Department of Civil Engineering, IIT Delhi

CEL 212: Environmental Engineering

Practice problems

Name___________________________ **Entry no.**__________________________**Group** ________

Q1. Plot the following data and determine the design dosage to obtain a residual of 0.75 mg/L free available? Re-draw the breakthrough curve if chlorine is only reacting/killing bacteria and provide reasons. ***[5+5=10 points]***

Chlorine dosage (mg/L)	0.1	0.5	1.0	1.5	2.0	2.5	3.0
Chlorine residual (mg/L)	0.0	0.4	0.8	0.4	0.4	0.9	1.4

Q2. Which of the following coagulant you would choose for settling biological solids and why? ***[5 points]***

Electrolyte	relative power for positive colloids	relative power for positive colloids
NaCl	1	1
$AlCl_3$	1	1000
$Al_2(SO_4)_3$	30	>1000

Q3. How does nitrification and denitrification differ in terms of oxygen and alkalinity adjustment requirements? ***[5 points]***

Q4. Two stacks of effective heights 100 m each are situated at 50 m apart (NO emission rates=80g/s) (stack #2 is located downwind of stack #1). Assume a wind speed of 4 m/s at 10 m (k for wind velocity profile =0.15) with stability class B covering both stacks. Calculate NO concentration C(200m,0,0) and C(-200m,0,0) where X is downwind distance of receptor from stack #1? Write down steps for determining setback distances in all directions including both stacks? ***[7+3=10 points]***

Q5. In a completely mixed aerobic biological reactor, if rate of substrate utilization is given by = (-kXS), determine expressions for substrate removal? Assume all other parameters required. ***[10 points]***

Q6. Fill in the blanks with calculations (25% negative marking) ***[6 points]***

No.	**Question**
1.	4-log reduction indicates ______________________% removal of pathogens.
2.	BOD for oxidation of 1 g/L bacterial cells_________________________________ ___________
3	Name three disinfection kinetic models

Q6. Answer "Yes" or "No". (25% negative marking) ***[4 points]***

No.	**Question**	**Yes**	**No**
1.	SRT can be smaller than HRT for anaerobic processes.		No
2.	Oxygen consumption rate for C-BOD is always higher than for N-BOD		No
3.	Recirculation in biological processes is done to dilute the incoming wastewater from primary sedimentation tank.		No
4.	Maximum pollutant concentration during dispersion of pollutant can happen outside the plume centreline as well.		No

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Note: Assume missing data (if any) and mention the same. Be precise in all open-ended questions.

Q1. Determine the settling velocity of a spherical particle with diameter of 20 micron and a specific gravity of 2.65 in water at 20°C? Is sedimentation a good option for removing this type of particles? Would increasing particle size with lower settling velocity help in increasing removal? $\mu=1.001\times10^{-3}$ $N.s/m^2$ at 20°C. ***[6+2+2=10 points]***

Q2. Define following terms (<100 words): (i) role of depth in type 1 and Type 2 settling, (ii) Time- to-critical deficit, (iii) order of exertion of C-BOD and N-BOD? ***[4+2+4=10 points]***

Q3. Find theoretical CBOD, NBOD and total COD of 2000 mg/L aerobic biomass ($C_5H_7O_2N$). If none of NBOD is exerted in first 5 days, estimate ultimate BOD (k1 for carbonaceous BOD=0.25/day)? How does this affect DO sag curve parameters? ***[2.5*4+10=20 points]***

$D(t) = [K_1*L_0]*[exp(-K_1*t)-exp(-K_2*t)]/(K_2-K_1) + [D_0 exp(-K_2*t)]$

Time for critical DO deficit (t_c)= $1/(K_2-K_1)*ln[(K_2/K_1)*(1-D_0*(K_2-K_1)/(K_1L_0))]$

Critical DO deficit (D_c)= $(K_1/K_2)*L_0 exp(-K_1*t_c)$

Q4. The IIT Delhi wastewater (pH10) has 100 mg/L suspended solids; 200 mg/L BOD_5; 10 rotaviruses/liter; calcium (50 mg/L), magnesium (10 mg/L), sodium (14.8 mg/L), bicarbonate (130 mg/L), chloride ions (11 mg/L). Calculate total hardness and hydroxide alkalinity of this water sample? ***[2.5+2.5=5 points]***

Q5. Draw a schematic for treating above mentioned IIT Delhi wastewater (Q4) for producing drinking water? Label different unit processes with appropriate sequence and provide brief reasons. ***[2+3=5 points]***

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Note: Assume missing data (if any) and mention the same. Be precise in all open-ended questions.

Q1. Untreated drinking water has 0.02 mg/L of geosmin. How much removal can be achieved by adding 10 mg/L PAC with isotherm: $Q_{eq} = 0.5(C_{eq})^{1.08}$ where Qeq (µg/mg); C_{eq} (µg/L). What does it inform about adsorption of geosmin on PAC? Would adding more PAC in water increase removal of geosmin from water? ***[5+3+2=10 points]***

Q2. During chlorination, Ct=100 for 2-log removal (free available chlorine= 1 mg/L). Calculate disinfection rate constant? Also, calculate Ct value for 4-log removal (free available chlorine =1 mg/L) and compare it with that for 2-log removal? ***[3+4+3=10 points]***

Q3. Say one needs to treat following water for removing 90% of hardness using ion-exchange process (capacity: 90 Kg hardness/m^3 material at 0.4m/minute flow rate). Calculate mass of resin required for removing 90% hardness? What would be efficiency of this ion exchanger for removing anions from this water? Explain. ***[6+4=10 points]***

Species	Free CO_2	Ca^{2+}	Mg^{2+}	Na^+	HCO_3^-	SO_4^{2-}
Conc. (mequiv/L)	1.0	4.0	1.0	2.0	2.5	4.5

Q4. For a flocculant suspension (negatively charged), determine the removal efficiency of a 5 ft deep basin an overflow rate equals to 10 ft/h? ***[10 points]***

Time, min	Percent suspended solids removed at indicated depth (in ft)				
	1.5	3.0	4.5	6.0	7.5
20	61				
30	71	63	55		
40	81	72	63	61	57
50	90	81	73	67	63
60	—	90	80	74	68
70	—	—	86	80	75
80	—	—	—	86	81

Q5. How does removal of flocculant suspension from Q4 change after the addition of alum in the settling column? Comment on effect of coagulation type of alum on removal of flocculant suspension from water? ***[6+4=10 points]***

Note: Assume missing data (if any) and mention the same. Be precise in all open-ended questions.

Q1. Calculate amount of solids produced during the use of lime-soda ash for softening of 1 MLD water? Also draw a schematic of ion exchanger units to remove ions from this water with all information labeled. ***[5+5=10 points]***

Purity in Soda	*100%*	Mg^{2+}	*18 mg/L*
Ca^{2+}	*44 mg/L*	Na^{+}	*16 mg/L*
Alkalinity (HCO_3^-)	*122 mg/L*	Purity in lime	*85%*

Q2. How do we get sweep coagulation and ionic layer compression after dissolving alum in water? For these two cases, draw figure of force as a function of distance between two particles. ***[6+4=10 points]***

Q3. Define Ct concept; ionic layer compression; alum coagulation versus ferric chloride coagulation. ***[2.5+2.5+5=10 points]***

Q4. A settling column analysis is run on a type-I suspension. The settling column is 2 m tall and the initial concentration of the well-mixed sample is 650 mg/L. Results of the analysis are below:

Time, min.	0	58	77	91	114	154	250
conc. remaining, mg/L	650	560	415	325	215	130	52

What is the theoretical efficiency of the settling basin that receives this suspension if the loading rate is 2.4×10^{-2} m/min? Describe significance of loading rate in obtaining particle removal? ***[5+5=10 points]***

Q5. Comment on decay of adenovirus using low pressure (LP) and medium pressure (MP) UV rays. Calculate dosages of LP rays for getting at least 99.9% removal? ***[5+5=10 points]***

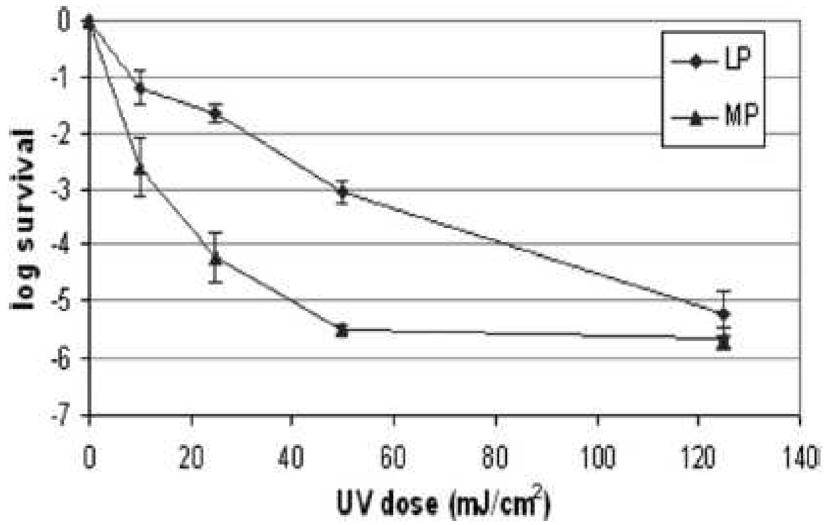

FIG. 2. UV inactivation of adenovirus as determined by cell culture infectivity assay data.

Note: Assume missing data (if any) and mention the same. Be precise in all open-ended questions.

Q1. Yamuna water (300 mg/L suspended solids, 10^6 MPN/100mL fecal coliforms, 400 mg/L BOD4 (k=0.2/day), 10mg/L ammonium ions, 44 mg/L calcium ions and 100 mg/L sodium ions) is mixed with environmental engineering laboratory wastewater (containing 1 M ferric chloride, pH5, 100 mg/L suspended solids and 100 mg/L BOD4(k=0.01/day). Answer the following:

(i) Comment on natural processes happening in the Yamuna river after the mixing? How is it affecting fate of different water quality constituents? **[10+10=20points]**

(ii) Calculate amounts of solids produced during the use of lime-soda ash for softening of 1 MLD Yamuna water taken from 1Km downstream of the mixing location? (purity of soda=100%, purity of lime=89%) **[10points]**

(iii) A settling column analysis (2m column) is run using the Yamuna water after mixing (total suspended solids=650mg/L) and following profile was obtained:

Time, min.	0	58	77	91	114	154	250
conc. remaining, mg/L	650	560	415	325	215	130	52

Draw "X" versus "velocity" curve and calculate the theoretical efficiency of the settling basin that receives this suspension if the loading rate is 0.4×10^{-2} m/min? **[6+4=10 points]**

Q2. How do we get sweep coagulation and ionic layer compression after dissolving alum in water? For these two cases, draw figure of force as a function of distance between two particles. **[6+4=10 points]**

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Q1. Consider an aerobic biological process. Determine the increase in mass of mixed-liquor VSS (Given that: V=4694 m^3; Q=5.71 Mgal/day = 5.71*3.85 MLD =21.98 MLD; X=3500 mg/L; Observed yield (Y_{obs})=0.3125; initial BOD (S_0)=250 mg/L,BOD in effluent (S_{eff}=6.2mg/L).

Solution:

Increase in mass of mixed-liquor VSS =

$$Px= Y_{obs}\, Q\, (S0-S) \quad (1)$$

If ratio of mixed liquor VSS to mixed liquor SS=0.8, then increase in total mass of MLSS = P_x/0.8 (say A)

Mass to be wasted = increase in MLSS-SS lost in effluent

=A-(flow rate * SS in effluent) (all units should be in Kg/d) =B (say)

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Determination of sludge wasting rate (Q_w)=?

$$□_c = VX/[Q_wX+Q_{eff}X_{eff}] \quad (2)$$

Say that X_{eff} is also given (say C)

So we can calculate Q_w now.

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Determination of recirculation rate:

Say aerator VSS conc. (biomass conc.) = 3500 mg/L

Return VSS concentration = 8000 mg/L (this is biomass which is being re-circulated in tank at flow rate equal to Qr)

So mass of biomass coming out of aerator = (Q+Qr)(3500 mg/L) where Q is incoming flow rate and Qr is recirculation flow rate.

So: (Q+Qr)(3500 mg/L) = (Qr)(8000 mg/L)

- ⇨ Recirculation rate = Qr/Q=0.78

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Food/Mass ratio and volumetric loading rate:

F/M=S_0/(□X)

□ = HRT= V/Q

F/M =(250 mg/L)/(□*3500 mg/L)=???

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Q. For given emission source and weather conditions, which plume situation, coning and fanning, result in higher ground level concentration? Answer using variation of dry adiabatic lapse rate and ambient lapse rate in their respective sketches.

Q. Discuss relationship between outdoor air pollutants and weather conditions (i.e., wind speed, wind direction, solar radiation, and temperature) in determining fate of these contaminants in air?

Q2. How does wastewater characteristic affect coagulation effectiveness of alum? Discuss in light of pH and alkalinity parameters.

Q3. Why do we add alum or polymers in secondary sedimentation tank?
Hint: For removing biological solids and for precipitating metallic hydroxides and phosphates.

Q4. A lake with volume of 10^5 m^3 is fed by a pollution-free stream with a flow rate of 50.0 m^3/s. The lake also receives inflow from an industrial outfit at a rate of 4.5 m^3/s that contains a non-conservative pollutant having a concentration of 90 mg/L. Some lab tests indicate that the pollutant (say concentration =C) decays following the first order kinetics [i.e., C(t)=C(0)* exp(-K*t)], and has a decay coefficient K of 0.21/day. Find the steady state concentration of the pollutant in the lake.

Solution:
$V_{lake}= 10^5$ m^3
Pollution free stream: Mass of pollutant input = Q_{stream}*conc. = (50.0 m^3/s)*0 =0
Industrial effluent: Mass of pollutant input = Q_{eff}*conc.
= (4.5 m^3/s)*90mg/L = (4.5*1000 L/s)*90mg/L =405 g/s
= 405*(24*3.600) kg/day=34,992 kg/day

Q5. Just downstream of the outfall from a point source of pollution, the DO of a river is 6 mg/L and the mix of river and waste has a BOD of 20 mg/L. The saturation value of DO is 9 mg/L. The deoxygenation constant is 0.20/day and the reaeration constant is 0.375/day. Water is moving at an average velocity of 0.25 m/sec.

(a) Find the critical time downstream at which the minimum DO occurs.
(b) Find the value of this minimum DO downstream.

$$t_c = \frac{1}{k_r - k_d} \ln\left[\frac{k_r}{k_d}\left(1 - D_a \frac{k_r - k_d}{k_d L_a}\right)\right]$$

$$D_c = \frac{k_d L_a}{k_r - k_d}\left(e^{-k_d t_c} - e^{-k_r t_c}\right) + D_a e^{-k_r t_c}$$

Q6. List 6 basic processes that may be used in surface water treatment (6 points). Using few words state what is the purpose of each process (6 points).

Q7. Why are coagulants used in water treatment? State the mechanisms of coagulation (4 points). List any two coagulants commonly used.

Q8. A sample of water having a pH of 7.0 has the following concentration of ions. Calculate the total hardness, carbonate hardness (CH), non-carbonate hardness (NCH), alkalinity, and total dissolved solids (TDS) in units of mg/L as $CaCO_3$ (3 points each).

Ion	Conc. (mg/L as ion)	M.W g/mol	*n*	*Eq. Wt (mg/meq)*	*Conc. (meq/L)*	*Conc.n mg/L as CaCO3*
Ca^{2+}	50	40.1	*2*	*20.05*	*2.49*	*125*
Mg^{2+}	10	24.3	*2*	*12.15*	*0.82*	*41*
Na^{+}	14.8	23.0	*1*	*23.0*	*0.643*	*32.17*
K^{+}	9.0	39.1	*1*	*39.1*	*0.230*	*11.50*
HCO_3^{-}	130	61.0	*1*	*61.0*	*2.13*	*106.5*
SO_4^{2-}	77.2	96.1	*2*	*48.05*	*1.606*	*80.33*
Cl^{-}	11	35.5	*1*	*35.5*	*0.31*	*15.5*

Solution:

Total hardness = 125 + 41 = 166 mg/L as $CaCO_3$.

Carbonate Hardness = Hardness associated with HCO_3^- and CO_3^{2-}.
= 106.5+ 0.0 = 106.5 mg/L as $CaCO_3$.
Non-Carbonate hardness = Total hardness – Carbonate hardness
= 166 – 106.5 = 59.5 mg/L as $CaCO_3$.

Alkalinity = $(HCO_3^-) + (CO_3^{2-}) + (OH^-) - (H^+)$

At a pH of 7.0, which is neutral, (OH^-) is almost equal to (H^+) so we can neglect these two. Therefore,

Alkalinity = 106.5 + 0.0 = 106.5 mg/L as $CaCO_3$.

TDS= sum of cations and anions
= 125 +41+32.17+11.50+106.5 +80.33+15.5 = 412 mg/L as CaCO3

Q. The pollutant triformomundane (TFM) has contaminated Lake Backwater. The lake has one river that feeds it with a flow rate of 6.3 m^3/s. The pollutant flows into the lake at a concentration of 1.5 mg/L. The volume of the lake is 8.8×10^8 m^3. A factory also dumps TFM into the lake at a concentration of 4.7 mg/L with a flow rate of 1 m^3/s. The decay rate of TFM averages 6×10^{-9} sec^{-1}. What is the concentration of TFM in the one river that flows out of Lake Backwater?

Accumulation = inputs – outputs ± reactions
Assume steady state, so accumulation = 0
Assume lake is well mixed, so $C_{lake} = C_{out}$

Q. Calculate the theoretical oxygen demand (in mg/L) of 250 mg/L ascorbic acid $C_5O_6H_8$.

Q. Name three disinfectants and how they kill microorganisms?

Q. Why is chlorine not preferred these days?

Q. What is the difference between Langmuir and Freundlich adsorption isotherm mechanisms?

Q. Adsorption: Untreated drinking water has 0.02 mg/L of geosmin, which gives earthy odor. How much removal can be achieved by adding 10 mg/L powdered activated carbon (PAC) in water? Assume geosmin adsorption on PAC is defined by Freundlich adsorption
$Q_{eq} = K_f (C_{eq})^{1/n}$ where Qeq is mass of geosmin adsorbed on PAC (µg) per mg of PAC; C_{eq} is concentraton of dissolved geosmin in water (µg/L), and K_f= 0.5 (µg/mg)(L/ µg)$^{(1/n)}$ and (1/n)=1.08.

Q. Ion exchange. Excess sodium intake can results in high blood pressure and inner ear problems for some people. The regulatory body recommends maximum allowable concentration to be 20 mg/L sodium in drinking water. Now sodium ions are used in ion exchange process. For reducing hardness from 6 to 1.5 meq/L in water, how much sodium ion is produced (mg/L) and if it poses any health risk based on given maximum concentration guideline.

Q. How does adsorption happen?

Q1. What will be the theoretical removal efficiency in a 1.8 m deep settling basin with a loading rate of 25 m^3/d/ (m^2)? Use following data as well. **[*10+10=20* points]**

Time (min.)	0	60	80	100	130	200	240	420
Conc. (mg/L)	300	189	180	168	156	111	78	27

Q2. The WWTP in the "AA" community discharges 1 millions liters/day of secondary effluent (initial BOD = 200 mg/L and oxygen consumption rate constant = 0.23/day at 20°C) into a "Red Cedar" stream whose minimum flow rate is 100 m^3/s (initial BOD = 0 mg/L and oxygen consumption rate = 0.23/day at 20°C). Using mass-balance approach, calculate initial BOD in stream after mixing of WWTP effluent? ***[20 points]***

Q3. Why microorganisms are required in biological processes? How does it differ in nitrification and denitrification processes? Can I use nitrifying bacteria in denitrification reactor? ***[5+ 5+5 =15 points]***

Q4. Explain type 4 settling using figures. Can it be used to remove 100 nm nanoparticles in a municipal wastewater treatment? ***[10 points]***

Q5. Explain the effect of dispersion in reducing air pollutants concentration on ground. ***[10 points]***

Q6. Explain the relationship between adiabatic lapse rates and atmospheric stability? ***[10 points]***

Q7. Answer "Yes" or "No". **Every question carries 25% negative marking.** ***[15 points]***

No.	Question	Yes	No
1.	For 5 m/s wind speed, the Pasquill stability types are independent of incoming solar radiation.		
2.	BOD/COD ratio for tap water is always lower than that for wastewater effluent.		
3.	Oxygen requirement in nitrification process is equal to that in denitrificiation processes.		
4.	Mean cell retention time is always smaller than hydraulic retention time.		
5.	Food-to-mass ratio is a dimensionless parameter.		
6.	Recirculation is conducted in activated sludge process to reduce SRT.		
7.	HOCl is more toxic to bacteria than monochloramine.		
8.	Ultimate BOD depends on bacteria used in the BOD experiment.		
9.	Ozone is preferred over chlorine due to its long residual time.		
10.	Ct value does not depend on disinfectant type.		
11.	Disinfection process does not depend on sample turbidity.		
12.	Nanoparticles are removed first from sedimentation tank than particles with size greater than 1 micron.		
13.	Stack design depends on wind conditions of the area under study.		
14.	Secondary solids settle better than primary solids during type 1 settling.		