UNIVERSITY OF ESWATINI
Faculty of Health Sciences
Department of Environmental Health Science

BACHELOR OF SCIENCE IN ENVIRONMENTAL MANAGEMENT AND WATER RESOURCES

MAIN EXAMINATION PAPER DECEMBER 2018

TITLE OF PAPER	: WATER TREATMENT
COURSE CODE	: EHS 429
DURATION	: 2 HOURS
MARKS	: 100

INSTRUCTIONS

READ THE QUESTIONS & INSTRUCTIONS CAREFULLY

:**QUESTION ONE IS COMPULSORY**

:ANSWER A TOTAL OF FOUR QUESTIONS OUT OF THE FIVE PROVIDED (QUESTION ONE PLUS ANY OTHER THREE QUESTIONS)

:EACH QUESTION **CARRIES 25** MARKS.

:WRITE NEATLY & CLEARLY

:NO PAPER SHOULD BE BROUGHT INTO THE EXAMINATION ROOM.

:BEGIN EACH QUESTION ON A SEPARATE SHEET OF PAPER.

DO NOT OPEN THIS QUESTION PAPER UNTIL PERMISSION IS GRANTED BY THE INVIGILATOR.

QUESTION ONE (25 marks and compulsory, i.e., must be answered)

The table below shows the results of water quality analysis of a sample of raw water intended for potable water treatment. Using the data provided in the table as well as the chemical equations and equilibrium constants provided below, answer the following questions (5 marks for each question).

i. Check the water quality analysis results for consistency and suggest if the analysis results are acceptable.
ii. Calculate the bicarbonate and permanent hardness in mg/L of $CaCO_3$
iii. Draw the ion bar chart of the raw water in meq/L
iv. Calculate the lime (in mg/L as $CaCO_3$) required to soften this water using excess lime treatment method.
v. Calculate the soda ash required (in mg/L as $CaCO_3$).

Parameter	Unit	Concentration (mg/L)	Molecular weight
TDS	mg/L	300	
Ca^{++}	mg/L	65	40.1
Mg^{++}	mg/L	20	24.3
Na^{+}	mg/L	15	23
K^{+}	mg/L	5	39.1
HCO_3^{-}	mg/L	200	61
$SO_4^{=}$	mg/L	120	96.1
Cl^{-}	mg/L	25	35.5
$H_2CO_3^{*}$	mg/L	20	62
pH	pH units	7.2	

Chemical equations and equilibrium constants

a. Neutralisation of carbonic acid:

$$CO_2 + Ca(OH)_2 \leftrightarrow CaCO_{3(s)} + H_2O$$

b. Precipitation of carbonate hardness due to calcium

$$Ca(HCO_3)_2 + Ca(OH)_2 \leftrightarrow 2CaCO_3 + 2H_2O$$

c. Precipitation of carbonate hardness due to magnesium

$$Mg(HCO_3)_2 + 2Ca(OH)_2 \leftrightarrow 2CaCO_{3(s)} + Mg(OH)_2 + 2H_2O$$

d. Removal of non-carbonate hardness due to calcium

$$CaSO_4 + Na_2CO_3 \leftrightarrow CaCO_3(s) + Na_2SO_4$$

$$CaCl_2 + Na_2CO_3 \leftrightarrow CaCO_3(s) + 2NaCl$$

e. Removal of non-carbonate hardness due to magnesium

$$MgSO_4 + Ca(OH)_2 + Na_2CO_3 \leftrightarrow Mg(OH)_2 + CaCO_3(s) + Na_2SO_4$$

f. Equilibrium constant for the dissociation of bicarbonate into hydrogen and carbonate ions:

$$10^{-10.33} = \frac{[H^+][CO_3^{2-}]}{[HCO_3^-]}$$

g. The ion product of water

$$[H^+]\,[OH^-] = 10^{-14}$$

QUESTION TWO (5 Marks each)

2A. Consider the following sets of parallel reactions taking place in the same reactor:

$$A + B \rightarrow 2C \quad \text{............ Reaction (i)}$$

$$A + B \rightarrow D \quad \text{............... Reaction (ii)}$$

Kinetics study showed that reaction (i) proceeds at the rate of 0.1 moles per hour (reduction for A and B). On the other hand reaction (ii) proceeds at the rate of 0.2 moles per hour (reduction for A and B and production for D.

i. State the overall rate of reaction of the system as a whole.

ii. Assuming the reaction rates stay constant how many moles of C and D are produced after 6 hours of reaction?

iii. Assuming the reaction rates stay constant how many moles of A and B are removed after 6 hours of reaction?

2B. List the six sequential steps that occur in a typical heterogeneous chemical reaction.

2C. Plot a profile of tracer salt concentration versus time for i) plug low reactor and ii) completely mixed flow reactor assuming that a tracer of known mass is added to the inlet of the reactor and the tracer salt concentration at the outlet flow is being measured with time after addition of the tracer salt. Initially the reactor flow has negligible concentration of the tracer salt. Assume that the retention time of the reactor is T = Volume/flow rate.

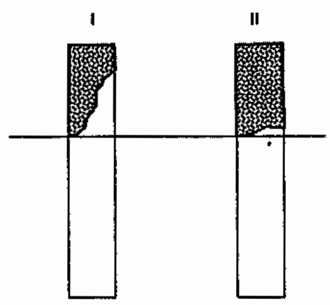
2D. An ion exchange resin that weighs 200 kg is employed for the removal of calcium from a given hard water. the concentration of calcium in the raw water to be treated is 400 mg/L. The ion exchange resin treats the water so that the treated water contains only 20 mg/L of Calcium. If a total of 60,000 liters water were treated, what will be the ion exchange resin capacity?

2E. State the advantages and disadvantages of choosing ion exchange media that has greater affinity for the ions to be exchanged.

QUESTION THREE (marks are indicated for each question)

3A. Discuss the problem of molecular screening in activated carbon processes. (5 marks)

3B. Two types of interfaces of the saturated zone for a given activated adsorption process are shown in the figure below labeled types I and type II. Compare the efficiency of adsorption and the characteristics of breakthrough curve for these two types of adsorption processes. (5 marks)



3C. A given activated carbon produced was found to possess a pH of 8.5. Discuss the potential of this activated carbon for the removal of organic matter in which:

i. The pH of the water is low......................[2 marks]

ii. The pH of the water is high ....[2 marks]

3D. A batch adsorption study of a given polluted water gave the data shown in the table below. If the raw water COD was 250 mg/L and the treated water COD should be restricted to 4.70 mg/L or less, determine:

iii. The total water volume that can be treated before breakthrough if the total weight of activated carbon provided is 100 kg and the rate of flow is 200 lit/day. ....[6 marks]

iv. Determine the length of time that this 100 kg activated carbon serves before it is taken out of operation because of breakthrough.

..........................[5 marks]

Flask No.	Wt. of Carbon (mg) (m)	Volume in Flask (mℓ)	Final COD (mg/ℓ) (C)	Wt. of Adsorbate Adsorbed (mg)	$\frac{x}{m}$ (mg/mg)
1	804	200	4.70	49.06	0.061
2	668	200	7.0	48.6	0.073
3	512	200	9.31	48.1	0.094
4	393	200	16.6	46.7	0.118
5	313	200	32.5	43.5	0.139
6	238	200	62.8	37.4	0.157
7	0	200	250	0	0

QUESTION FOUR (25 Marks and marks are indicated for each question)

4A. For each of the experimental cases described in Table below, Calculate the apparent odour synergism between two compounds A and B. ....[8 marks]

	Compound A	Compound B	Olfactile added total	Olfactle found in mixture
Olfactile added				
Case I	0.3	0.5	0.8	1.0
Case II	0.5	0.3	0.8	0.8
Case III	0.8	0.75	1.55	1.0

4B. Determine the Threshold odour number (TON) and the Odour Intensity Index (OII) for a sample water when the number of 25:175 dilutions made was 3 times after which a 70 mL of the diluted sample was transferred to the 200 mL flask to achieve the just detectable odour. ....[8 marks]

4C. The removal of iron by oxidation using oxygen can be modeled as a first order reaction (assuming that the concentration of oxygen in the aerator supply remains constant). The first order apparent reaction rate constant, K_{app}, for the removal of iron by precipitation through oxidation is then given by the formula:

$$K_{app} = \frac{1.68 * 10^{-15}}{[H^{+}]^{2}} \quad min^{-1}$$

Where:
K = The apparent reaction rate constant for the oxidation of iron by aeration in min^{-1}
$[H^{+}]$ = The hydrogen ion concentration in moles/L.

Determine the detention time (in minutes) of the reactor tank required to achieve 99% removal of dissolved iron by aeration. ....[9 marks]

QUESTION FIVE (5 marks each)

5A. Compare the advantages and disadvantages of:

i. Inside-out membrane operation and
ii. Outside-in membrane operations

5B. According to the information provided on the percent rejection for MF and UF membranes in Figure Q5-1 shown below, determine the retention ratings of i) MF membrane ii) UF membrane.

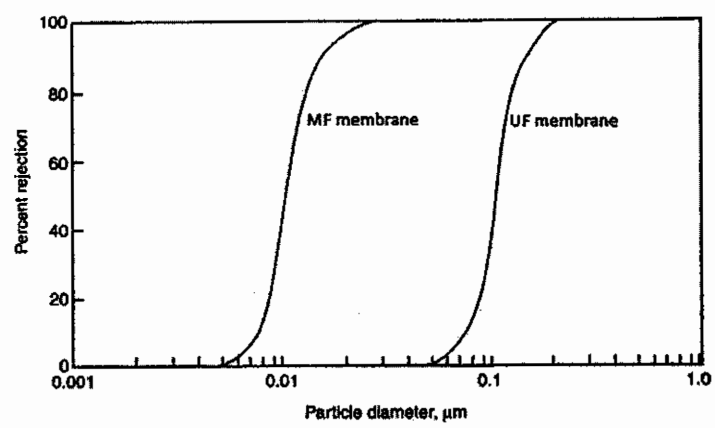


Figure Q5-1: Percent rejection of MF and UF membranes

5C. Compare the osmotic pressures created by equal concentration (100 mg/L) of NaCl and $CaCl_2$. Explain the reason for the difference in the osmotic pressures created by these minerals concentrations.

5D. Compare the rejection rates of membrane filters and ultra filters against:

i. Giardia lamia cysts
ii. bacteria
iii. viruses

5E. In terms of hydrophobicity what characteristics of membranes are desirable to avoid fouling of membranes?