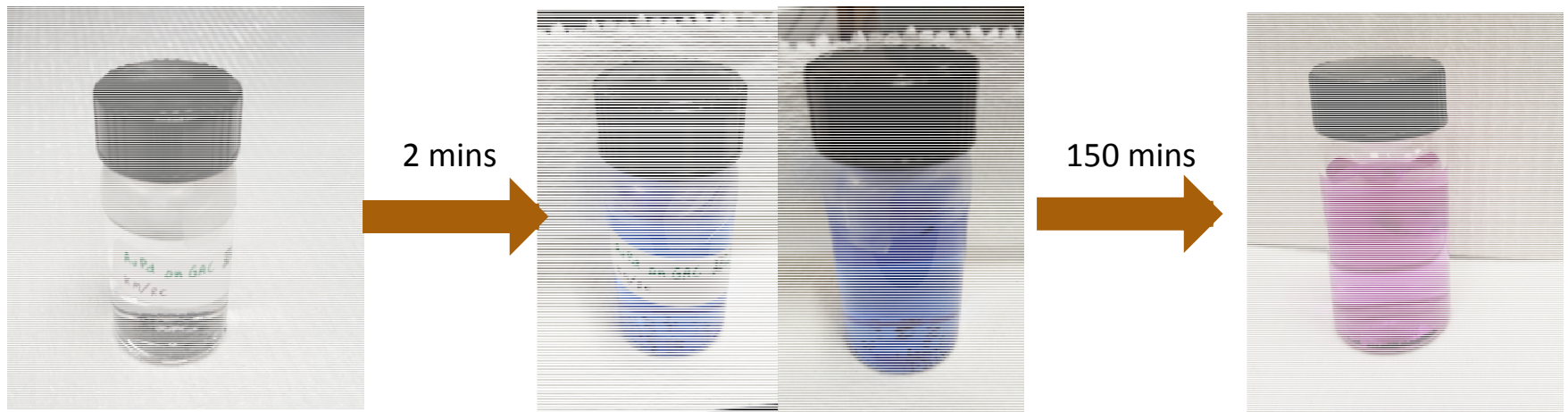
Also plan to use other characterization, such as TEM, XPS, UV Vis, FT-IR

Screening Test

Resazurin: a chemical commonly used to determine cell viability

Acts as reduction reaction, similar to contaminants.

Varies in color based on reaction: adsorbed, oxidation or reduction.



Testing: Batch Testing

1. Catalyst placed in vials, with DI water
2. Vials capped and sparged with H₂ gas through injection
3. Contaminant spiked into vial and shaken vigorously
4. Gas chromatography analysis of the headspace of the vial



Model Contaminant: TCE (C_2HCl_3)

Trichloroethylene (TCE)

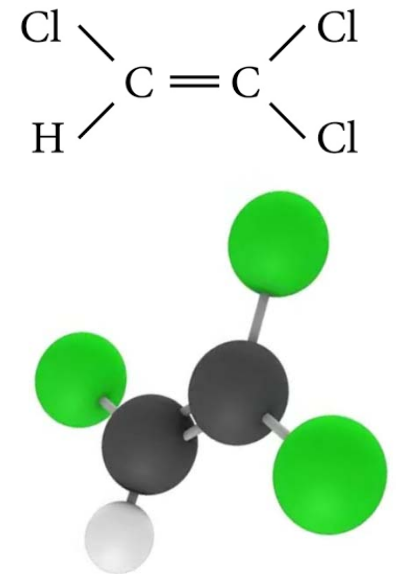
- A common degreasing agent used in manufacturing
- In groundwater, the EPA danger threshold is 5ppb, or 0.005 mg/L [8]
- Representative of other contaminants

The catalyzed reaction converts TCE (and intermediates) into ethene and then ethane, by hydrodehalogenation [9]

Now also testing trichloropropane and carbon tetrachloride.



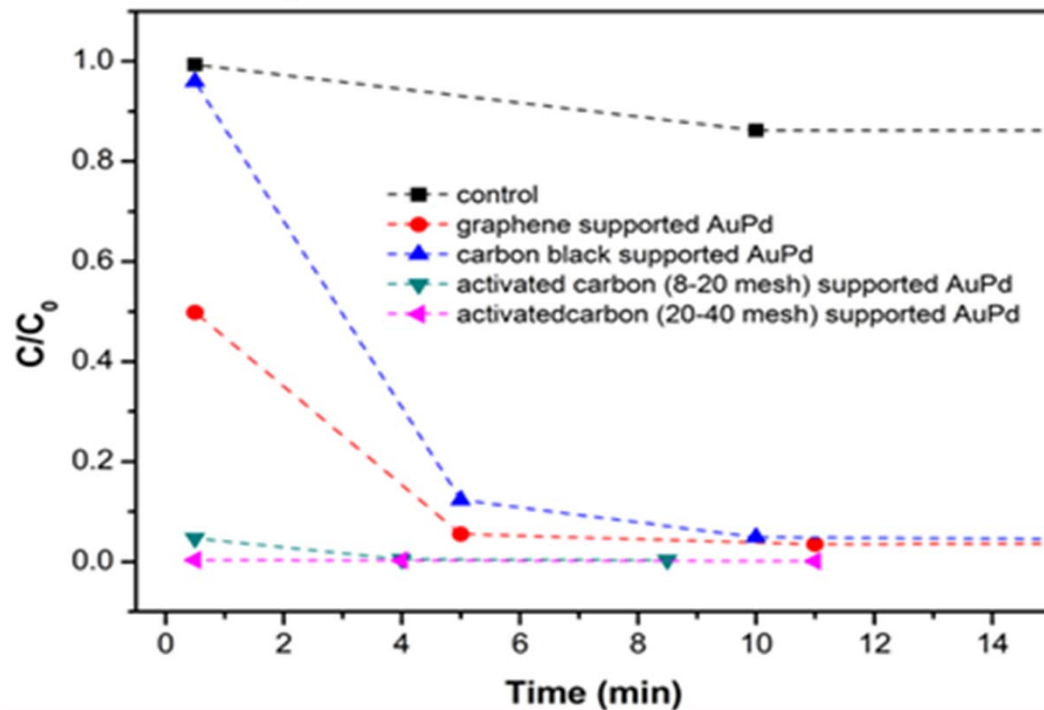
[10]



[11]

RESULTS

Dr. Wen Qian's research:




Our Results:

Testing performed this week, not received back

Possible variances to consider depending on data:

- Testing procedure
- Re-activate the carbon
- Intended/improved molar ratios

Project Future

- Characterization using different techniques– TEM/EDS, FT-IR, XRD, XPS, UV-Vis
 - Batch testing confirmations and paper submission
 - Molar ratios and catalyst loading effects on performance
 - Synthesis of other bimetal catalysts
 - Further solutions to fouling
 - Continuous reactor
- 

References

1. Image from <http://water.usgs.gov/edu/pictures/watercyclekids/earth-water-distribution-kids-screen.png>
2. Image from http://water.epa.gov/learn/kids/drinkingwater/watertreatmentplant_index.cfm
3. United States Geological Survey: <http://water.usgs.gov/edu/wugw.html>
4. Image from <http://www.carbonanswers.com/carbonadsorptionabsorption.html>
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6. M. Chen, "The Promotional Effect of Gold in Catalysis by Palladium-Gold," *Science* 310, no. 5746 (October 14, 2005): 291–93, doi:10.1126/science.1115800.
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8. Statistic taken from U.S. EPA: <http://www.epa.gov/iris/subst/0199.htm>
9. Michael S. Wong et al., "Cleaner Water Using Bimetallic Nanoparticle Catalysts," *Journal of Chemical Technology & Biotechnology* 84, no. 2 (February 2009): 158–66, doi:10.1002/jctb.2002.
10. Images from <http://www.rocketdynecleanupcoalition.org/wp-content/uploads/2010/08/Blue-TCE-barrel.jpg>
11. Images from "Trichloroethylene." Wikimedia Foundation, n.d. Web.

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