Biochar as a filter media for removing lead and arsenic in water

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Terra Preta

A very dark, fertile manmade (anthropogenic) soil found in the Amazon Basin; “black earth” or “black land”

High OM and CEC -> fertile soil in terra preta today…

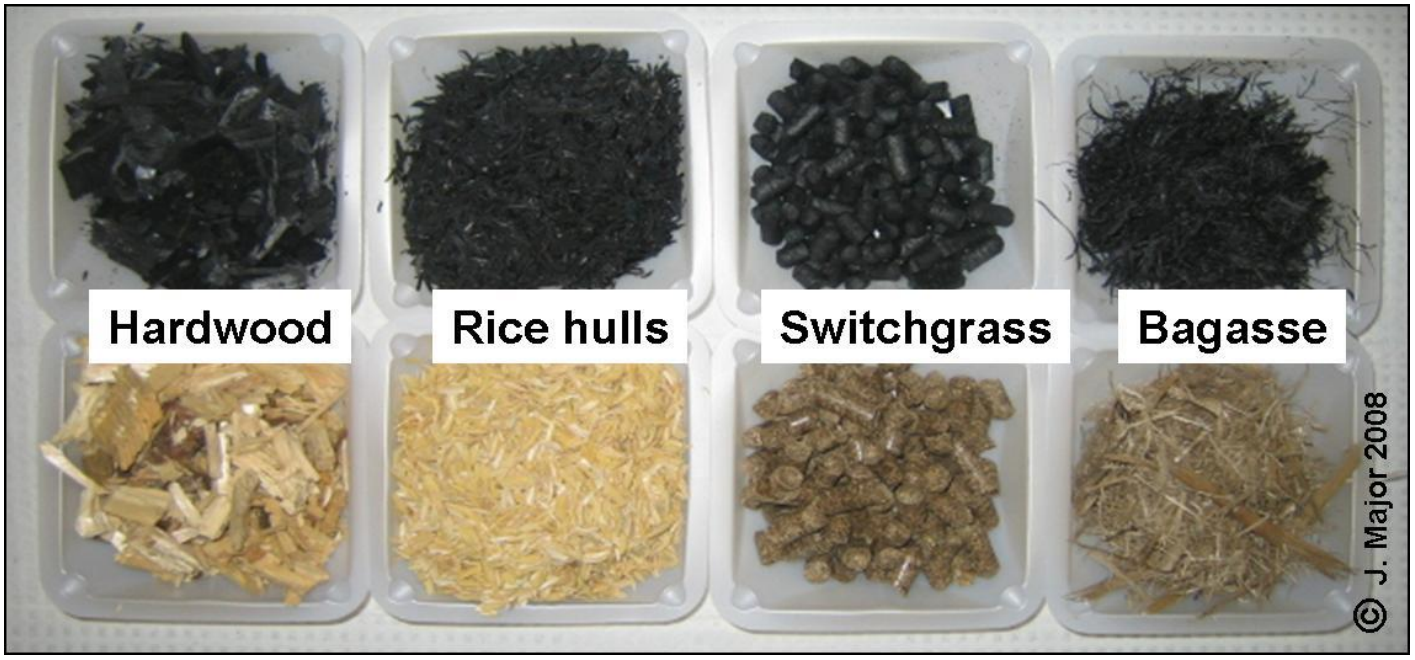
http://www.ultrakulture.com/2015/10/25/terra-preta-amazonian-super-soil-ancient-ways-of-bio-designing-rainforests/

If this woody aboveground biomass were converted into biochar by means of simple kiln techniques and applied to soil, more than 50% of this C would be sequestered in a highly stable form.

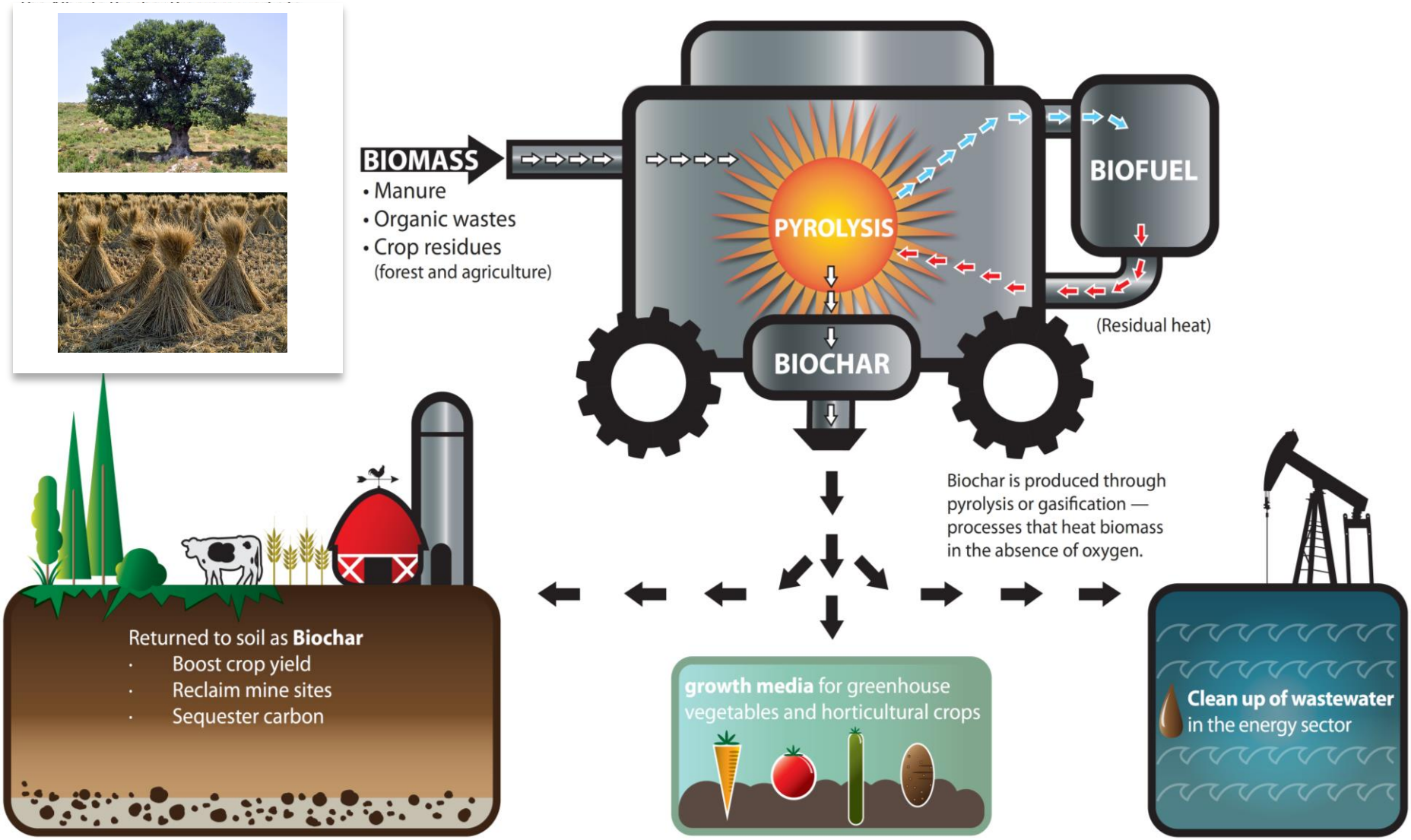
http://www.biochar.org/joomla/images/stories/charcoalkiln.jpg

Biochar

- A black carbon obtained from the thermochemical conversion of biomass in an oxygen-limited environment.
- Soil amendment and other environmental applications.



How biochar is made, and its potential applications



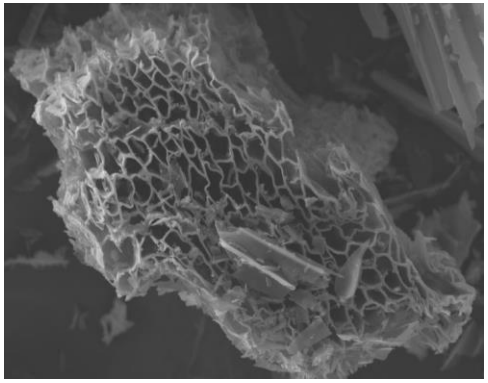
http://fingerlakesbiochar.com/blog/page/3/

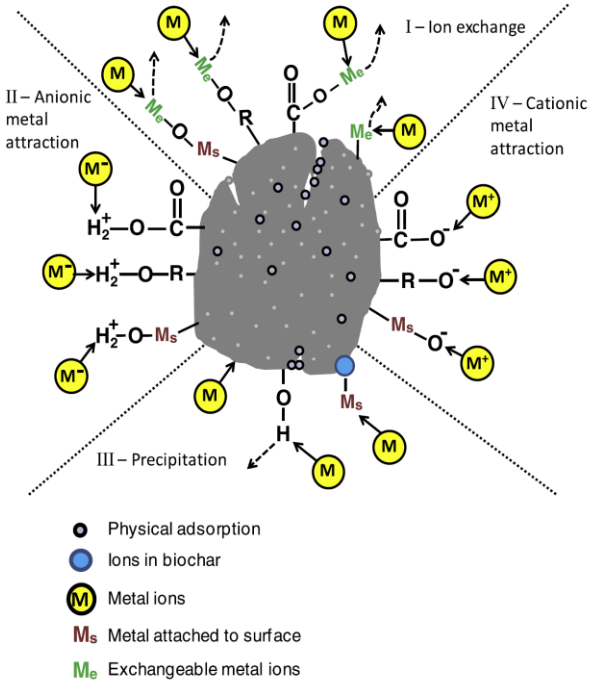
Pristine Biochar

- Woody and grass materials
  - Wood and grass including invasive species
  - Forestry residues
  - Sawdust and lumber residues
- Agricultural wastes
  - Shells, hulls, etc
  - Manure
  - Citrus residuals
- Solid waste
  - Yard wastes
  - Municipal sludge

Engineered Biochar

- Impregnations
  - Nano metal oxyhydroxides (e.g., Magnetized biochar)
  - Graphene and carton nanotube
- Surface activation
  - Activated carbon
  - Oxidation
  - Coating

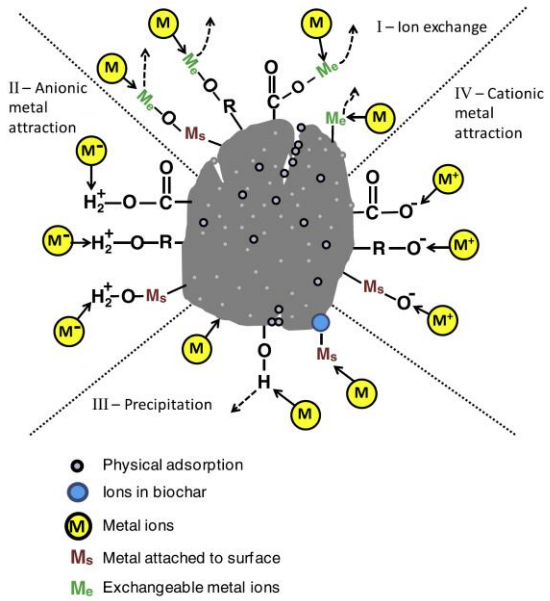


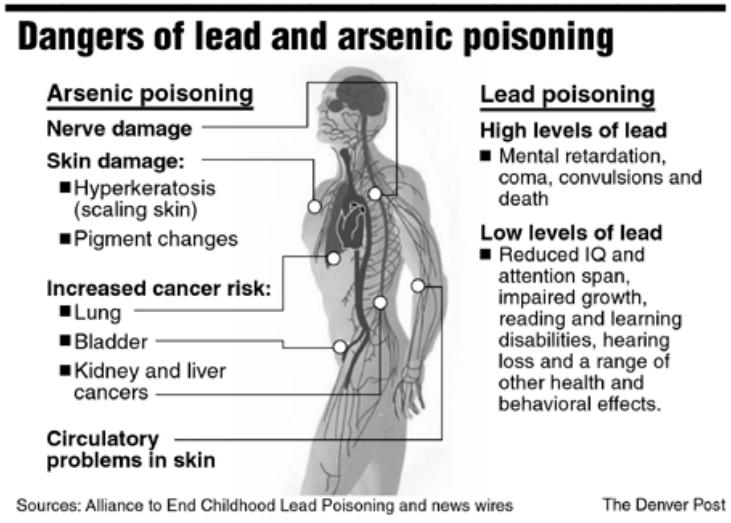


Heavy metal removal in water

- Membrane filtration
- Ion exchange resin
- Precipitation
- **Adsorption**

Primary MCL (Max. Contaminant Level)
- Arsenic: < 10 ppb
- Lead: < 15 ppb



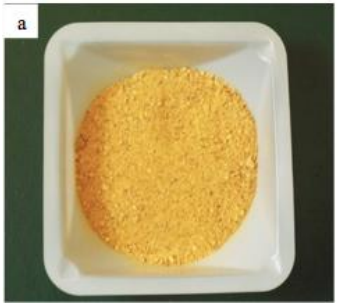


Ahmad, M., Rajapaksha, A. U., Lim, J. E., Zhang, M., Bolan, N., Mohan, D., & Ok, Y. S. (2013). Biochar as a sorbent for contaminant management in soil and water: a review. Chemosphere, 99, 19-33.

Study objectives

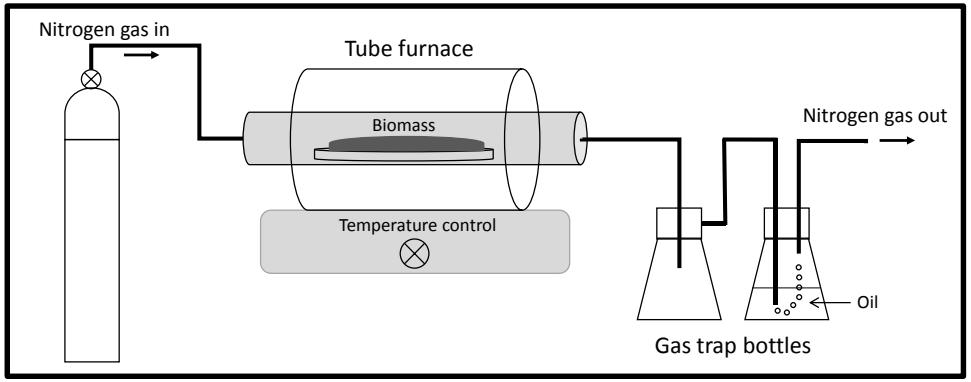
- To produce biochars using locally-sourced feedstock materials
- To evaluate the biochars for their efficacy in binding aqueous lead and arsenic.
- To investigate biochar performance affected by pyrolysis temperature and feedstock types.

Biochar Production in this study



Orange peel Corn Stover pistachio shells

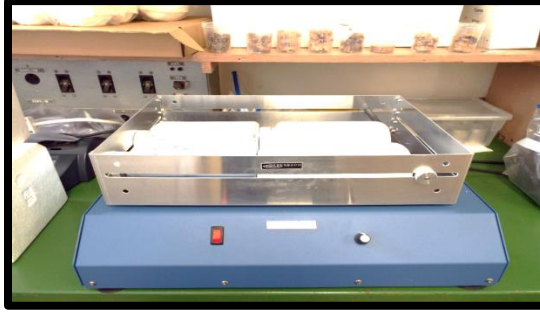
Pyrolyzed each biomass at three different temperatures (300 °C , 450° C, and 600°C) for 1 hr.

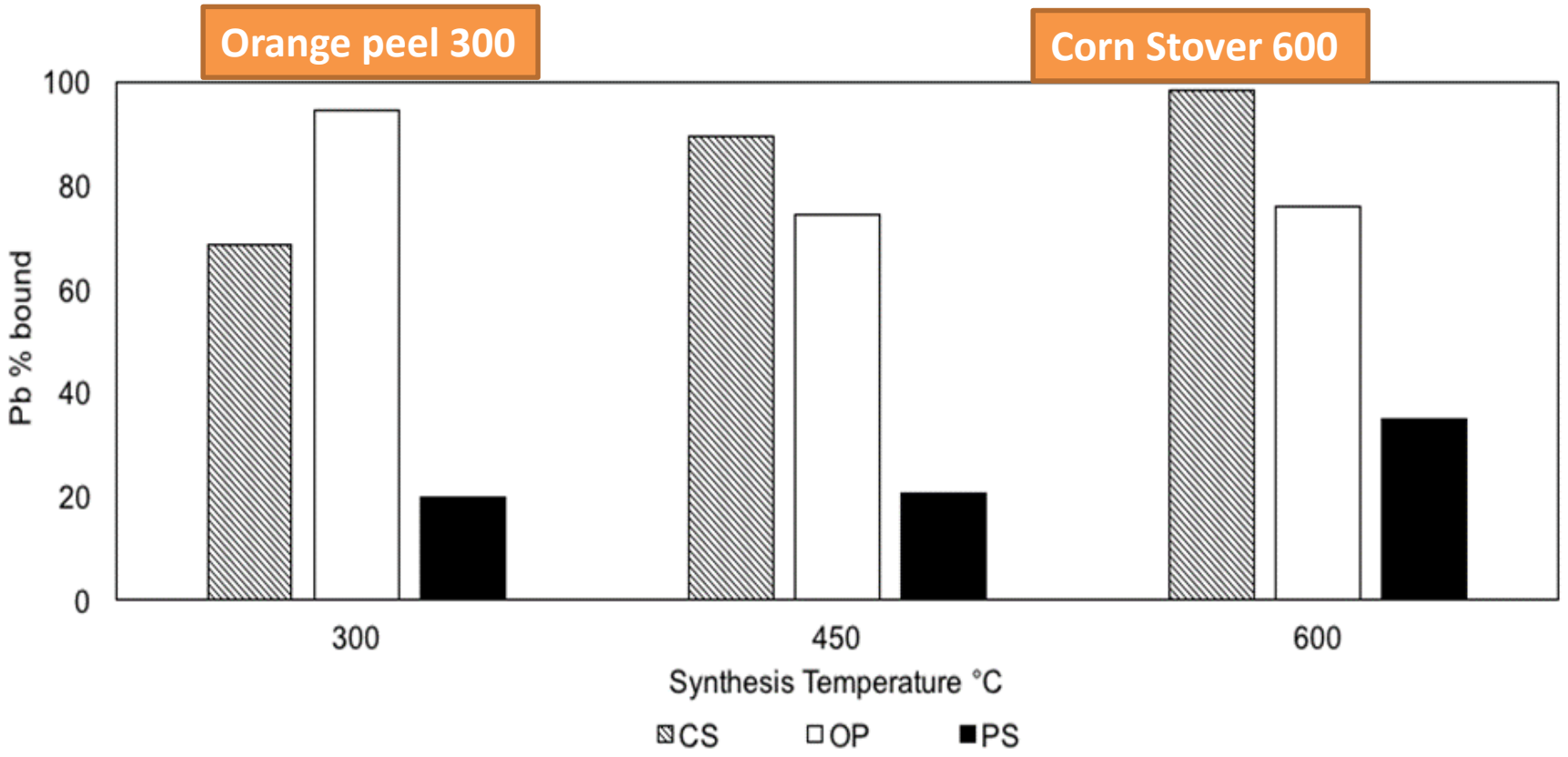


Adsorption experiment

- **Single Point Adsorption**: used 10ppm of Pb, 10 mg of biochar, and 4ml of solution.
  - The single point adsorption studies were done to determine which biochar pyrolyzed at a different temperature was more effective in removing lead.
- **Effect of solution pH**: solutions were adjusted to a pH range of 2-6
- **Adsorption isotherms**: the adsorption isotherm were conducted at varying concentrations of aqueous Pb (5, 10, 25, 50, 100, and 250 mg L^{-1}) in triplicates and their pH was adjusted to pH 6.

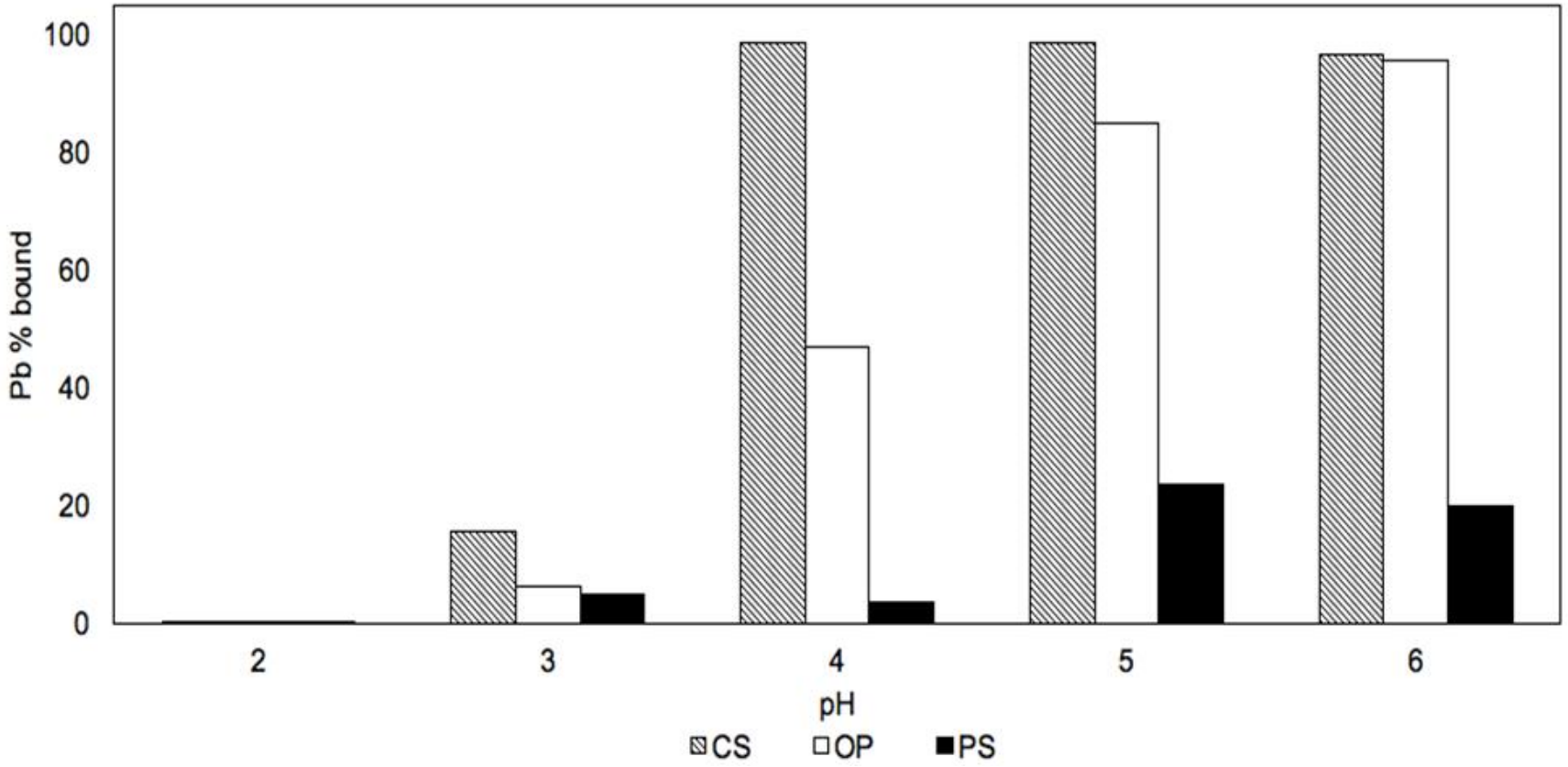
Adsorption experiment with 10 ppm lead solution





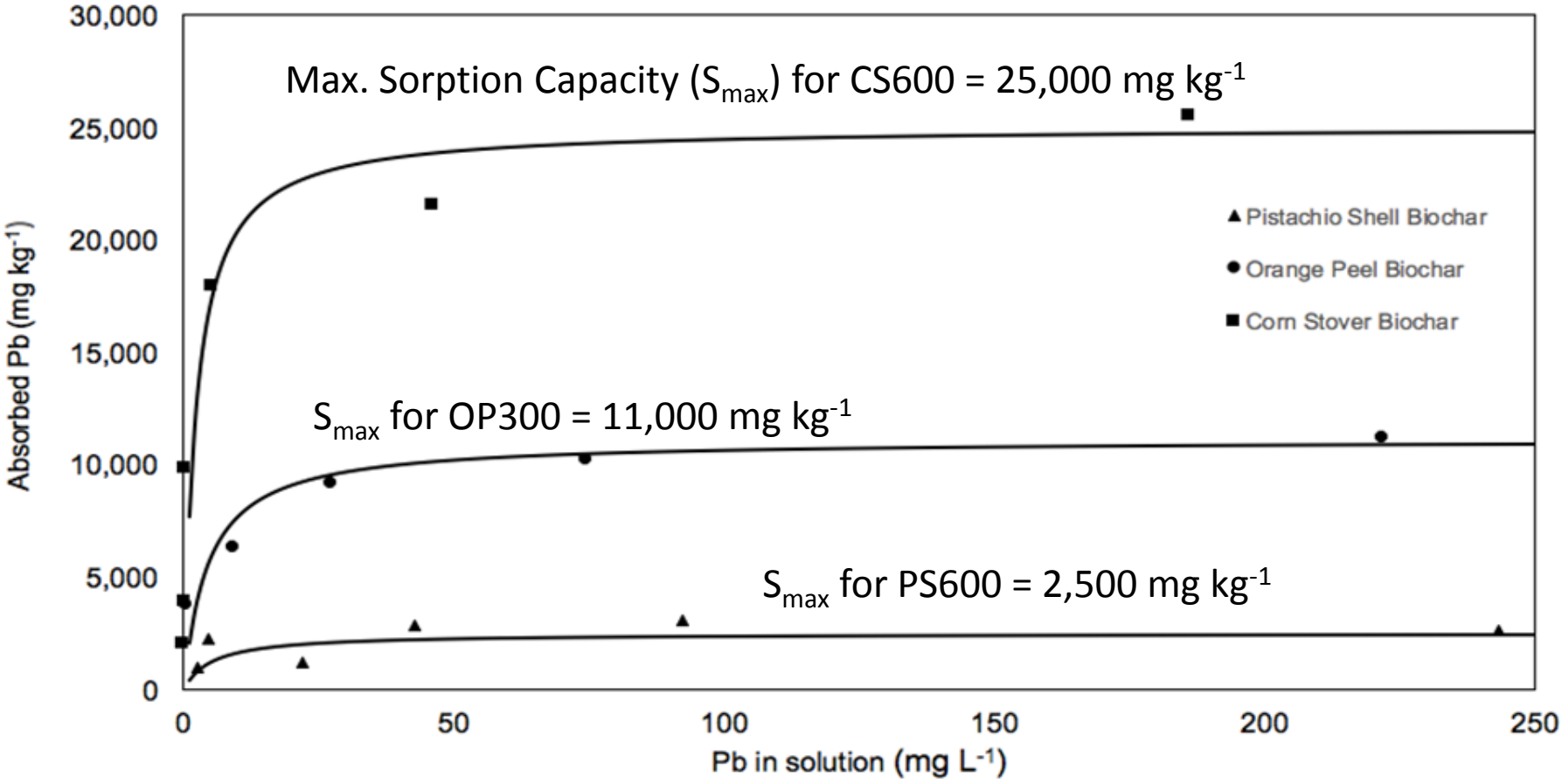
- Pyrolysis temperature > 450 °C for corn stover biochar resulted in greater Pb binding while lower temperature did better for orange peel biochar.

Effect of solution pH on Pb binding onto the biochars



- Pb adsorption efficiency increases with the increase in pH

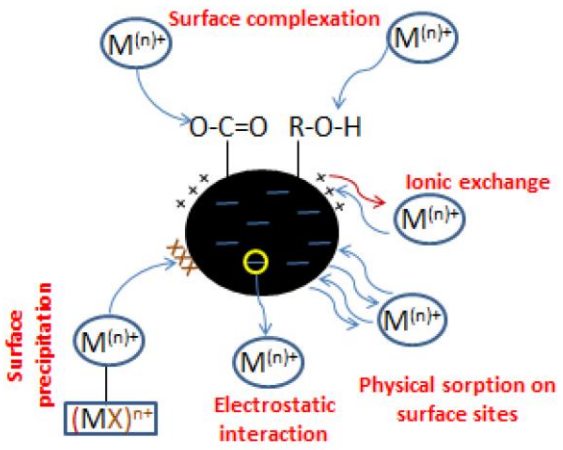
Pb adsorption isotherm fitted by Langmuir model

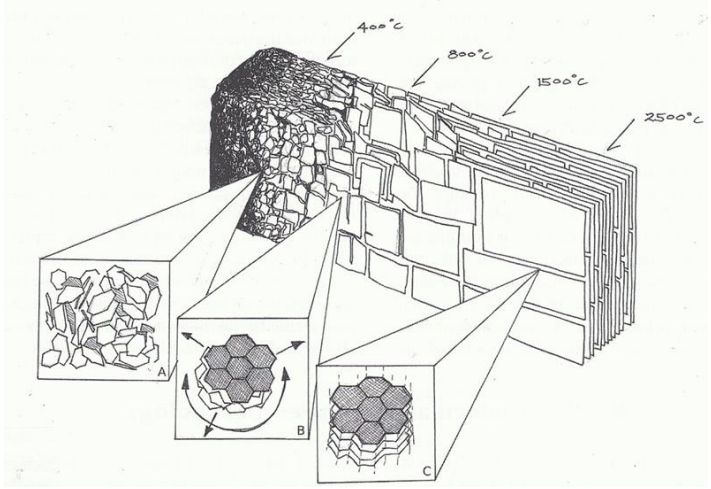


Biochar characterization

Feedstock	*Temperature (°C)*	*Yield (%)*	*pH*	*[a]EC (μScm^{-1})*	*[b]SA (m^2/g)*	*Ash (%)*	*Moisture (%)*	*C^c (wt.%)*	*O^c (wt.%)*
Orange Peel	300	42.88	8.99	278	8.873	4.0	1.60	77.11	22.89
	450	29.25	9.34	606	0.811	5.0	2.50	83.99	16.01
	600	25.80	9.37	725	2.208	2.0	1.00	91.98	8.02
Corn Stover	300	36.66	8.16	284	1.432	1.0	6.25	79.97	20.03
	450	25.41	8.38	327	1.071	2.0	7.50	84.43	14.73
	600	21.25	8.72	457	3.623	2.0	5.00	87.33	11.14
Pistachio Shells	300	42.40	7.36	151.3	0.980	1.0	1.00	81.58	18.36
	450	24.32	7.49	165.2	3.320	2.60	2.50	88.33	11.55
	600	20.23	7.52	181.9	268.94	2.60	2.50	92.08	7.78

Inyang, M. I., Gao, B., Yao, Y., Xue, Y., Zimmerman, A., Mosa, A., ... & Cao, X. (2016). A review of biochar as a low-cost adsorbent for aqueous heavy metal removal. Critical Reviews in Environmental Science and Technology, 46(4), 406-433.



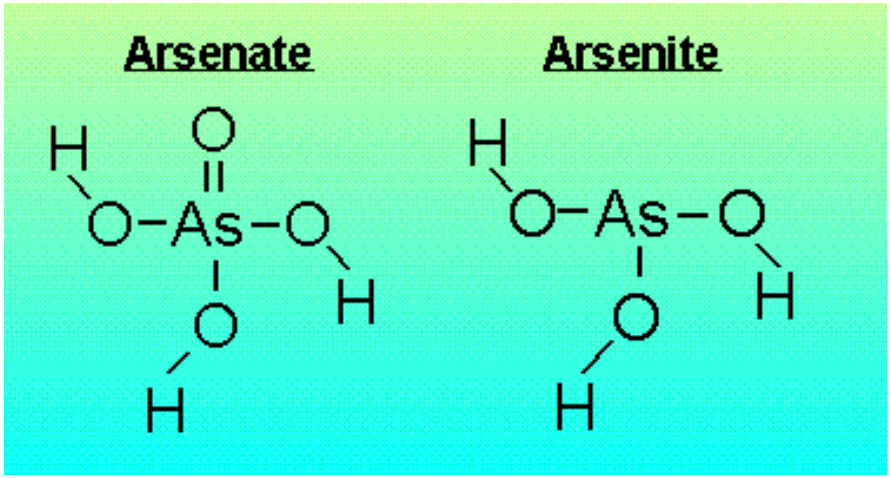


Arsenic removal with orange peel biochar

- As (III) is more toxic (40-60 times) than As (V)

$$H_3AsO_4 + 3H^+ + 2e^- \longrightarrow H_3AsO_3 + H_2O$$

Arsenate, As (V) — Arsenite, As (III)



http://2the4.net/arsenicart.htm

Our preliminary data showed that As binding was poor with OP biochar…..

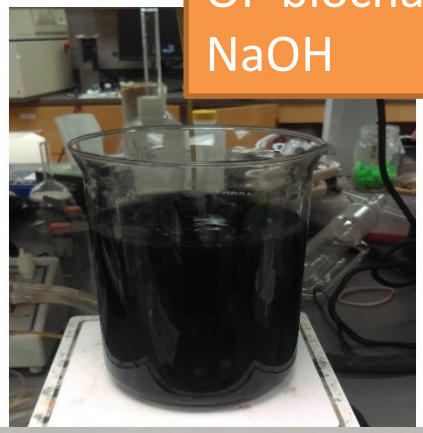
- Because arsenic stays as an oxyanion and biochar surface is mostly negatively charged.

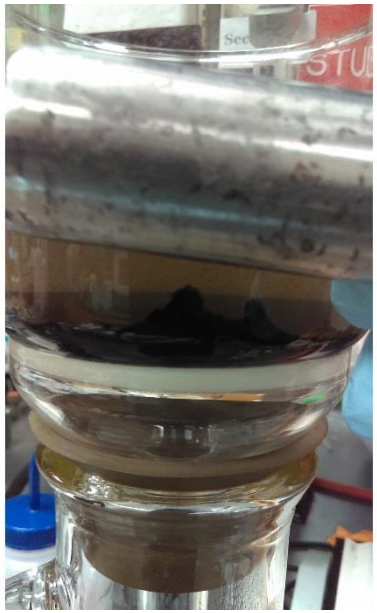
Magnetized biochar

- Coated biochar surface with iron oxide -> magnetized biochar

$FeCl_2$

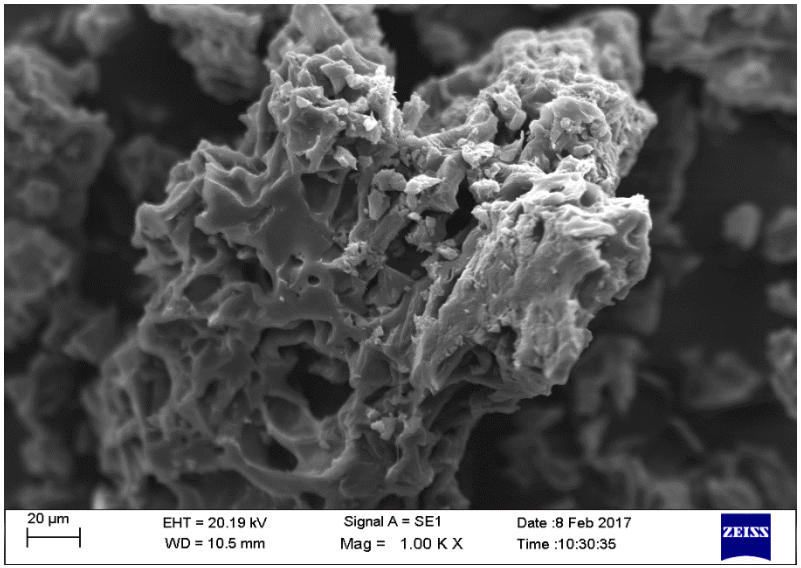
OP biochar + NaOH



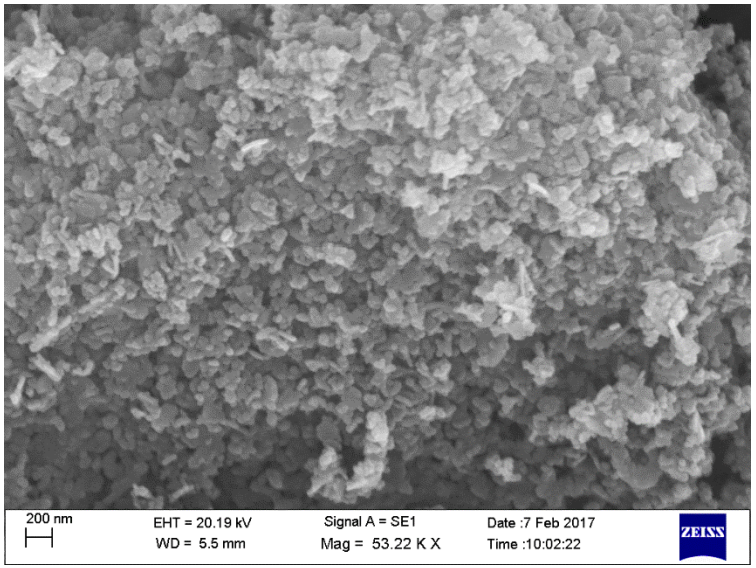


Magnetized OP biochar

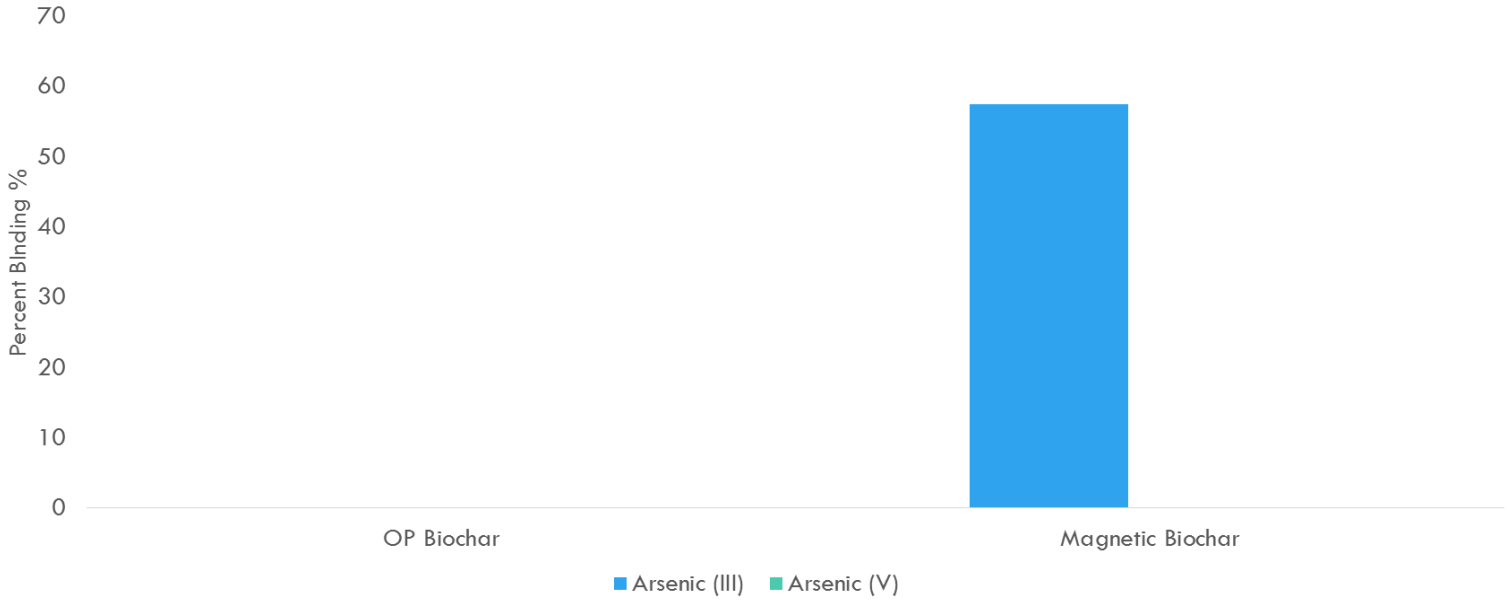
OP biochar before magnetization

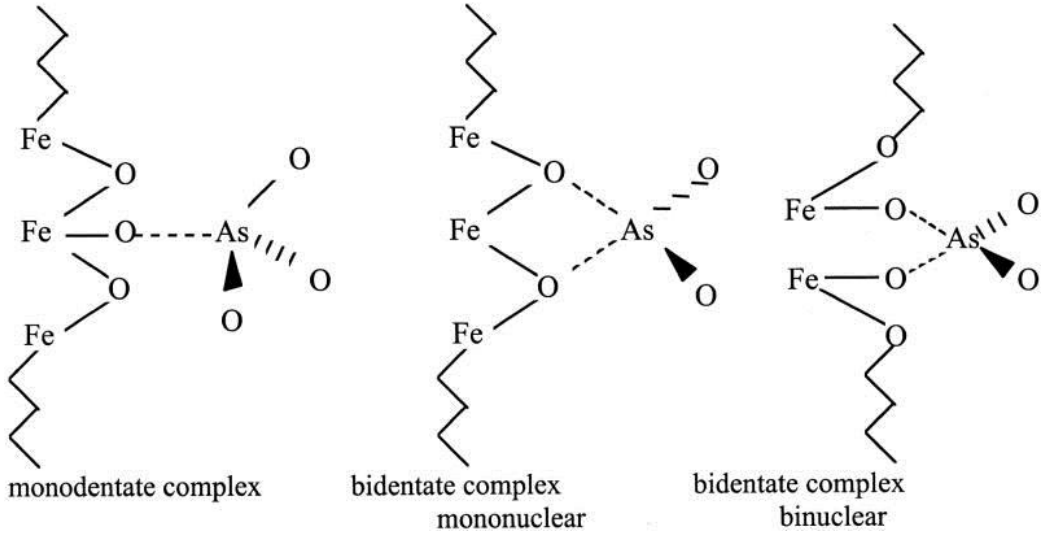


OP biochar after magnetization



As (III) and As (V) adsorption study is in progress.

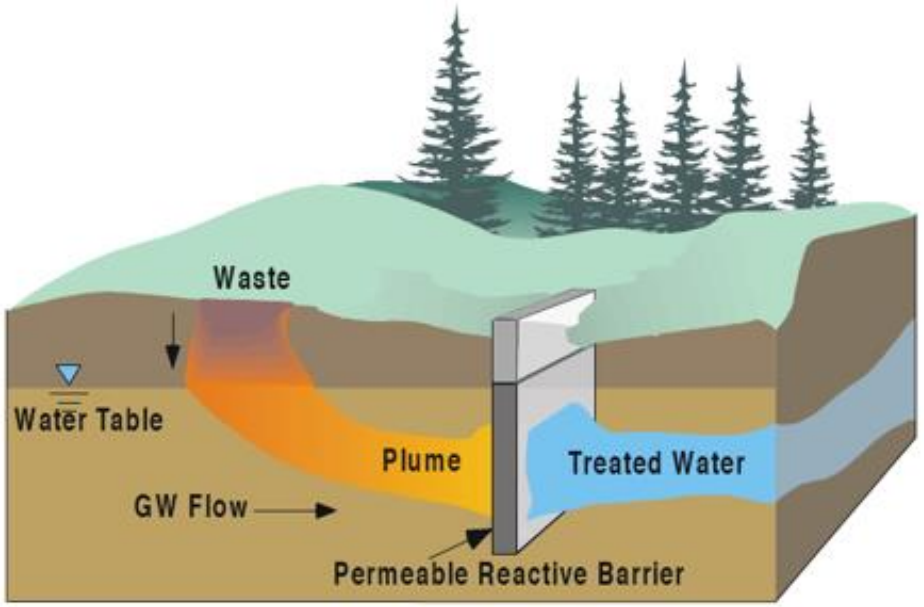




O'reilly, S. E., Strawn, D. G., & Sparks, D. L. (2001). Residence time effects on arsenate adsorption/desorption mechanisms on goethite. Soil Science Society of America Journal, 65(1), 67-77.

Applications of biochar for stormwater management

- Filtration media in new/existing treatment systems (e.g., filter socks, bioswale, permeable reactive barrier, etc.)



“Water is the driver of Nature.”
“We might say that the earth has the spirit of growth; that its flesh is the soil.”
- Leonardo da Vinci

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