ENV 504: Remediation of soil and groundwater
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Problem set # 5: adsorption processes

Problem 1:
A groundwater aquifer in California has been contaminated with atrazine, an organic agricultural chemical, at a concentration of 300 μg/L. The State Health Department permits a maximum of 3 μg/L atrazine in drinking water. To meet the State's requirement, it is proposed to use activated carbon to treat the groundwater pumped from a group of wells that produce the groundwater at a rate of 2 m^3 per minute. The equilibrium isotherm for adsorption of atrazine on activated carbon is given by
$C_s=C^{0.003}$
where C_s =sorbed concentration (μg sorbed per g activated carbon) and C= equilibrium aqueous concentration (μg/L).
Granular activated carbon (GAC) is to be used to control this atrazine problem.
Adsorbent bed length L=15m
GAC bulk density ρ_b=425 kg/m^3
A breakthrough time of 30 days is deemed reasonable

For simplicity, we will assume that the adsorption zone is S-shaped and symmetrical.

a- Calculate the empty bed contact time (minutes).
b- Assuming that the flow is treated in a single bed, what diameter is needed?
c- Approximately how long before the effluent concentration of the bed rises to 3 μg/L? How many bed volumes does this represent?
d- Calculate the average rate at which the GAC adsorbent must be reactivated (in gram of activated carbon per m^3 water treated).

Problem 2
An industrial facility needs to treat a wastewater stream discharging 500 m^3/day containing 12 mg/L of an organic contaminant. A pilot scale GAC column test indicates that the GAC has a maximum carbon loading capacity of 80 mg/g when in equilibrium with the influent concentration. The packed bulk density of the chosen carbon is 450 kg/m^3. The design target is an EBCT of 15 minutes.

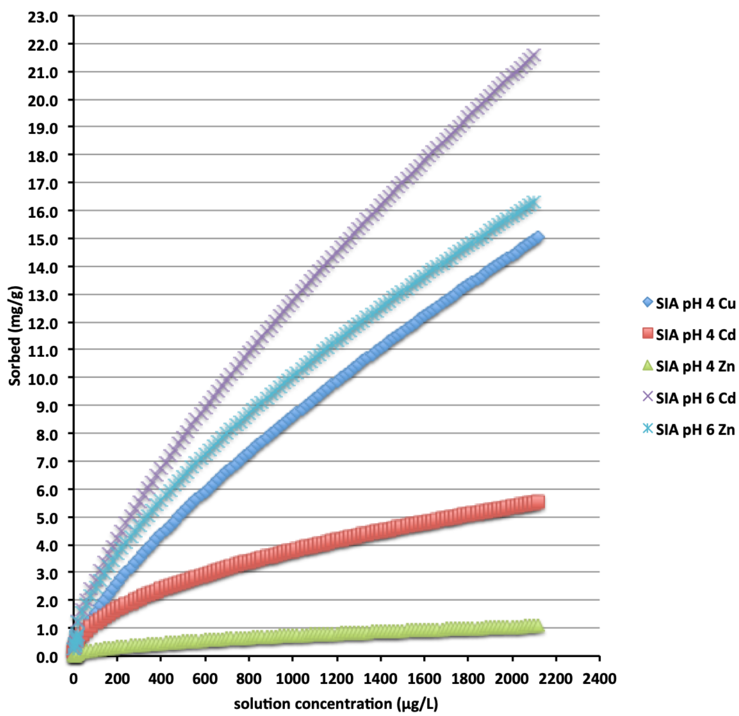
1. Compute the required volume of the GAC bed V_b
2. Calculate the total mass of GAC required to fill the contactor.
3. Assuming an ideal plug flow system where the entire bed reaches complete exhaustion at breakthrough, calculate the bed life before carbon replacement is mandatory.

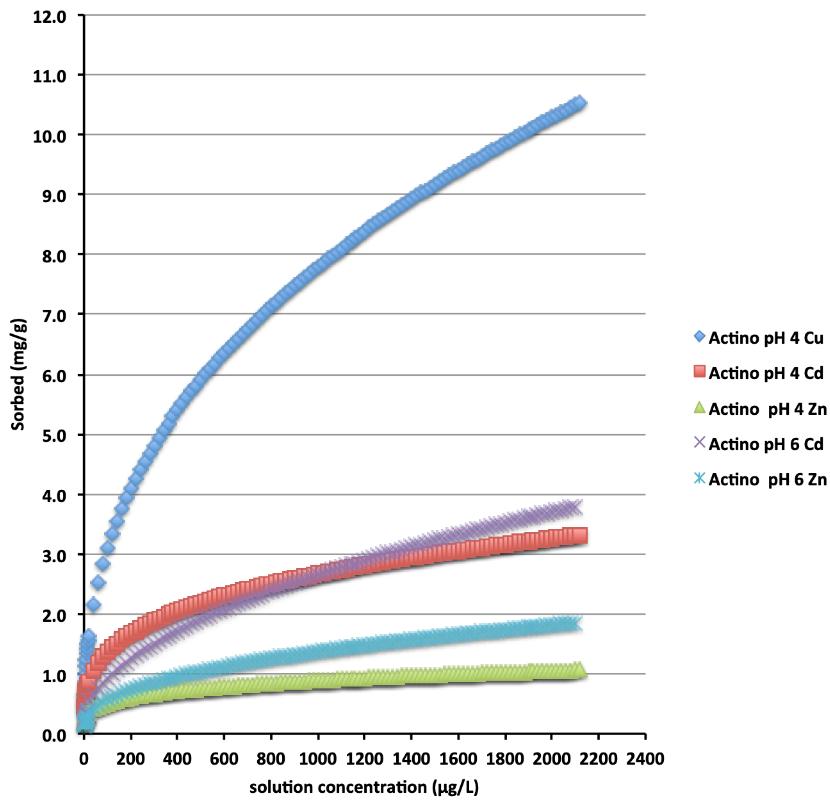
Problem 3:
The goal is to remove metals from the following effluents using packed bed reactors containing either silica immobilized algae (SIA) or Actinomycetes.
Waste steam 1: 2 mg/L Cu^{2+}, 2 mg/L Cd^{2+}, 2 mg/L Zn^{2+}, pH 4. All concentrations must be below 600 μg/L.

Waste stream 2: 1.2 mg/L Cd^{2+}, 1.5 mg/L Zn^{2+}, pH 6. All concentrations must be below 600 μg/L.

Equilibrium isotherms for all three metals with SIA and actinomycetes are given in the next page. The beds contain each 50 kg of sorbent and the flow rate is 5 L/min. Additivity is assumed for the sorption of these metals on these sorbents. Hence, the sorption behavior of single metal is expected to be the same as in the presence of other metals.

Which of the two sorbents would you use for each of the waste streams?





Problem 4:

A pilot-scale column test was conducted to treat water containing 4.0 mg/L of an organic chemical using a GAC bed with a total depth of 2.5 meters. The operating flow rate results in a superficial linear velocity of 8.0 m/h.
Effluent monitoring data yielded the following breakthrough time indicators:

- Breakthrough time t_b= 32 hours (when effluent concentration reached the detection limit of 5% of influent)
- Exhaustion time t_e=48 hours (when effluent concentration reached 95% of influent)

1. Calculate the length of the Mass Transfer Zone (MTZ) .
2. Determine the fraction of the GAC bed capacity that is utilized at the breakthrough point.
3. Calculate the total length of the bed required if the system needs to run for 120 hours before breakthrough happens, assuming the velocity of the fluid does not change.