Sorptive Removal of Emerging Micropollutant, Bisphenol-S, from Water Using Powdered Activated Carbon

OPERATION TRAINING COMMITTEE OF OHIO, INC.

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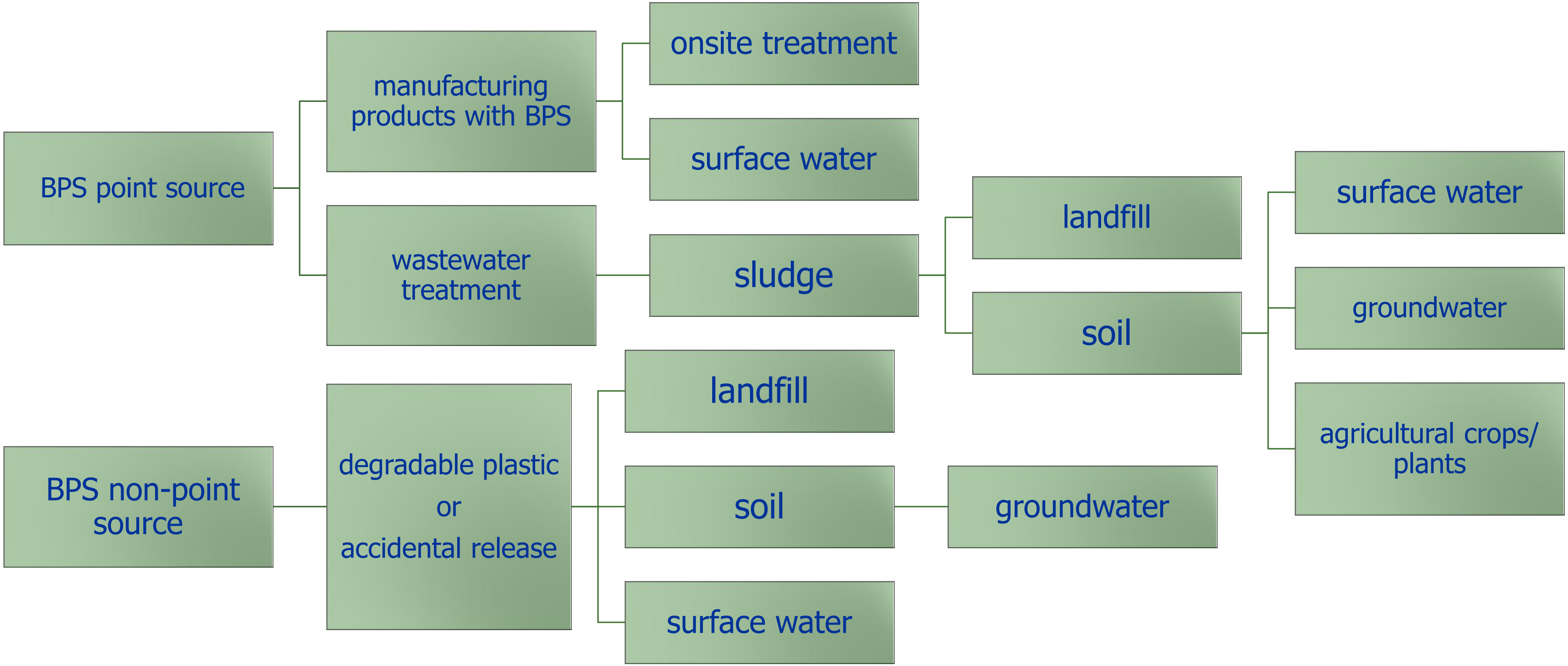
Bisphenol Analogues- BPA, BPS, BPF

- **Bisphenol analogous (BPs)** are chemicals used in the polymer industry to make polycarbonate and epoxy resins. BPA, BPS, and BPF are the most common bisphenol analogues (BPs)

- **For at least 40 years, BPA** was used to harden plastic, as a coating, or in other applications. In recent years, it was replaced by **BPS** in some countries because:
  - BPA is readily breaks down and leaches from products.
  - BPA is an endocrine-disrupting chemical
  - It is thermally unstable, which makes it possible to breakdown and leach from products

- **Endocrine disrupting compounds (EDCs)** are pollutants with estrogenic activity at very low concentrations and are emerging as a major concern for water quality.

Bisphenol Fate and Transport: Various point and non-point sources of BPs could lead to their release into environmental and biological systems



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Research Objectives

- To investigate the effectiveness of powdered activated carbon (PAC) for BPS sorption

- To investigate the influence of different solution conditions such as:
  - PAC dose
  - Contact time
  - pH conditions
  - Ionic strength

Significance of Problem- Bisphenols in the Environment

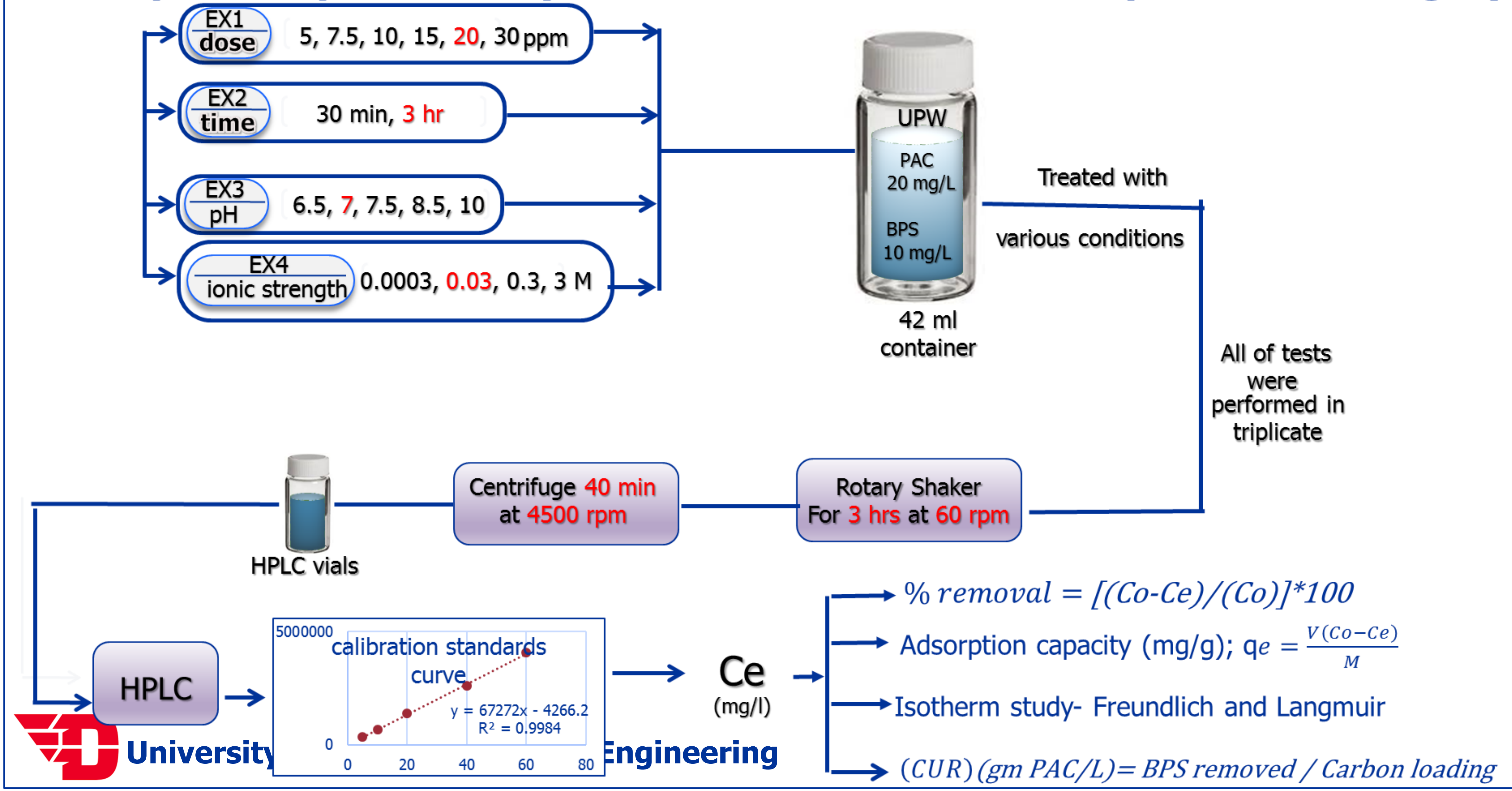
- Endocrine-disrupting chemical, pseudo-persistent pollutant that is not easily removed via conventional treatment processes

- Globally found in water and wastewater sources
  - 30% of groundwater samples and average concentration was 1.9 mg/m^3
  - The average concentrations of BPA in groundwater in the US varies between 0.006– 2.55 mg/m^3
  - In the US, the estimated amount of BPs released from factories to water bodies and land through wastewater discharges was 45,900 kg per year

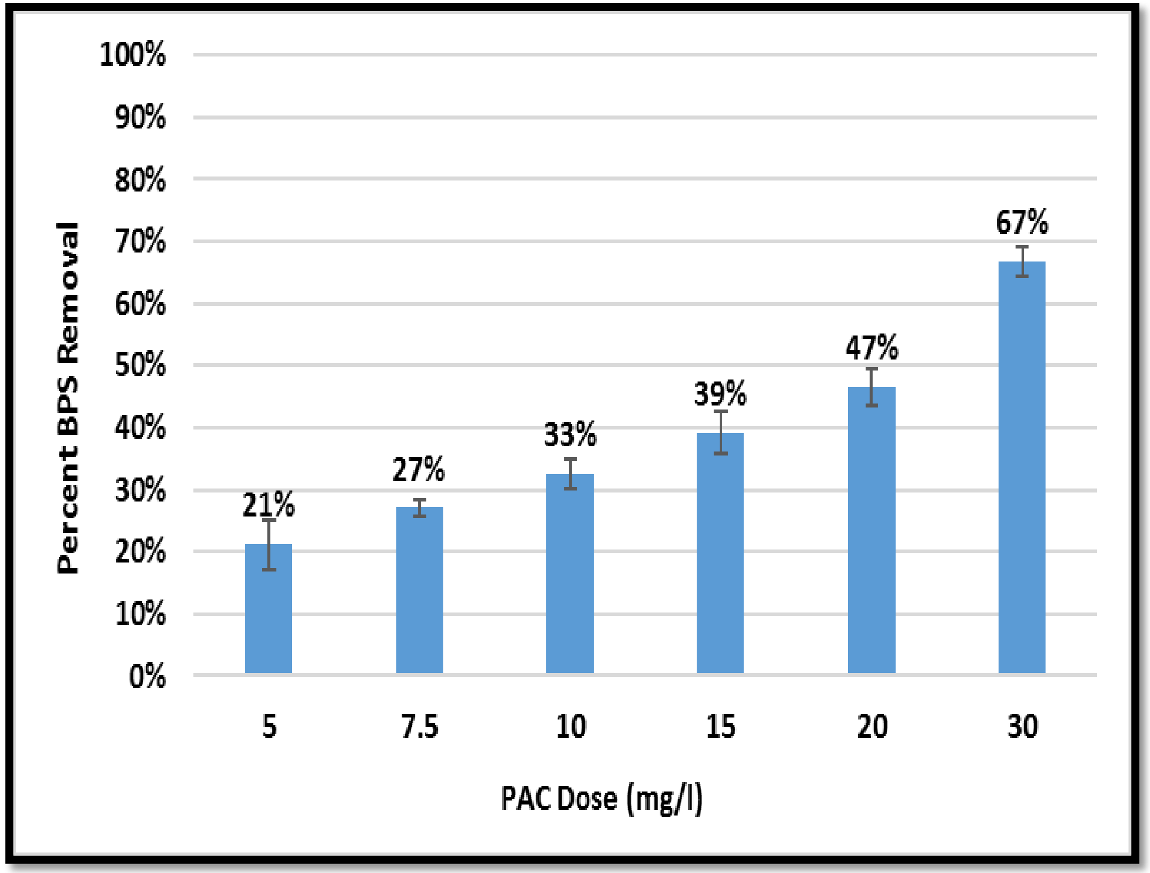
Significance of Problem- Bisphenols in the Environment

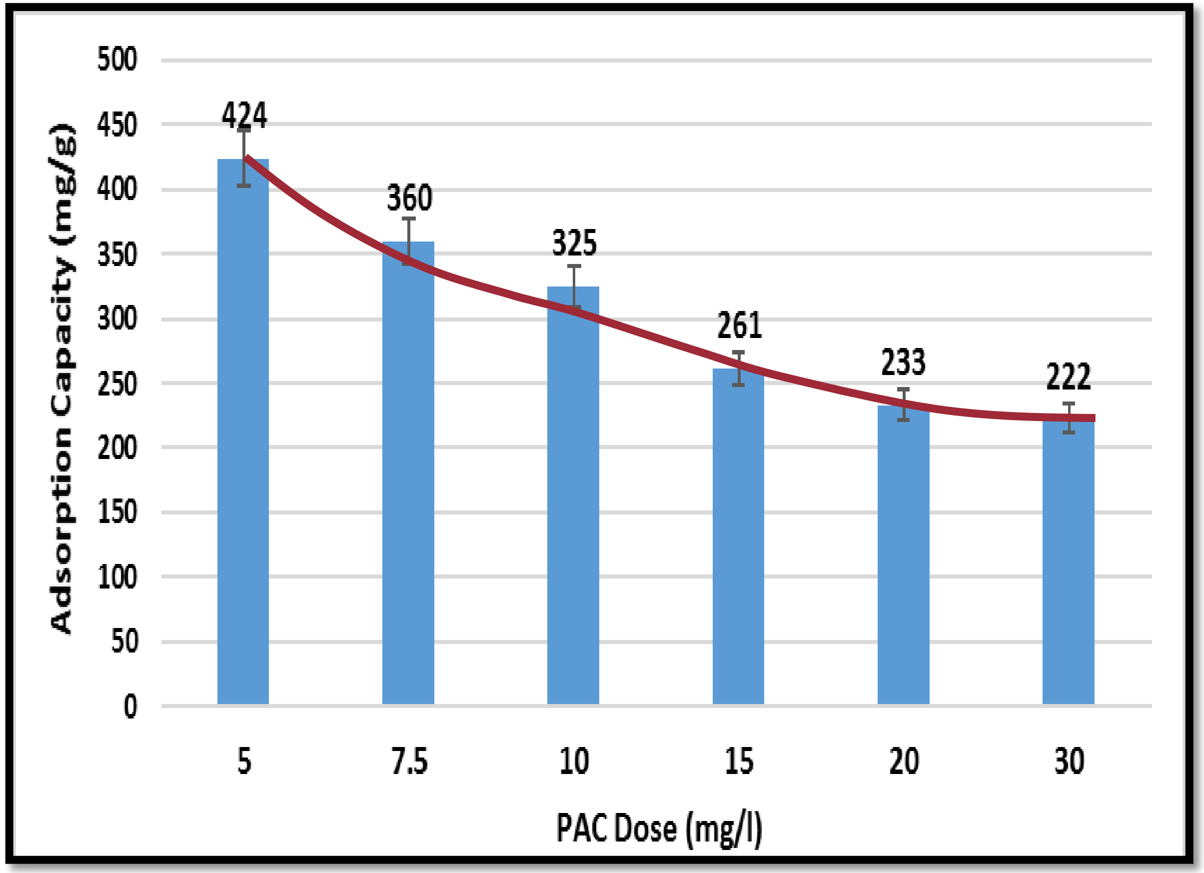
- Wastewater sewage solids or biosolids that may contain BPs can be applied to land and enter the soil
- BPA in four landfill leachates ranged from 15 to 5400 ng/mL
- Health effects observed in animal and/or cell culture studies include obesity and reproductive health problems, neurological behavioral problems, breast and prostate cancer
- In the U.S., at least 97% of human urine samples tested contained BPS

Adsorption experiments (carbon dose, contact times, pH, ionic strength)



Carbon Dose: 20 mg/L PAC dose is sufficient for BPS removal





47% removal at 20 mg/L PAC dose, 233 mg BPS removed/g PAC

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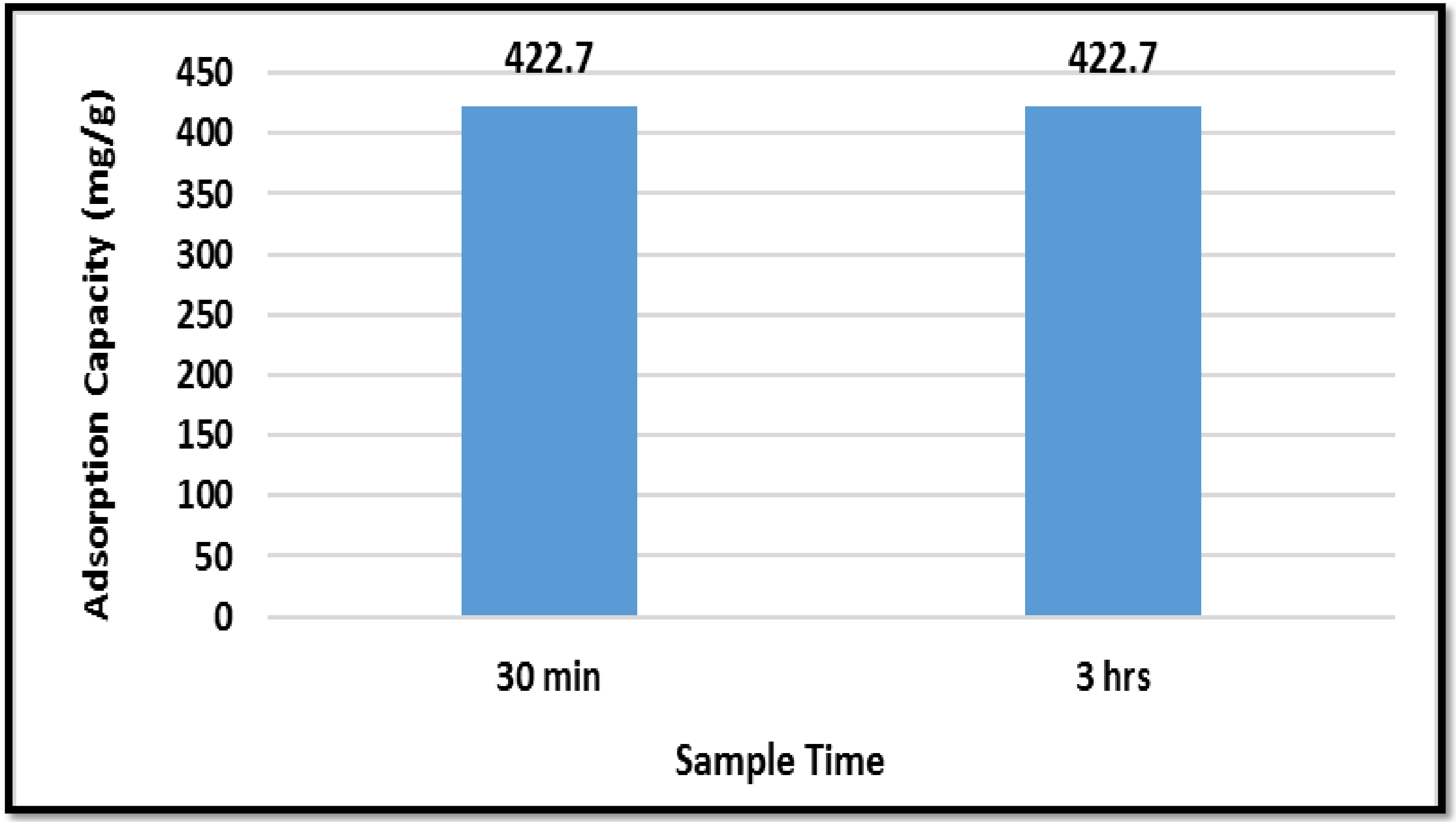
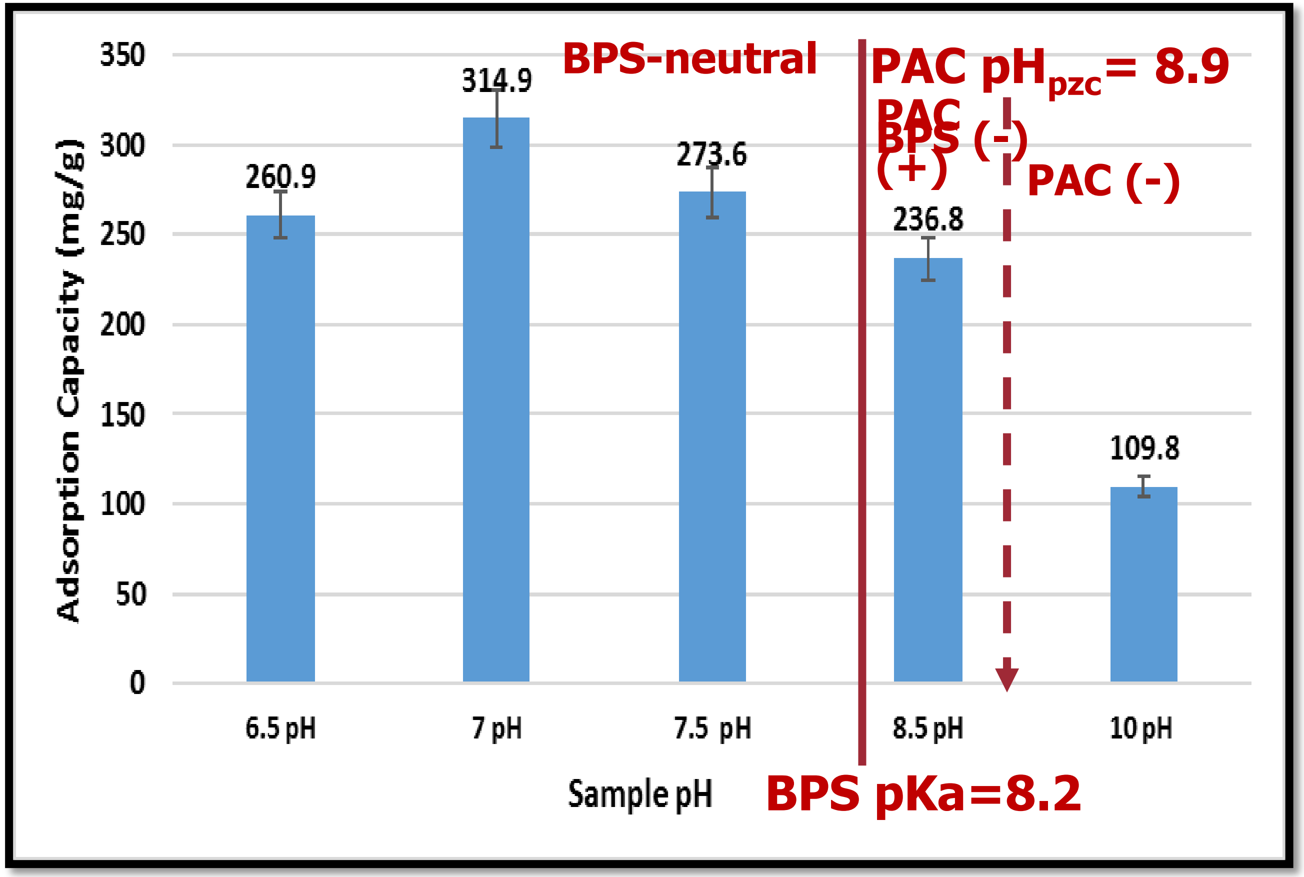
Contact Time:

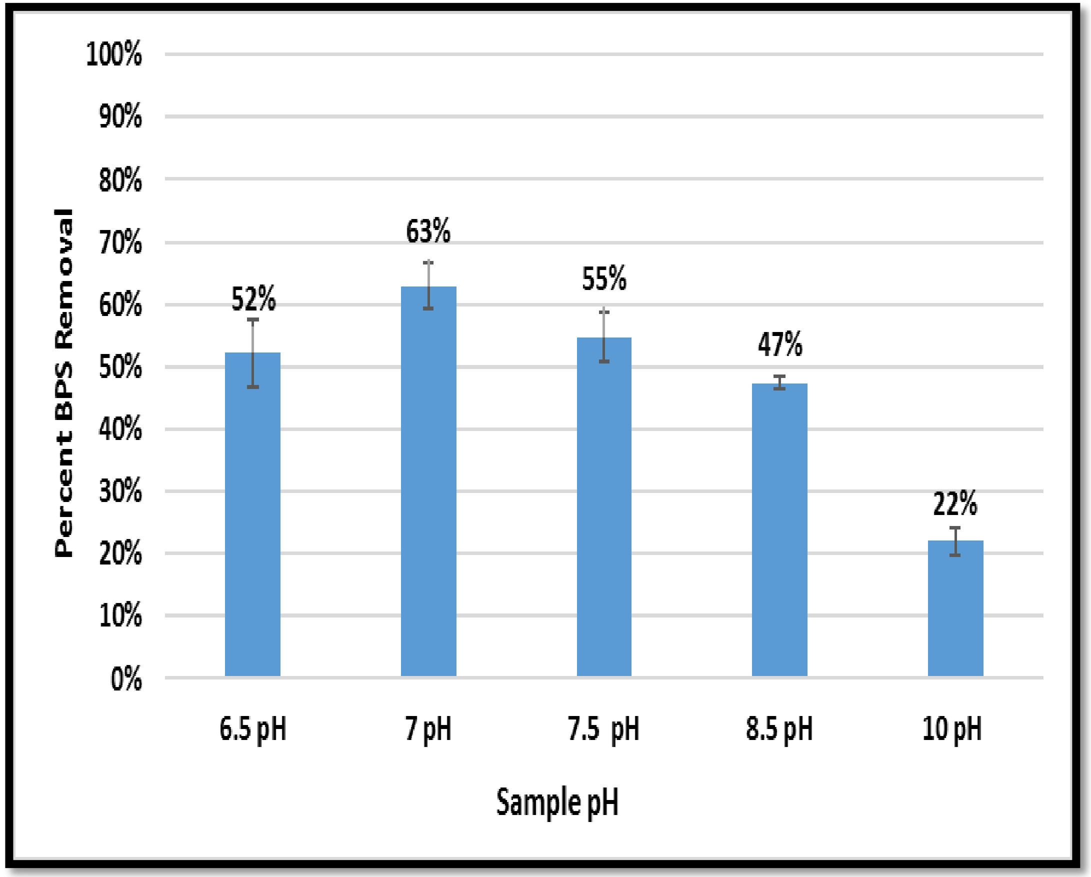
Quickly reached equilibrium; no difference between 30 minute and 3 hour contact time (85% removal)



3 hour contact time practical; selected to ensure equilibrium

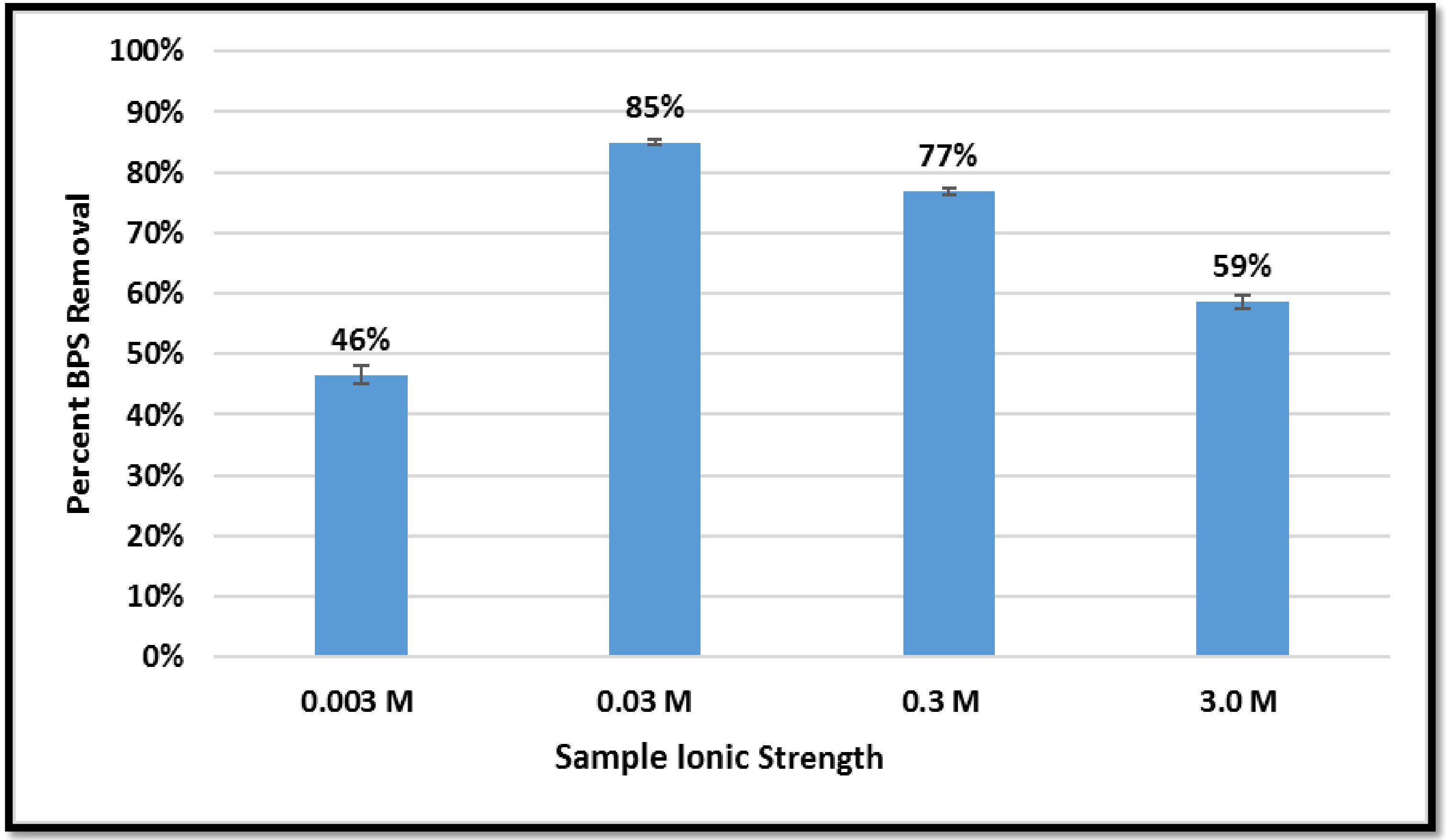
pH: Improved BPS removal below pH 8.2; lower removal above pH 8.2





Optimal removal at pH 7 (315 mg/g; 63% BPS removal)

Ionic strength: Optimal removal at lower ionic strength (85% removal; 425 mg/g at 0.03 M) likely due to salting out effect

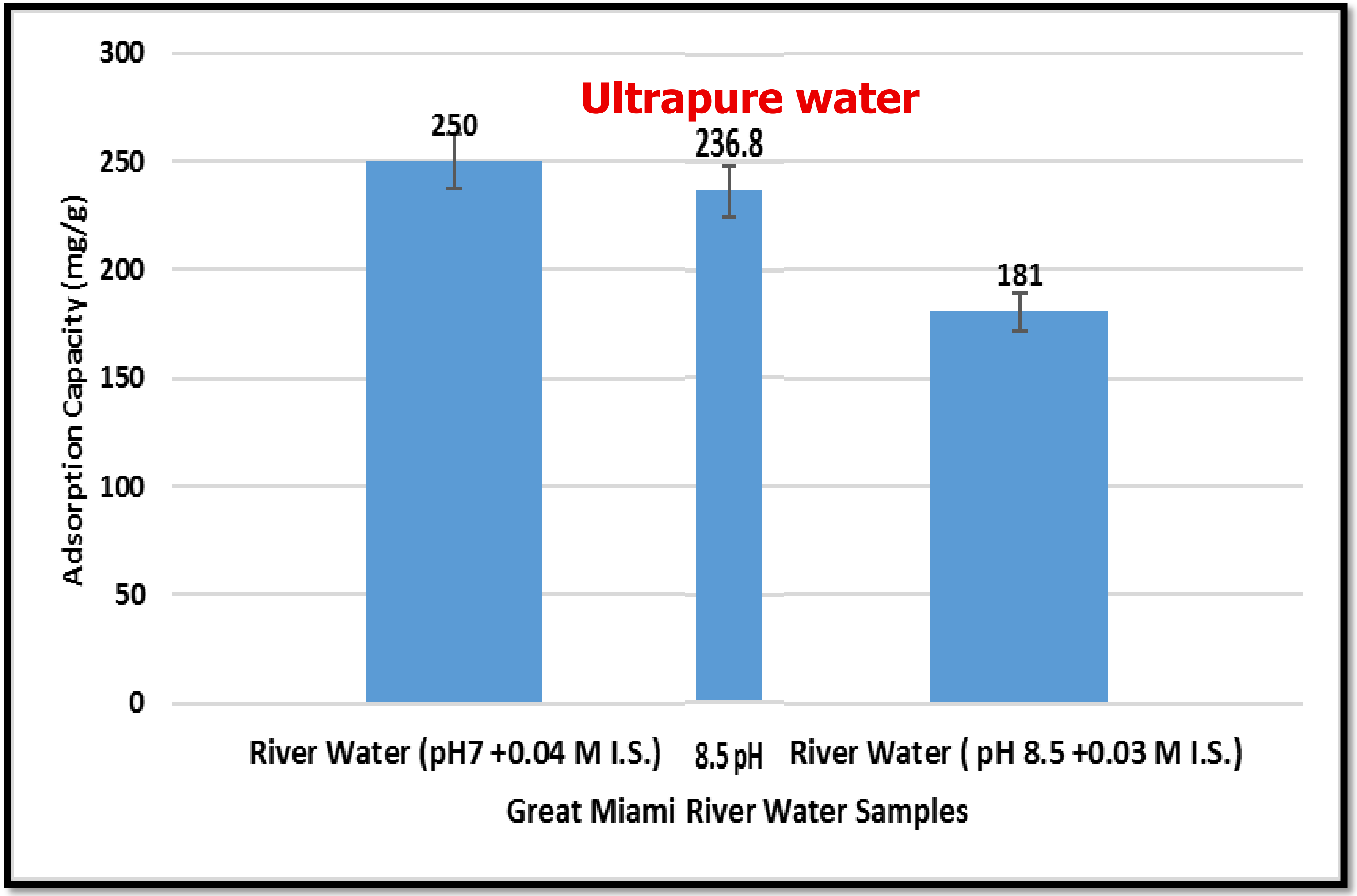


Higher than 0.03 M, less BPS sorption due to competitive sorption or PAC aggregation

In Great Miami River water, lower pH and ionic strength conditions yielded better BPS removal

50% BPS removal (250 mg/g) at pH 7 at 0.04 M ionic strength

**At pH 8.5 in ultrapure water, 237 mg BPS/g PAC vs. 181 mg BPS/g PAC in natural water-
Highlights competitive effects of natural organic matter**



Isotherms: Monolayer BPS sorption to fixed number of sorption sites (Langmuir Isotherm), and pH conditions had dominant influence on sorption

r-Value	Isotherm Type/Description of Adsorption Process
$r > 1$	Unfavorable
$r = 1$	Linear
$0 < r < 1$	Favorable
$r = 0$	Irreversible

Adsorption Isotherm Model	Ionic Strength	pH	Carbon Dose
Freundlich Isotherm			
K_F (mg/g)(L/mg)$^{1/n}$	537.5	2431	16.5
N	2.16	0.68	0.64
R^2	0.949	0.944	0.979
Langmuir Isotherm	**Type 1**	**Type 1**	**Type 2**
Q_0 (mg/g)	200	3333	588
K_L (L/mg)	1.02	0.00296	0.052
R^2	0.977	0.953	0.981
r	0.089	0.97	0.66

Carbon Usage Rate: Despite target BPS concentration, the carbon usage rate was about 0.02 g PAC/L; no additional PAC costs with more stringent treatment goals

Freundlich Isotherm	BPS remaining (mg/l)	BPS Removed (mg/l)	Percent BPS Removal	Adsorption Capacity q_e (mg BPS/g PAC)	CUR (g PAC/L)
Carbon Dose Isotherm	5.5	4.5	45%	240	0.019
I.S. Isotherm	5.5	4.5	45%	233	0.019
I.S. Isotherm	2	8	80%	400	0.02
pH Isotherm	5.5	4.5	45%	200	0.023
Langmuir Isotherm	**BPS remaining (mg/l)**	**BPS Removed (mg/l)**	**Percent BPS Removal**	**Adsorption Capacity, q_e (mg BPS/g PAC)**	**CUR (g PAC/L)**
Carbon Dose Isotherm	5.5	4.5	45%	244	0.018
I.S. Isotherm	5.5	4.5	45%	239	0.019
I.S. Isotherm	2	8	80%	400	0.02
pH Isotherm	5.5	4.5	45%	188	0.024

Conclusions/Findings

- Powdered activated carbon treatment can be effective for BPS removal in ultrapure water.
- However, in natural water such as river water, the presence of organic matter can limit BPS sorption (50%)
- Low pH conditions (pH <8) and low ionic strength conditions will provide water quality conditions conducive for BPS sorption
- The Langmuir isotherm model appears to describe BPS sorption
  - Monolayer sorption
  - Fixed adsorption sites
- The carbon usage rate for BPS sorption to the tested activated carbon is about 0.02 g PAC/L water treated

Future Work

- Examine additional natural water systems- groundwater and treated wastewater
- Examine natural and engineered adsorbents
  - Biochar
  - Nano-graphene oxide
- Examine leaching characteristics of BPS from products in contact with water

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