1.85 WATER AND WASTEWATER TREATMENT ENGINEERING
HOMEWORK 5 – SOLUTIONS

Question 1 (2 points)

A small community has used an unchlorinated ground-water supply containing approximately 0.3 mg/L of iron and manganese for several years without any apparent iron and manganese problems. A health official suggested that the town install chlorination equipment to disinfect the water and provide a chlorine residual in the distribution system. After initiating chlorination, consumers complained about water staining washed clothes and bathroom fixtures. Explain what is occurring due to chlorination

Answer

Once chlorination was initiated, the iron and manganese, which previously was in reduced, dissolved form, was oxidized by the chlorine. The oxidized iron is relatively insoluble and precipitates out of the water as rust-colored particles. Manganese similarly is oxidized and forms black particles. These precipitates cause stains in laundry and bathroom fixtures.

Question 2 (2 points)

Untreated well water contains 1.2 mg/L of iron and 0.8 mg/L of manganese at a pH of 7.5. Calculate the theoretical dosage of potassium permanganate required for iron and manganese oxidation.

Answer

Oxidation reactions are:

$$3Fe^{2+} + MnO_4^- \rightarrow 3Fe^{3+} + MnO_2$$

$$3Mn^{2+} + 2MnO_4^- \rightarrow 3Mn^{3+} + 5MnO_2$$

In the first reaction each mole of iron (MW = 55.8) requires one-third mole of $KMnO_4$ (MW = 39.1 + 55.0 + 4 x 16.0 = 158). Therefore 1.2 mg/L Fe will use 1.2 x 158/3 / 55.8 = 1.13 mg/L of $KMnO_4$. Similarly, Manganese (MW = 55.0) requires two thirds mole of $KMnO_4$. Therefore, 0.8 mg/L of manganese will use 0.8 x 2/3 x 158 / 55 = 1.53 mg/L of $KMnO_4$. The total requirement is 1.13 + 1.53 = 2.7 mg/L $KMnO_4$.

Question 3 (3 points)

A wastewater containing phenol at a concentration of 0.4 mg/L is to be treated by granular activated carbon. Batch tests have been performed in the laboratory to determine the relative adsorption of phenol by GAC. Testing entails adding a mass of carbon to V = 1 liter of the 0.4 mg/L-solution, allowing the solution to reach equilibrium over 6 days, and then measuring the resulting equilibrium concentration of phenol. Results are shown in the table below. Develop a Freundlich isotherm to fit these data.

Mass of carbon, M (gm)	Initial conc., C_0 (mg/L)	Equilibrium conc C_e (mg/L)
0.52	0.400	0.322
2.32	0.400	0.117
3.46	0.400	0.051
3.84	0.400	0.039
4.50	0.400	0.023
5.40	0.400	0.012
6.67	0.400	0.0061
7.60	0.400	0.0042
8.82	0.400	0.0023

Answer: From spreadsheet calculation:

Data tabulation**:**

Mass of carbon, M	Initial conc. C_0	Equil. conc C_A	C_0-C_A	V * (C_0 - C_A)	q_A = V (C_0 - C_A) / M	log C_A	log q_A
(g)	(mg/L)	(mg/L)	(mg/L)	(mg)	(mg/g)		
0.52	0.4	0.322	0.078	0.078	0.150	-0.492	-0.824
2.32	0.4	0.117	0.283	0.283	0.122	-0.932	-0.914
3.46	0.4	0.051	0.349	0.349	0.101	-1.292	-0.996
3.84	0.4	0.039	0.361	0.361	0.094	-1.409	-1.027
4.5	0.4	0.023	0.377	0.377	0.084	-1.638	-1.077
5.4	0.4	0.012	0.388	0.388	0.072	-1.921	-1.144
6.67	0.4	0.0061	0.3939	0.3939	0.059	-2.215	-1.229
7.6	0.4	0.0042	0.3958	0.3958	0.052	-2.377	-1.283
8.82	0.4	0.0023	0.3977	0.3977	0.045	-2.638	-1.346
Mass of adsorbent		Liquid phase concentration	Change in conc. in water	Mass adsorbed to carbon	Solid phase concentration		

Data are plotted below and fall more or less on a straight line. Determine approximate slope from first and last points on line: (Note that linear regression would be more accurate.)

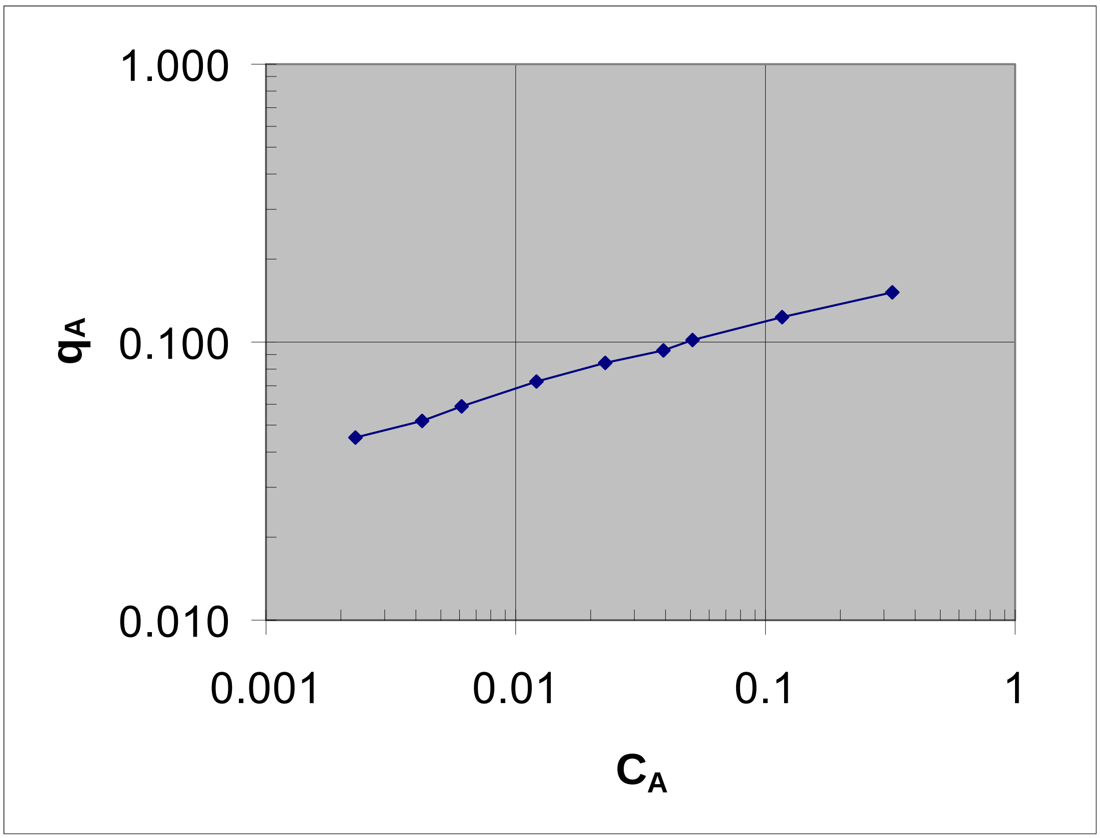
Slope = 1/n = [(log $q_{A,max}$) - log ($q_{A,min}$)]/[log($C_{A,max}$)-log($C_{A,min}$)]

1/n = 0.243

Next determine $K_F = q_A / C_A^{/n}$ for each data point and find average K_F value:

Mass of carbon, M	Equil. conc C_A	$q_A = V(C_0 - C_A)/M$	$K_F = q_A/C_A^{1/n}$
(g)	(mg/L)	(mg/g)	
0.52	0.322	0.150	0.198
2.32	0.117	0.122	0.206
3.46	0.051	0.101	0.208
3.84	0.039	0.094	0.207
4.5	0.023	0.084	0.210
5.4	0.012	0.072	0.211
6.67	0.0061	0.059	0.204
7.6	0.0042	0.052	0.197
8.82	0.0023	0.045	0.198
		Average =	0.204

Data plot:



Question 4 (3 points)

An ion exchange resin is used to remove nitrate from a water supply with the ionic concentrations shown below. The total resin capacity is 1.5 equivalents per liter of resin.

Cations	**meq/L**
Ca^{2+}	1.4
Mg^{2+}	0.8
Na^{+}	2.6

Anions	**meq/L**
SO_4^{2-}	0.0
Cl^{-}	3.0
NO_3^{-}	1.8

a. Do the anions and cations balance? (1 point).

b. What volume of water can be treated with each liter of resin? (2 points)

c. Qualitatively, how would your answer differ if the concentrations of Cl^{-} and SO_4^{-} were reversed? (1 point).

Answer:

a. Σcations = 4.8 meq/L
Σanions = 4.8 meq/L Charges balance!.

b. Each liter of resin can remove 1.5 equivalents. Only chloride is present in quantity and nitrate is well above chloride in ion exchanger preference series shown in lecture, therefore can ignore exchange of ions other than nitrate:

Concentration of nitrate = 1.8×10^{-3} eq/L

Volume treated = 1.5 eq / 1.8×10^{-3} eq/L = 833 liters

c. Since SO_4 is above NO_3 in the preference series, if SO_4 were present rather than Cl, SO_4 would be adsorbed instead of NO_3. There were would be far less, if any, NO_3 adsorption. Another resin or much greater amount of resin would be needed.