Arsenic adsorption onto lignite under saturated flow conditions: Experiment and reactive transport modeling

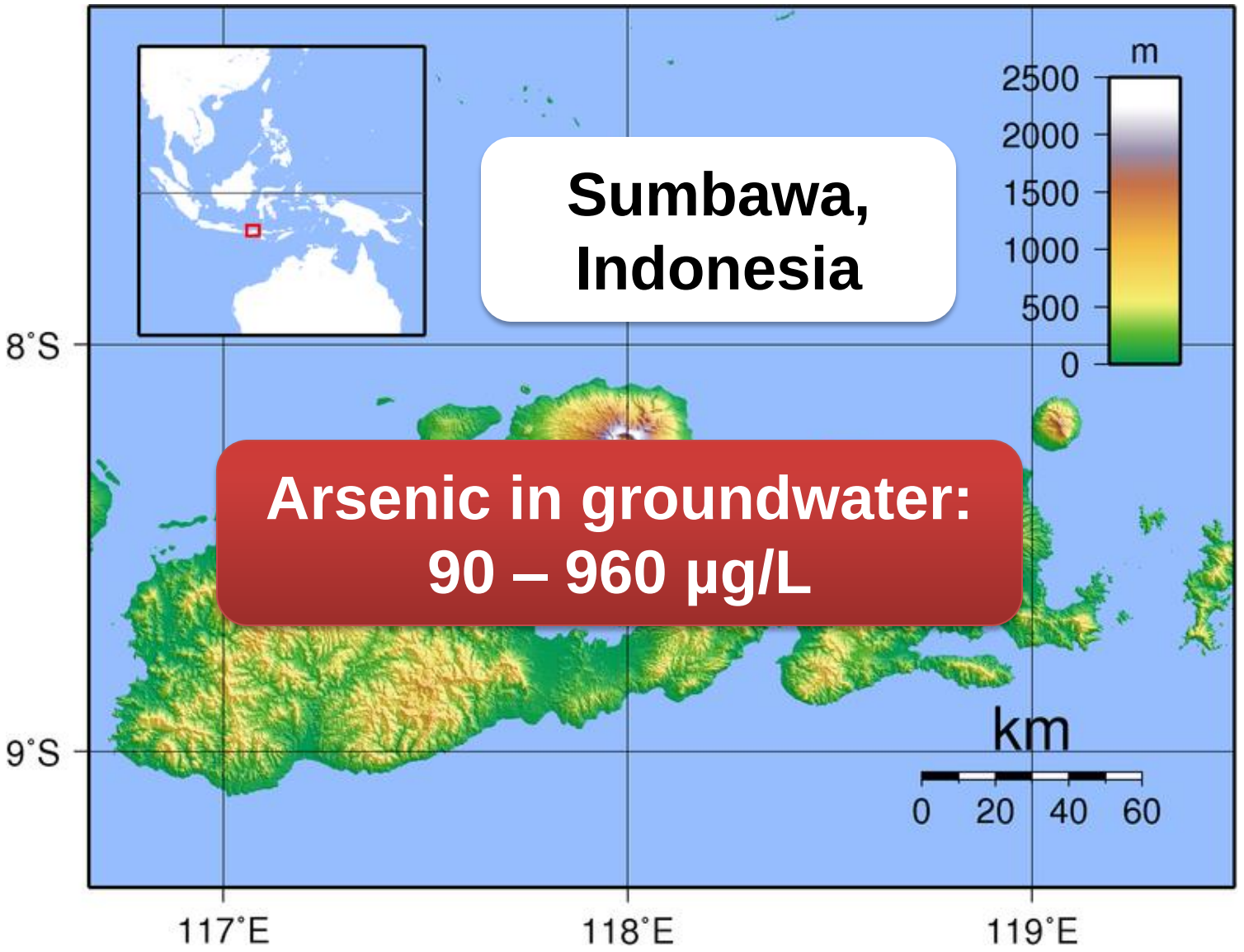
C. B. Tabelin [1*], B. Ty[2], K.K. Mar[3], D.P.E. Putra[3], T. Igarashi[1] and T. Yoneda[1]

[1]Faculty of Engineering, Hokkaido University, Sapporo, Japan

[2]Faculty of Engineering, University of the Philippines-Diliman, Quezon City, Philippines

[3]Faculty of Engineering, Gadjah Mada University, Yogyakarta, Indonesia

What is the motivation in conducting this study?

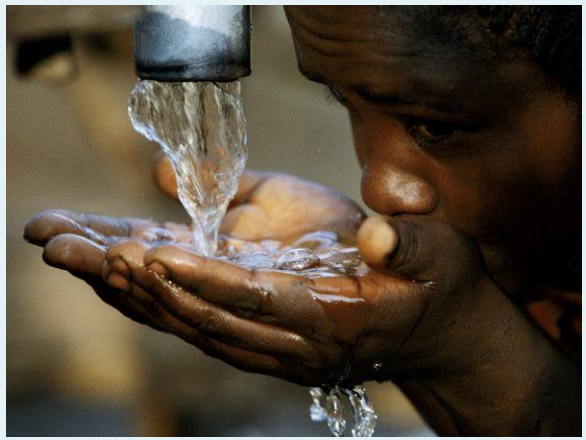


Why is arsenic problematic?

Acute poisoning

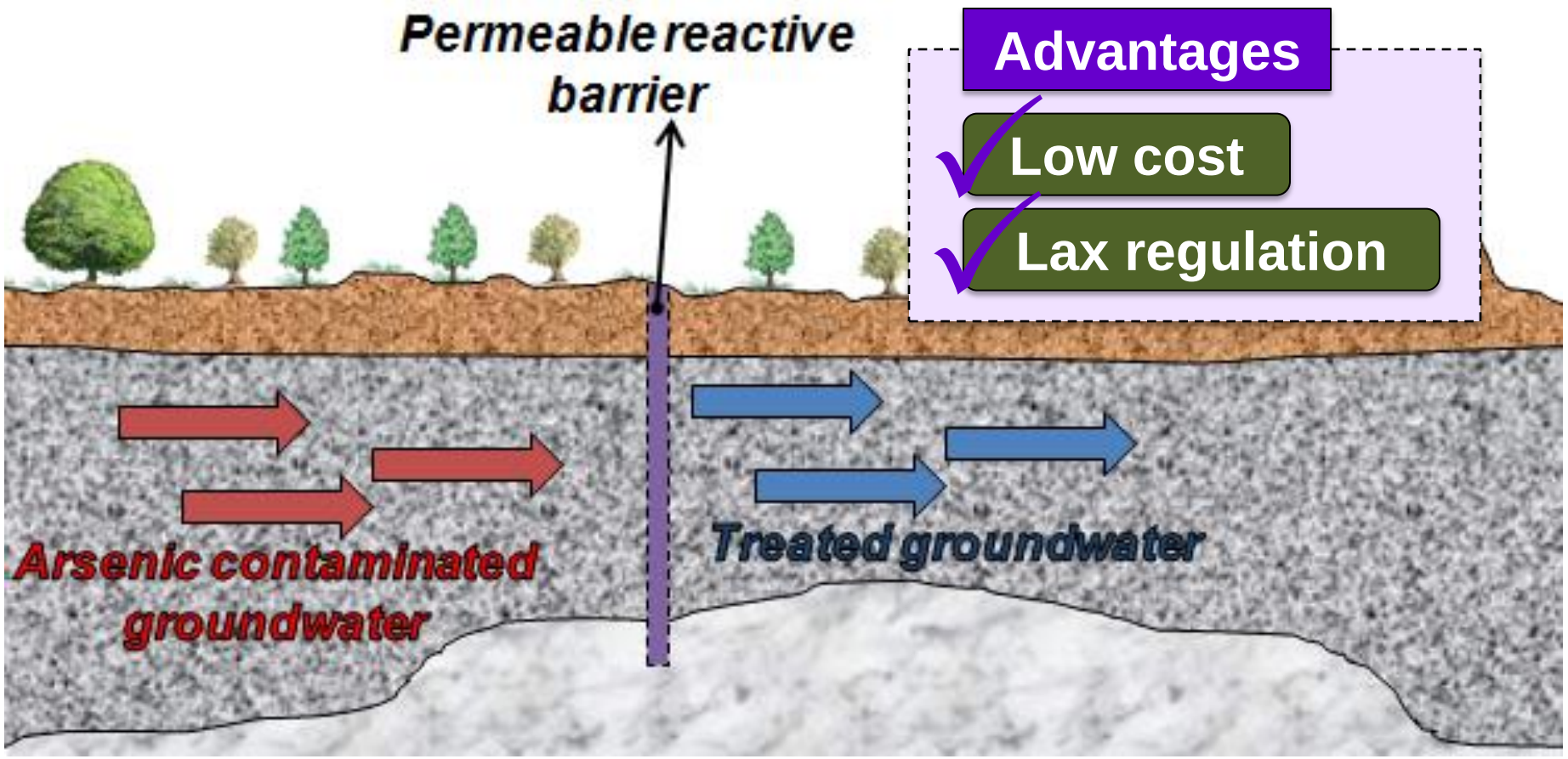
Death

Chronic poisoning

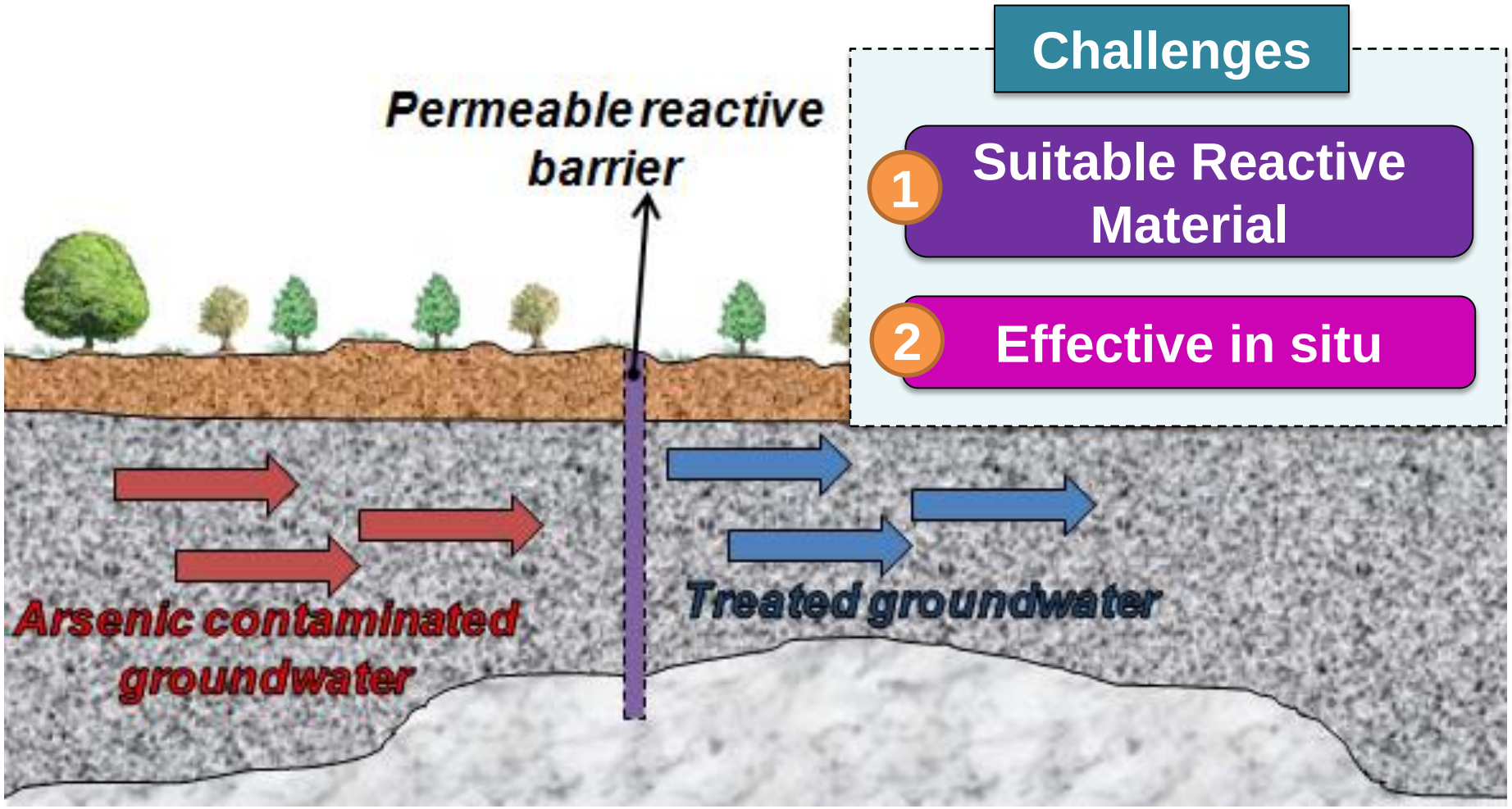


Cancer

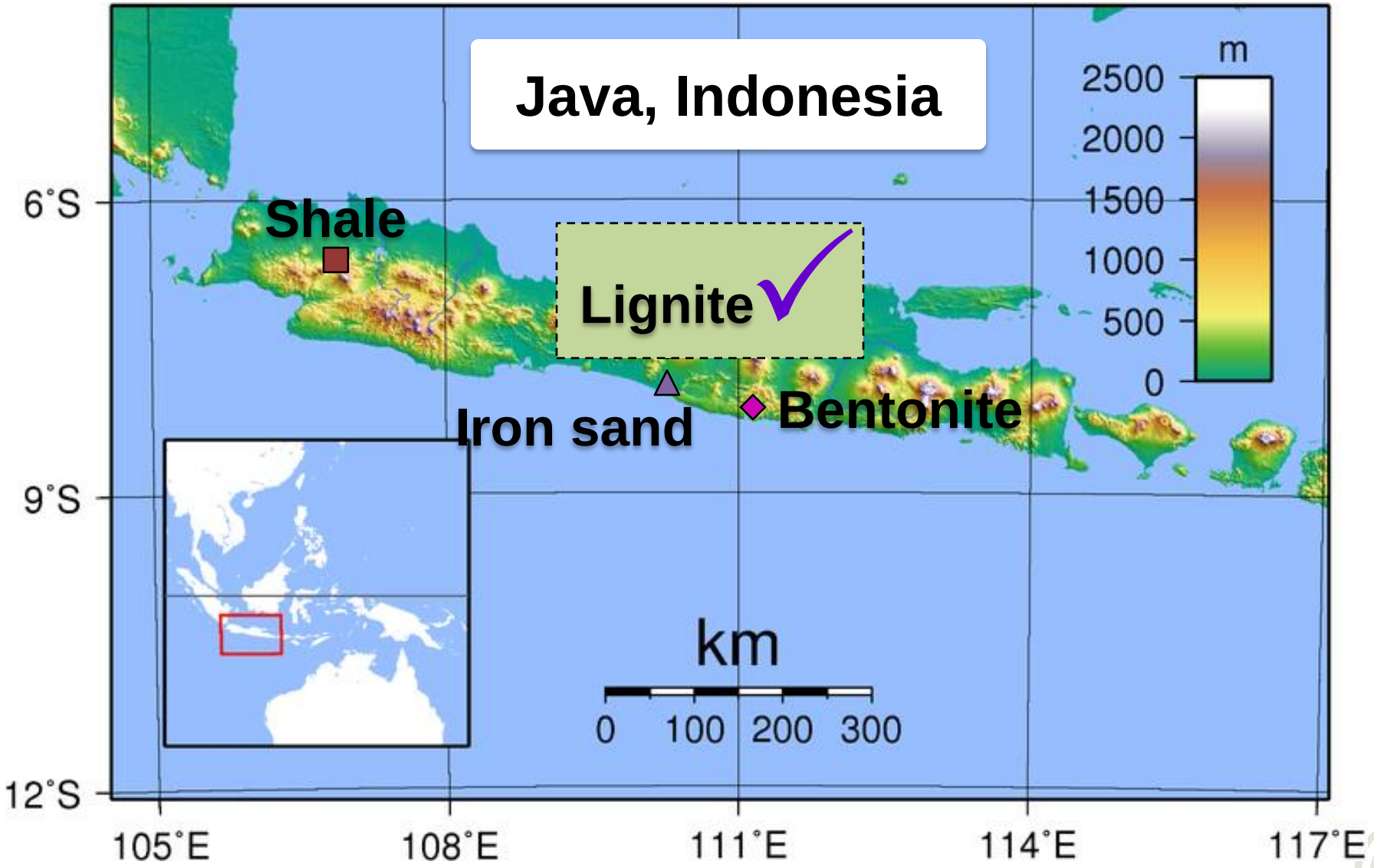
How can this problem be remediated?



How can this problem be remediated?

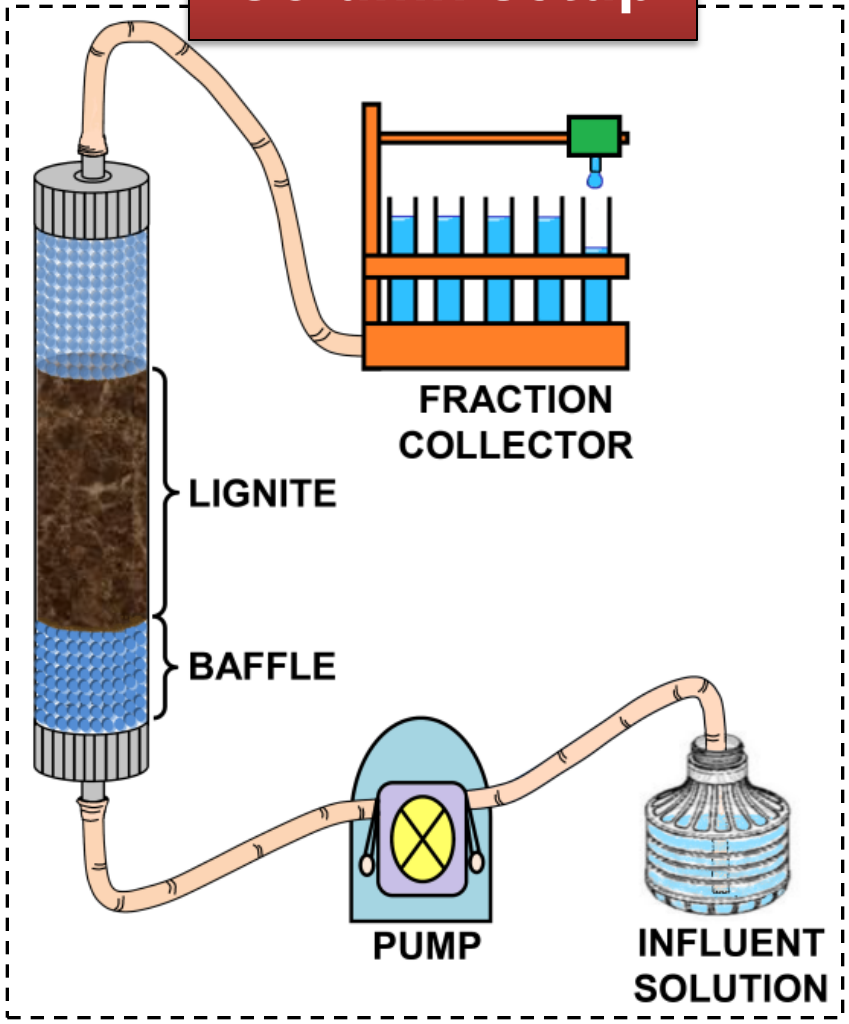


What potential reactive materials were evaluated?



What are the objectives of this study?

Column setup



1. Evaluate the adsorption of arsenic onto lignite under saturated flow conditions

2. Investigate the effects of soluble phases on arsenic adsorption

3. Estimate the K_D of arsenic onto lignite under saturated flow conditions

What are the chemical and mineralogical properties of lignite?

Lignite

Chemical properties

- Total Organic Carbon = 33 wt.%
- Arsenic = 1.8 mg/kg

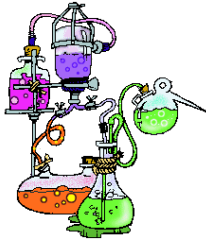
Mineralogical properties

- Pyrite (FeS_2)
- Orpiment (As_2S_3)

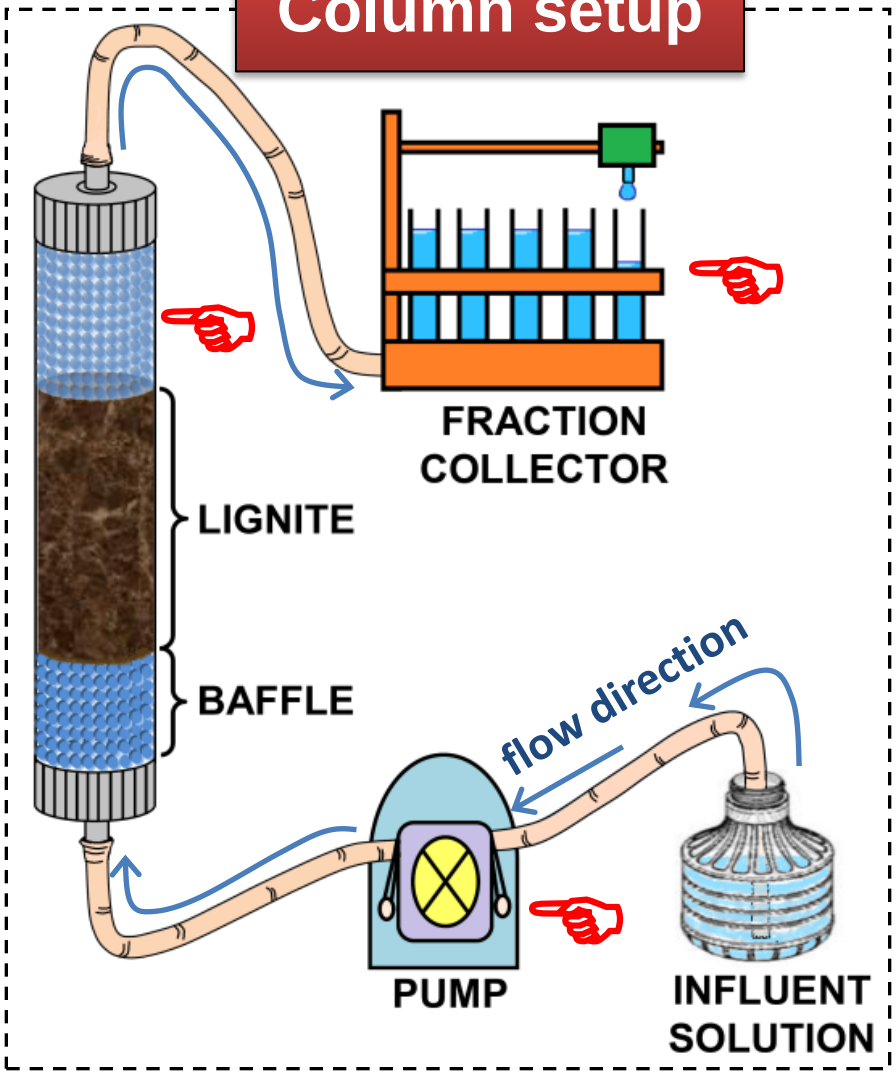
Leachate properties

- pH = 2.5 – 2.7
- Arsenic ≈ 0.8 μg/g

Under what conditions were the column experiments conducted?



Column setup



Initial and flow conditions

- Weight of adsorbent = 17.35 g
- Thickness = 6 cm
- Particle density = 1.87 g/cm^3
- Particle size = 0.5 – 1.0 mm
- porosity = 0.658

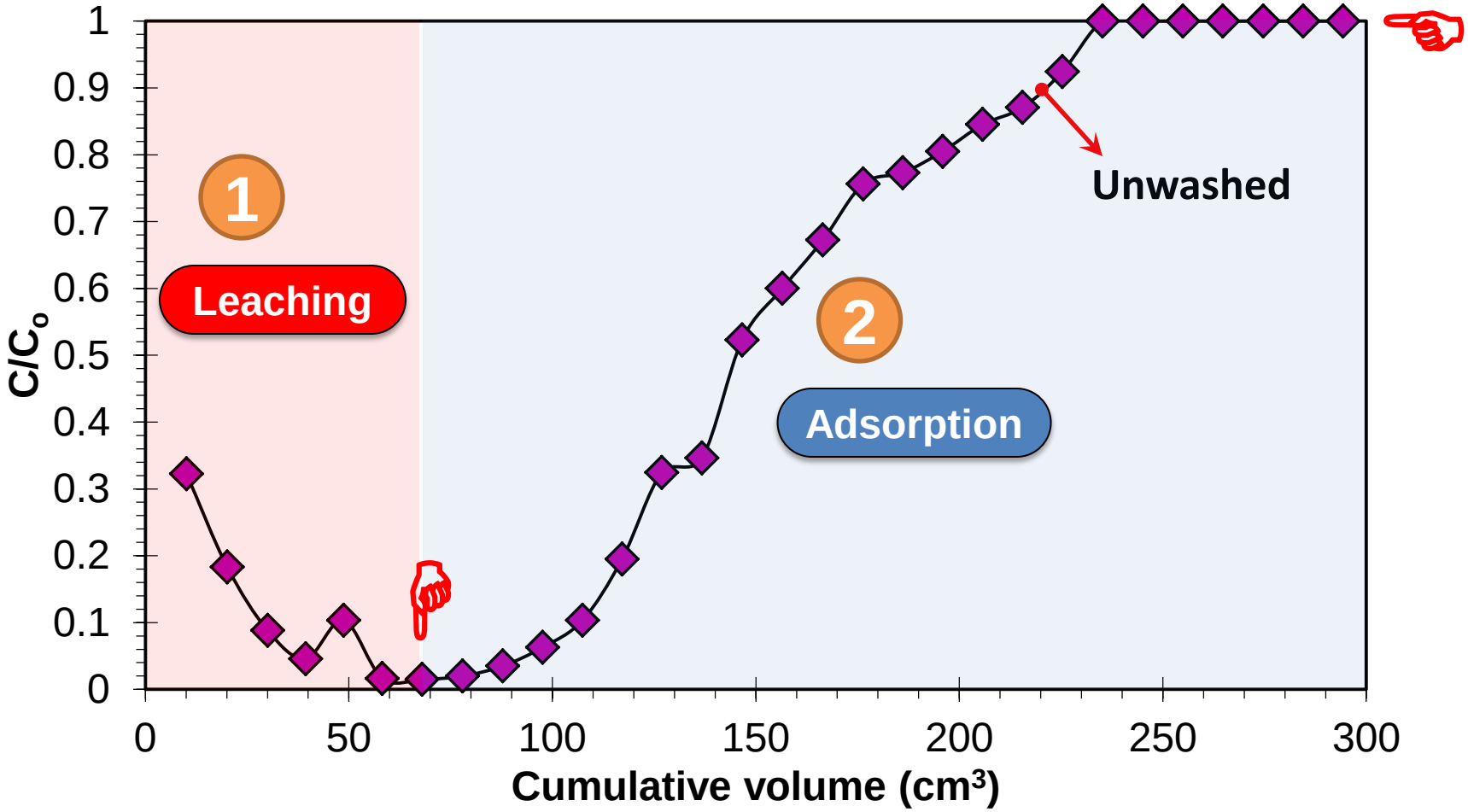
1 Unwashed

- Flow rate = 0.224 cm^3/min
- Lignite was used directly

2 Washed

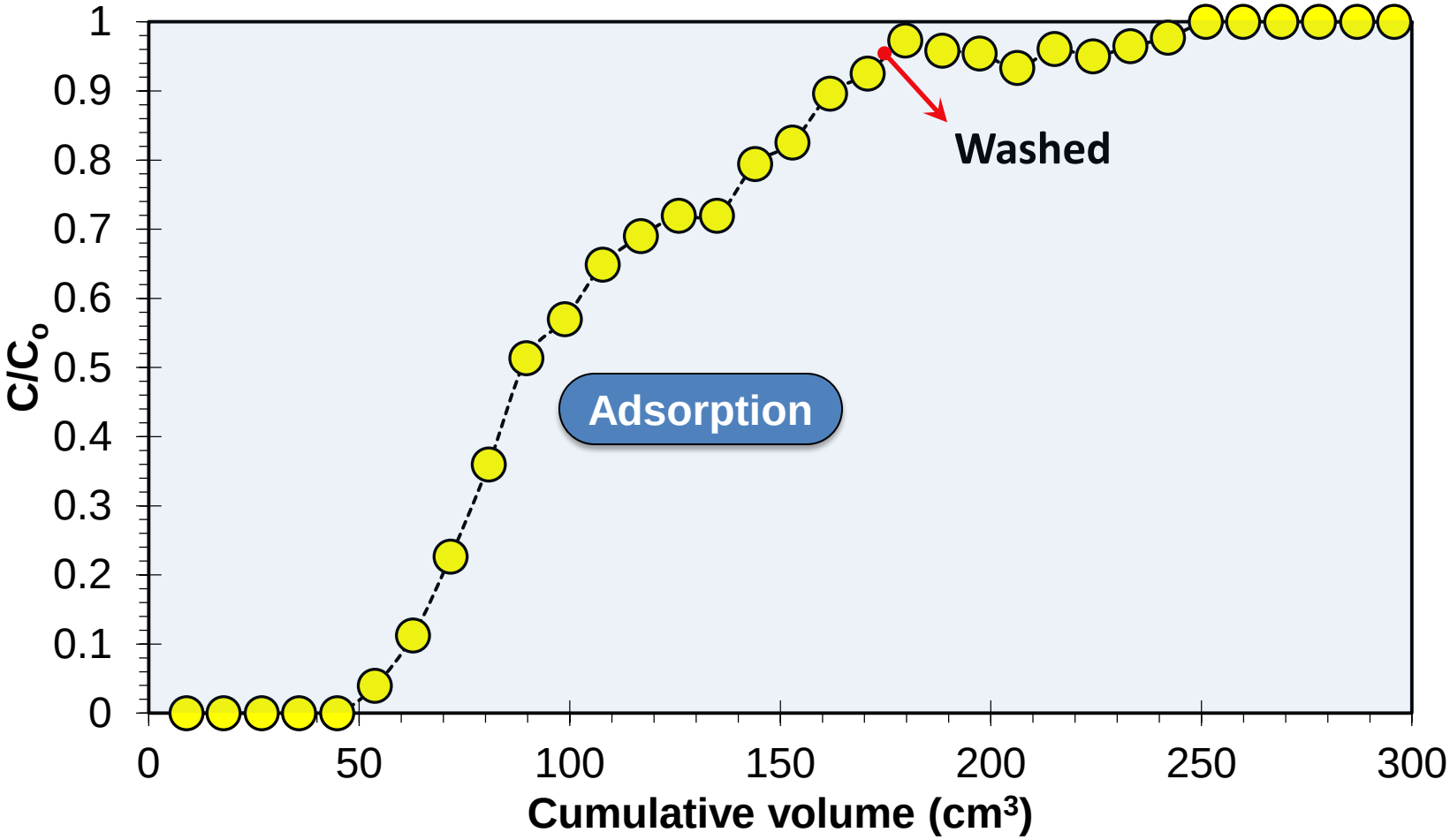
- Flow rate = 0.244 cm^3/min
- Washed with deionized water for 24 h

What was the adsorption performance of the unwashed lignite sample?



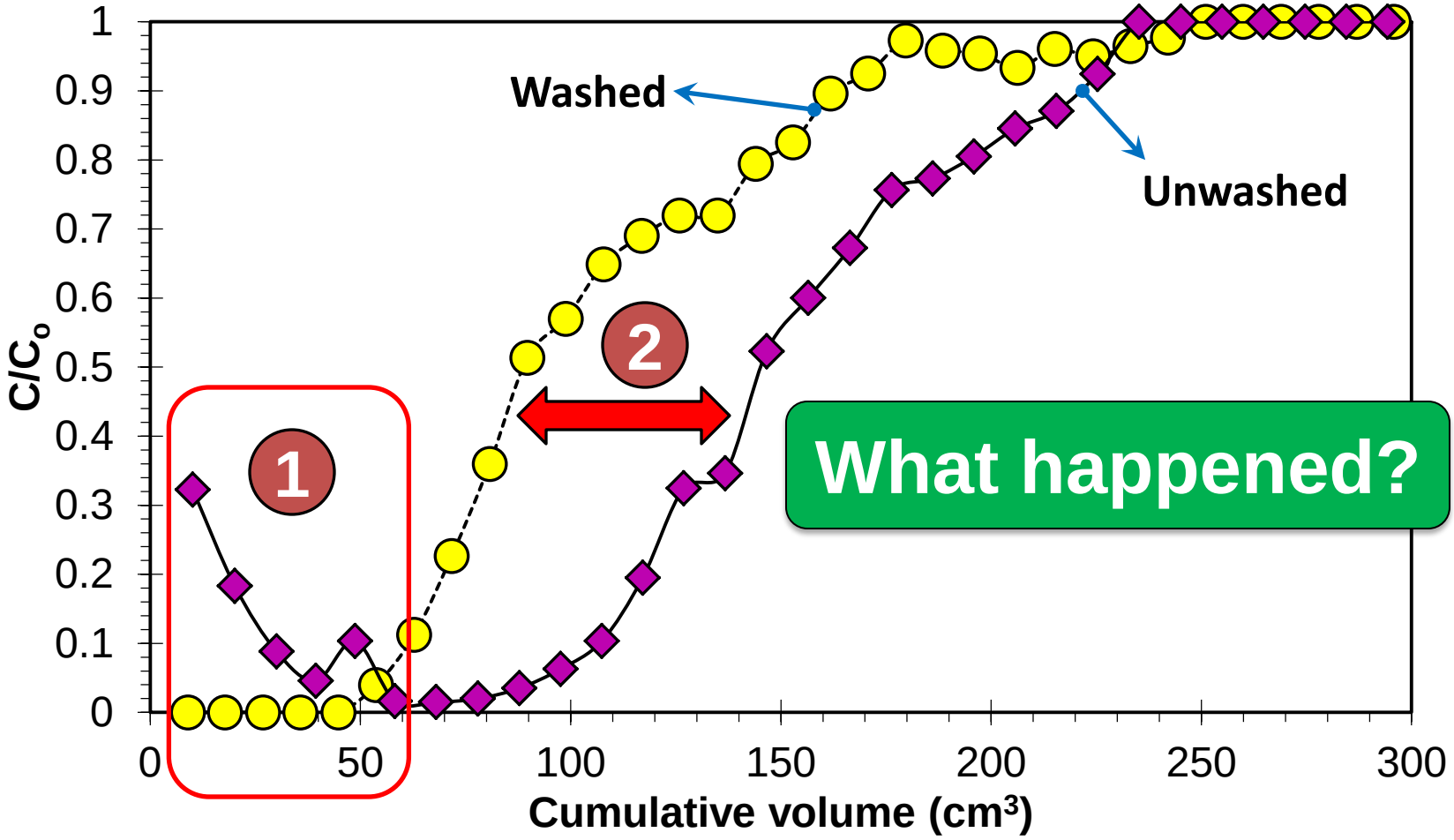
✓The breakthrough curve of arsenic had a leaching and adsorption dominant region.

What was the adsorption performance of the washed lignite sample?



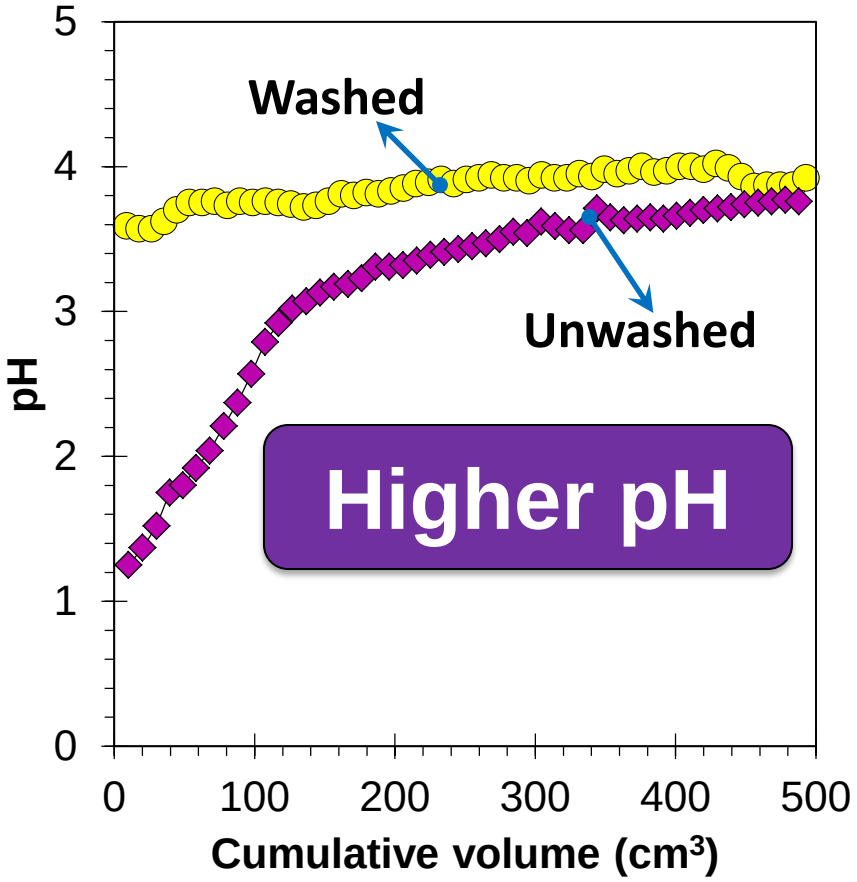
✓The breakthrough curve of arsenic after washing did not contain an initial leaching region.

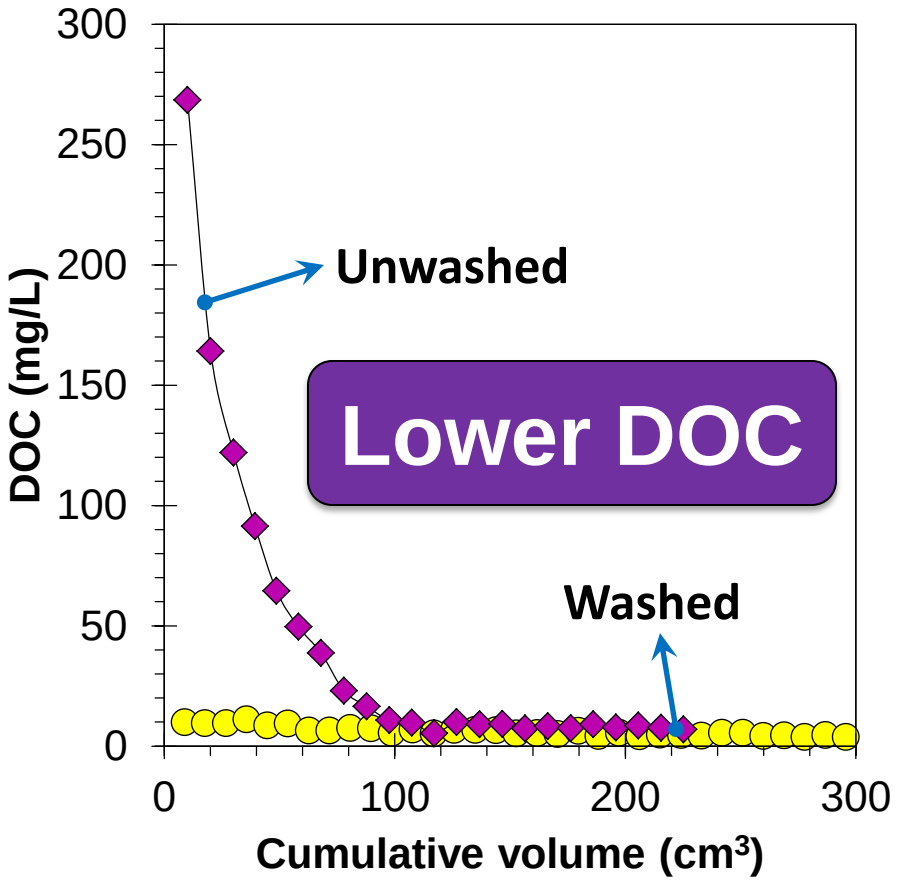
What is the adsorption performance of lignite under saturated flow conditions?



✓Washing removed the initial leaching region but reduced the overall adsorption capability of lignite.

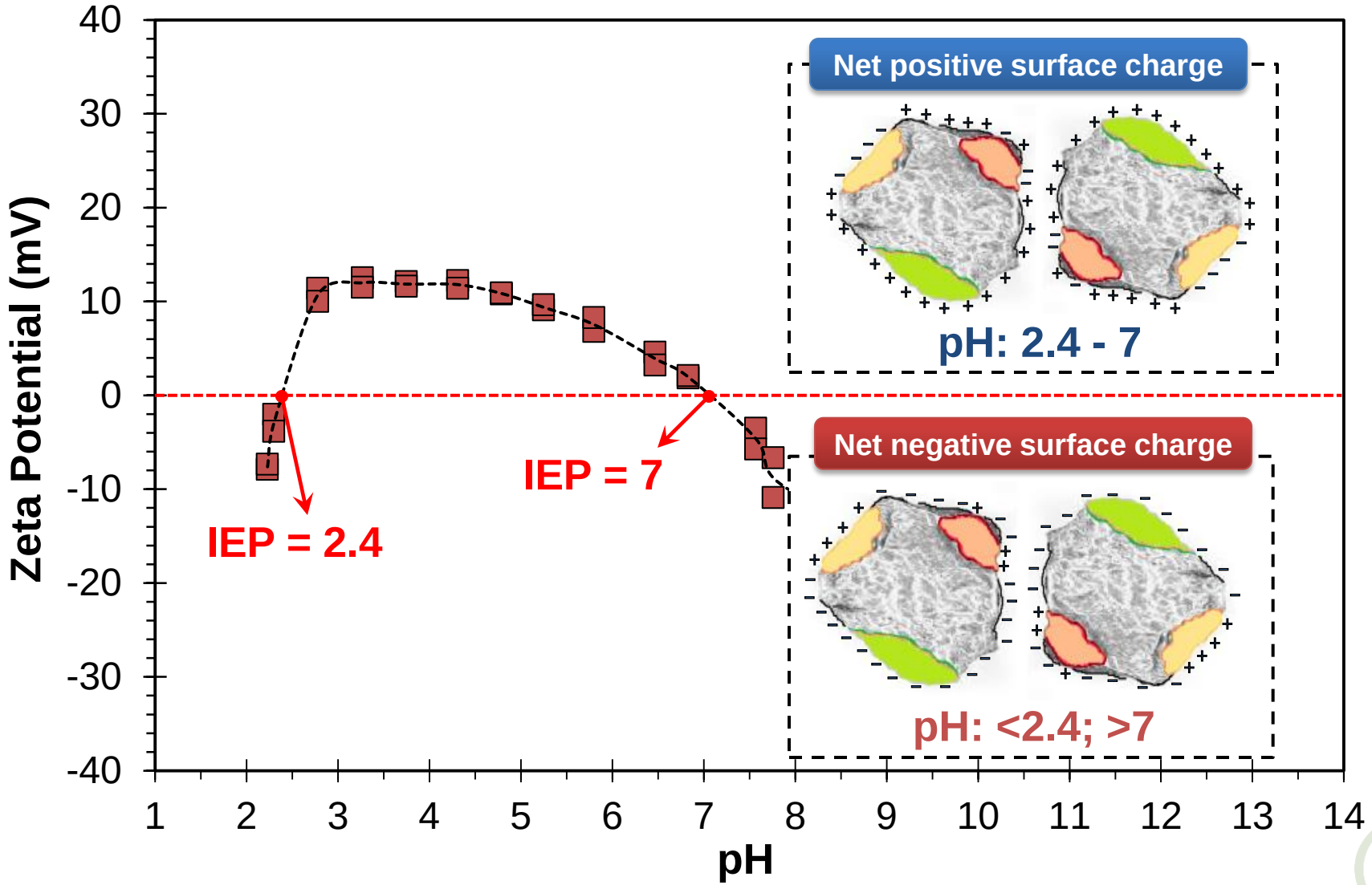
Why did the leaching region disappear after washing?



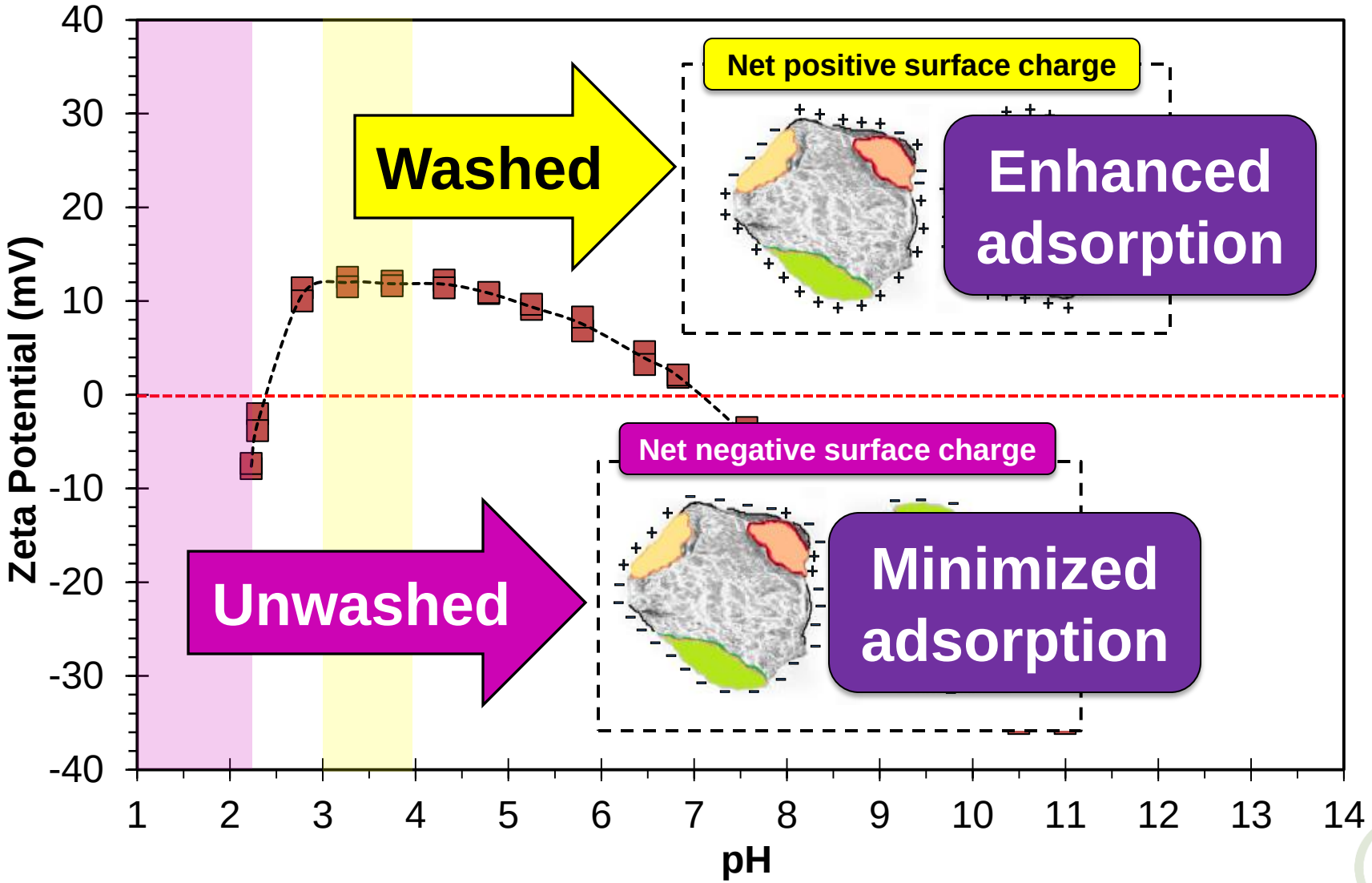


✓Initially, the effluents from the unwashed sample have very acidic pH and high DOC concentration.

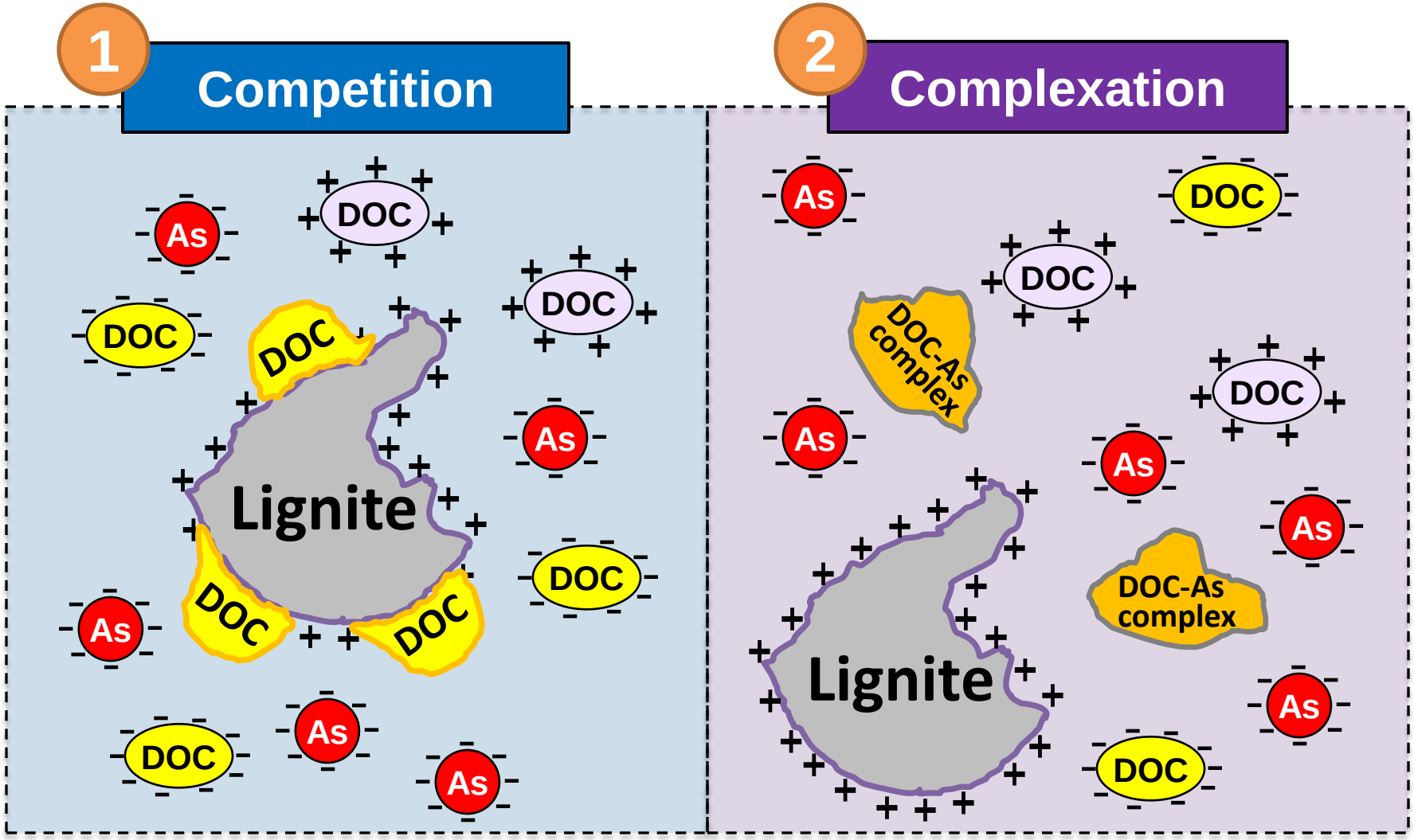
How did the pH affected arsenic adsorption?



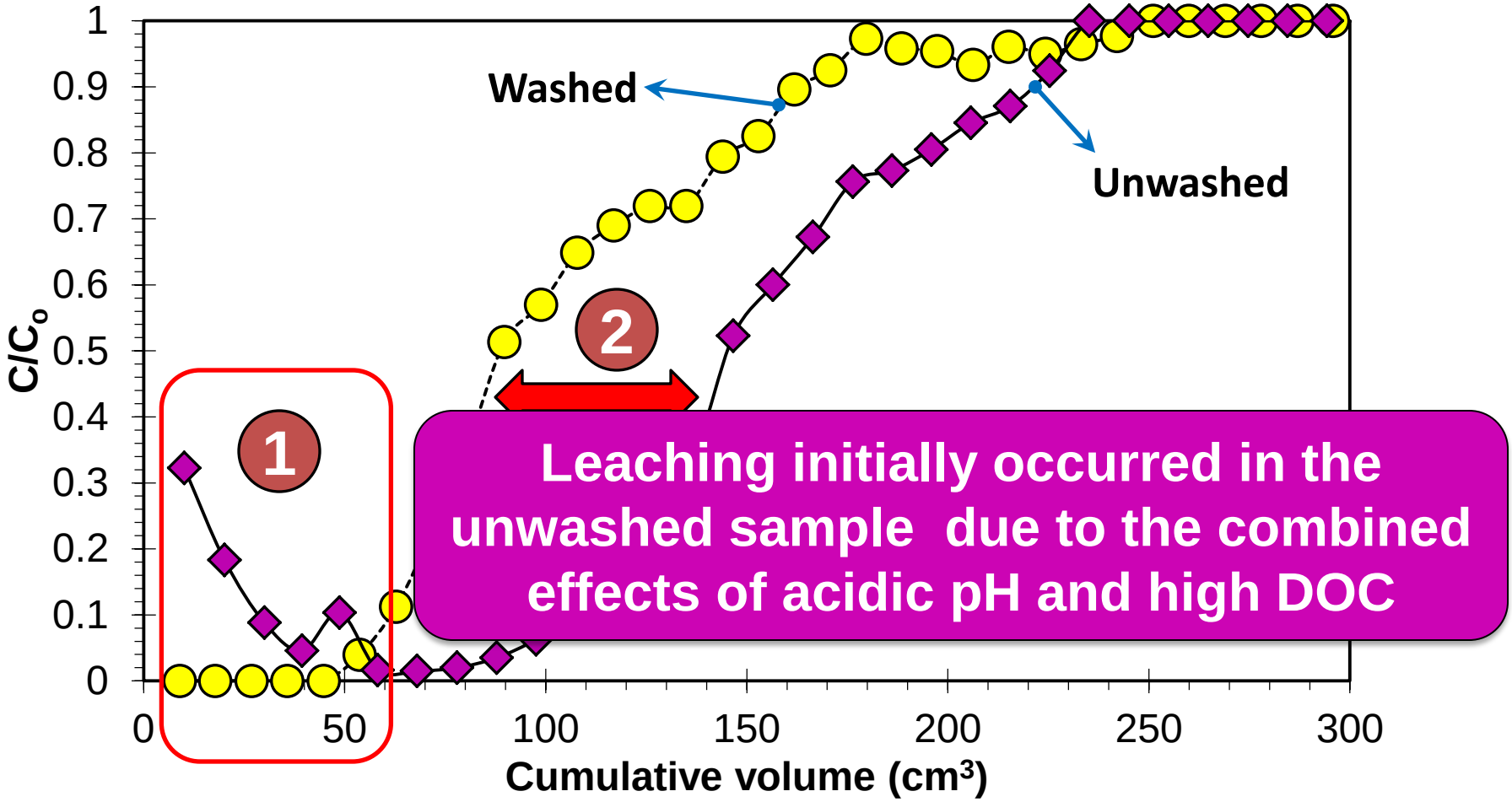
How did the pH affected arsenic adsorption?



How did DOC affected arsenic adsorption?

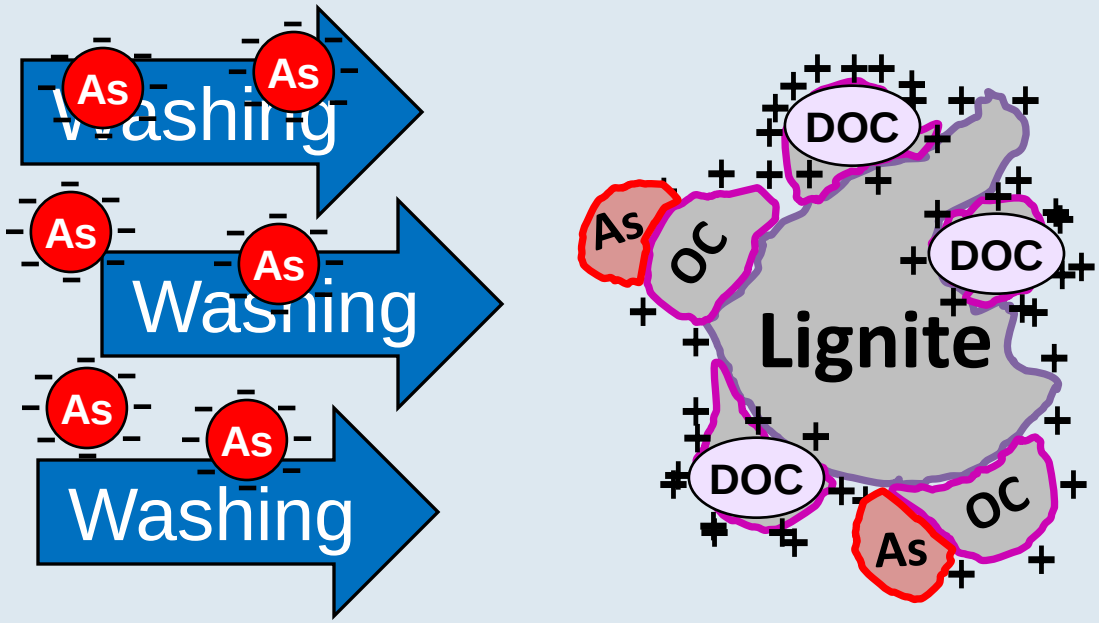


What is the adsorption performance of lignite under saturated flow conditions?



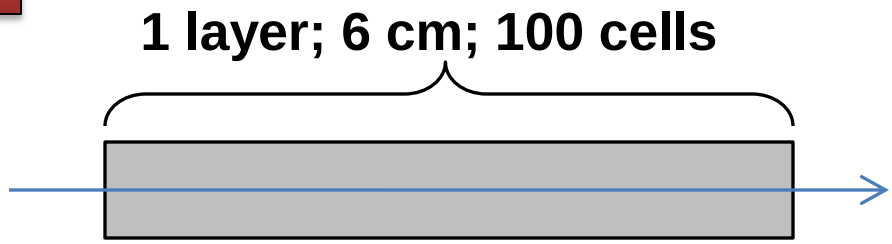
Why did the adsorption of arsenic onto lignite decreased after washing ?

Washing removed some of the positively charged functional organic groups of lignite



How was the distribution coefficient (K_D) estimated?

Simulation



Equation

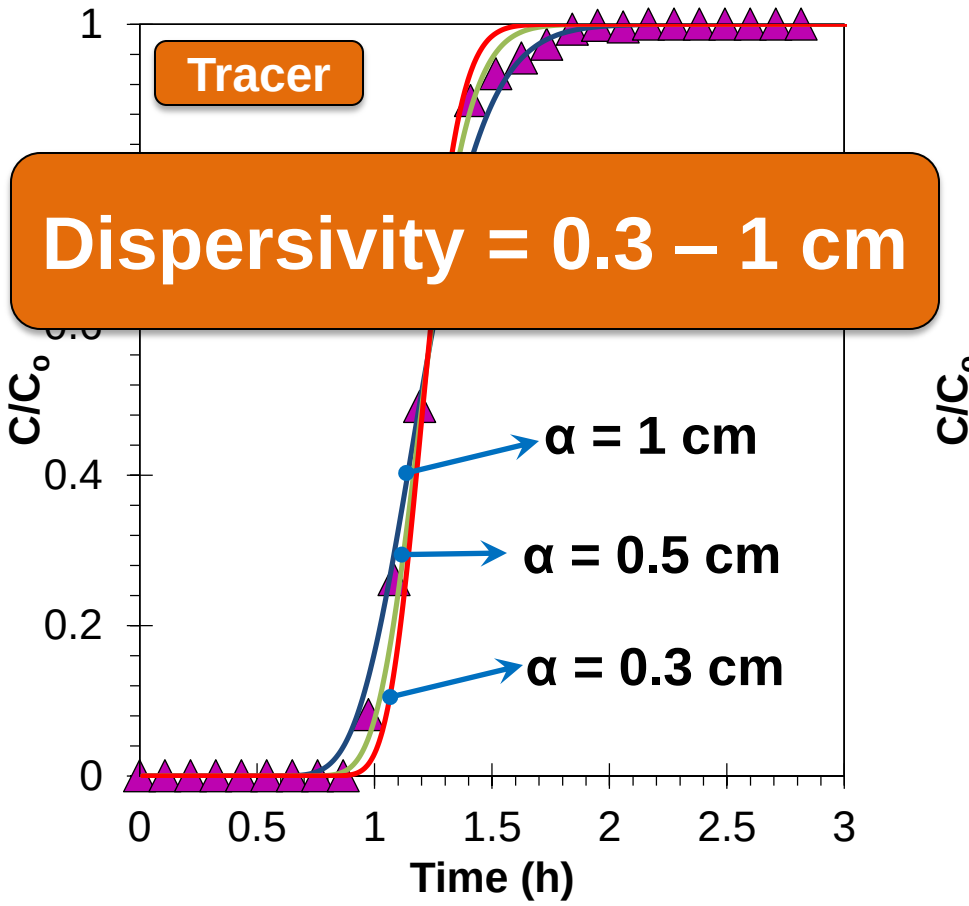
$$D_L \frac{\partial^2 C}{\partial x^2} - \bar{v} \frac{\partial C}{\partial x} - \frac{\partial q}{\partial t} = \frac{\partial C}{\partial t} \quad ; \quad q = K_D * C$$

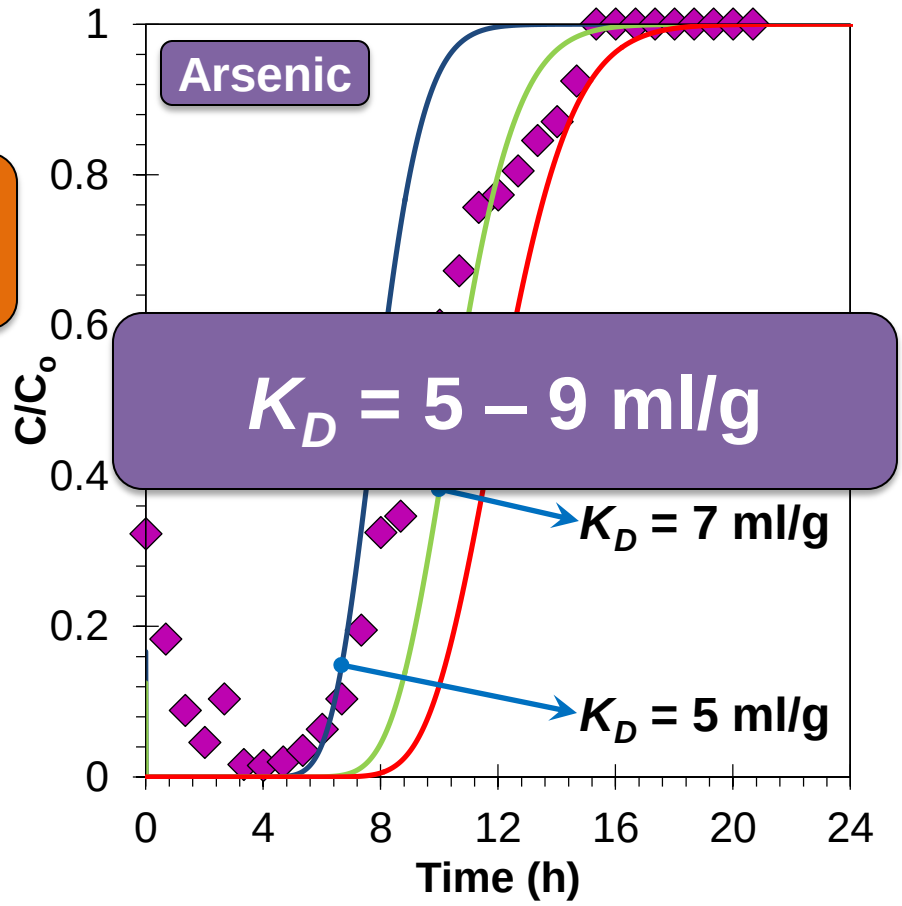
Dispersion — Advection — Reaction → Linear adsorption

Conditions

- Flow condition = Saturated-steady state
- Flow direction = Forward
- Solute transport conditions = Flux

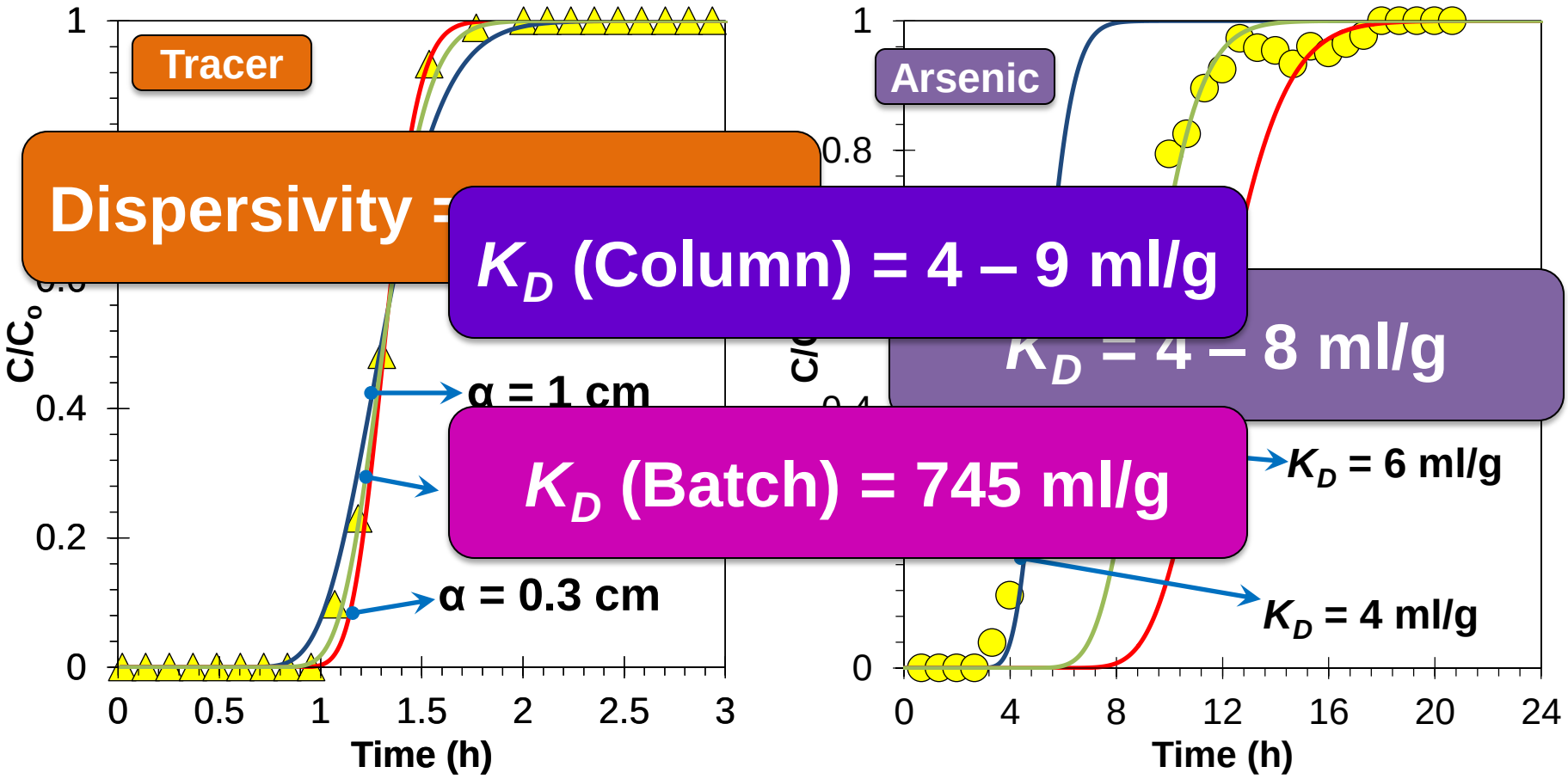
How was the distribution coefficient (K_D) estimated?





✓PHREEQC was able to estimate the distribution coefficient of lignite under saturated flow conditions

How was the distribution coefficient (K_D) estimated?

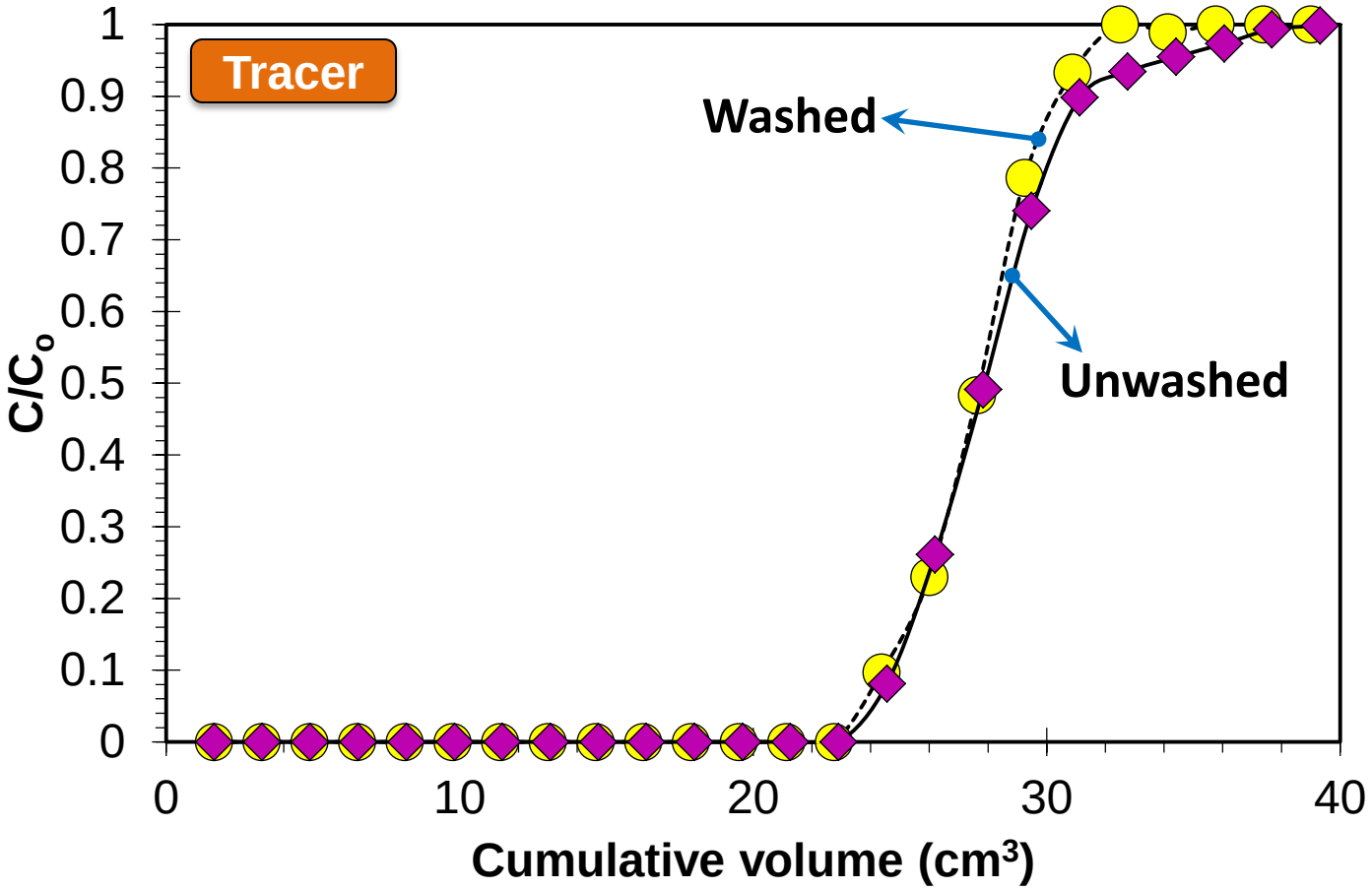


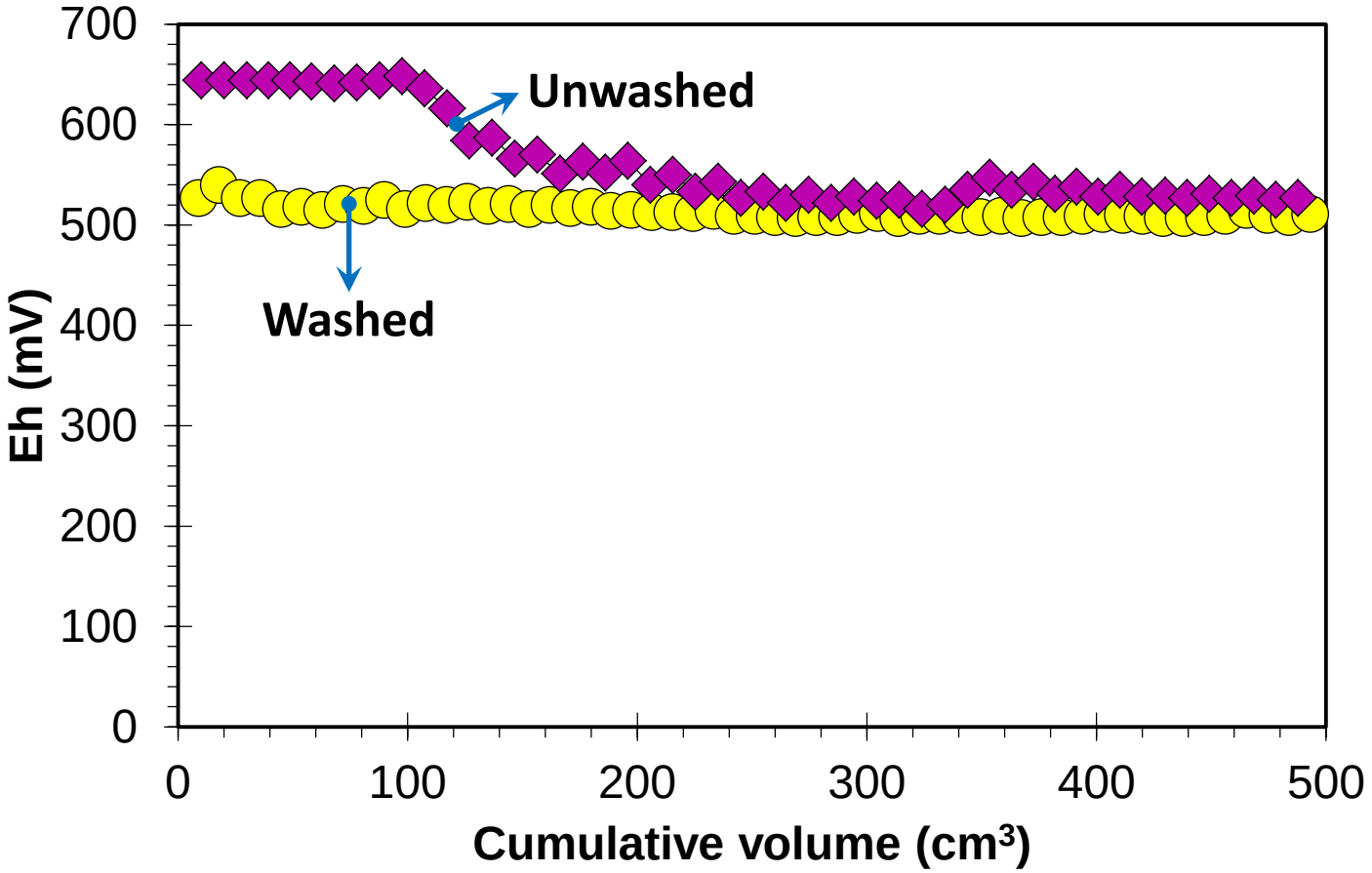
✓Adsorption of arsenic substantially decreased under saturated flow conditions

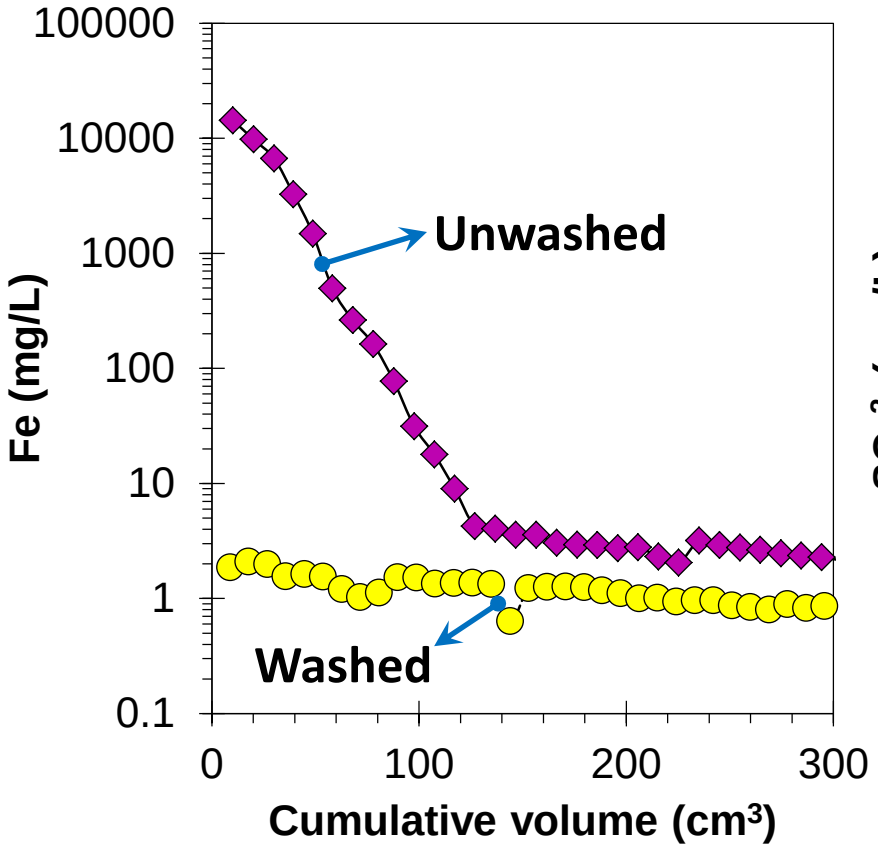
Conclusions

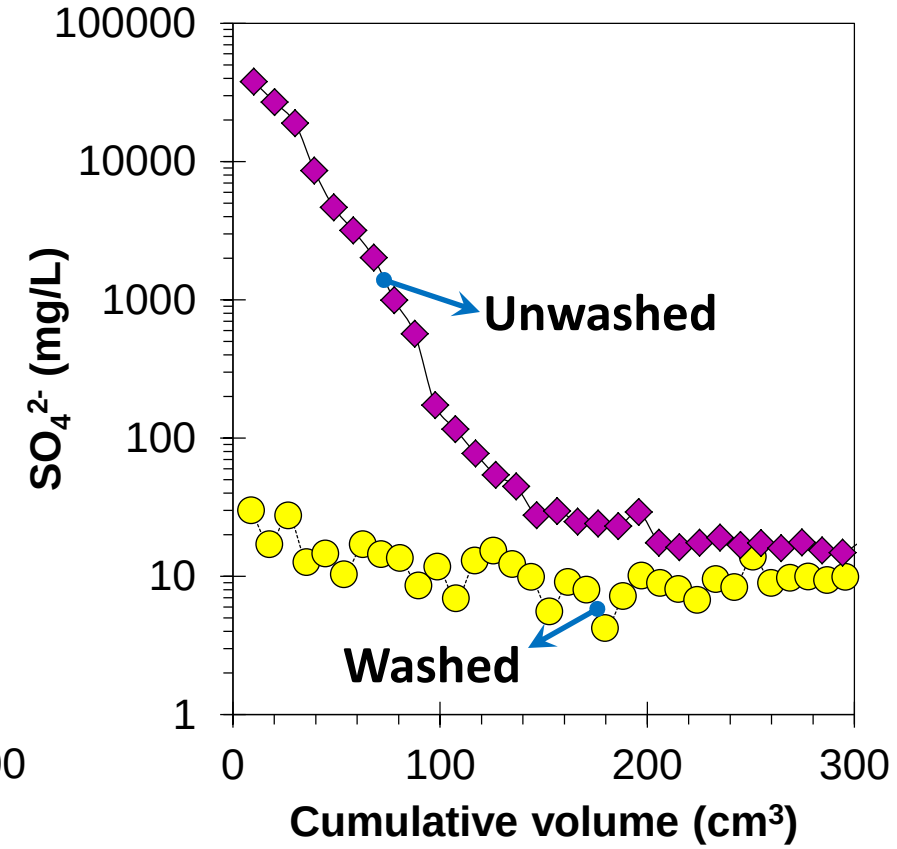
- Lignite was capable of sequestering arsenic under saturated-steady state flow.
- The effects of pH and DOC were very pronounced under saturated flow conditions.
- The one-dimensional advection-dispersion equation with linear adsorption could be used to give rough estimates of the K_D values of adsorbent materials close to the actual field conditions.

Thank you for listening…


Tracer
Washed
Unwashed
C/C$_o$
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
Cumulative volume (cm^3)


700
600
500
400
300
200
100
0
Eh (mV)
Unwashed
Washed
0
100
200
300
400
500
Cumulative volume (cm³)


100000
10000
1000
100
10
1
0.1
Fe (mg/L)
Unwashed
Washed
0
100
200
300
Cumulative volume (cm³)


100000
10000
1000
100
10
1
SO4 2- (mg/L)
Unwashed
Washed
0
100
200
300
Cumulative volume (cm³)