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THE UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
2019 ACADEMIC YEAR
CEE 4412 – ENVIRONMENTAL ENGINEERING I
UNIVERSITY END OF YEAR EXAMINATIONS

TIME: THREE (3) HOURS CLOSED BOOK

INSTRUCTIONS TO CANDIDATES

1. THE PAPER CONTAINS SEVEN QUESTIONS. ATTEMPT ANY FIVE.
2. ALL SOLUTIONS SHOULD BE CLEARLY NUMBERED.
3. WHERE INFORMATION IS NOT GIVEN, MAKE AND STATE YOUR ASSUMPTIONS.
4. MARKS WILL BE LOST FOR UNTIDY AND UNORGANISED PRESENTATION.
5. A GLOSSARY OF SOME SELECTED EQUATIONS AND INFORMATION IS PRESENTED IN THE ANNEX.

QUESTION ONE

a) State whether true or false:

i) Treatment of solid waste through the process of incineration is only possible if the net calorific value of the solid waste is positive.

ii) Siting a water source like a well 30m upstream of a pit latrine will guarantee protection from microbiological contamination.

iii) Improving solid waste management in a locality would contribute to reducing water related insect vector diseases.

iv) Usually, suspended solids of organic nature when present in water have no effect on human health but results in aesthetic problems.

v) Absence of dissolved oxygen in water in a water distribution system may result in odour problems within the system.

vi) The term "Maximum Peak Factor" refers to the ratio between the flow during some specified time to the average flow over the supply period.

b) State why air binding, as it applies to slow sand filters, is objectionable in water treatment and briefly explain how its occurrence can be prevented.

c) Relatively clear water (with a turbidity of 5NTU) with a very low buffering capacity from Mwambashi Dam is being experimented on. In one experiment, the water is subjected to coagulation/flocculation, rapid sand filtration and then chlorination. In another experiment, it is subjected to precipitation (Lime - SODA softening), rapid sand filtration and then chlorination. Water samples were then obtained from both experiments for microbiological analysis after a chlorination contact time of 15 minutes. In one sample there where completely no faecal coliforms present while in the other, there were 10 CFU/100mL of sample. State which of the two samples is likely to still have faecal coliforms giving one reason for your answer.

[6 + 6 + 8]

QUESTION TWO

a) Using any two reasons, justify the use of indicator microorganisms as a means to determine the microbiological quality of water in a water treatment plant.

b) Give any two reasons why iron in drinking water above a concentration level of 0.3mg/L is objectionable.

c) One category within the environmental classification of communicable diseases is "Housing-Related Diseases". Give and discuss one example on how housing can impact on the health of a community.

d) Mpongwe Water Treatment Plant abstracts 300m^3/hour of water from the Mpongwe River which is treated by the unit operations of sedimentation, rapid sand filtration and then chlorination. It is estimated that water losses in the sedimentation process is at 5 percent of the abstracted water while the losses at the filtration stage is at 10 percent of the water received from the sedimentation process.

i) Compute the daily water production from the treatment plant.

ii) Given that this water is to be chlorinated using chlorine gas with an effectiveness of 90 percent, compute the rate (in grams per minute) at which a chlorinator should be dispensing the chlorine in the system. It has been experimentally established that 0.9mg/L of chlorine needs to be dosed to this particular water if the desired concentration of 0.3mg/L of residual chlorine is to be available in the system at the furthest point of use within the system.

[3 + 3 + 4 + 10]

X **QUESTION THREE**

a) Discuss any two advantages of a "pumped" water distribution system over a "gravity" water distribution system.

b) A water supply system is being designed for Kilati District which has a population of 100,000 residents. The average daily per capita water consumption of the district is 150 liters. Data from the Central Statistics Office shows that the district's population will grow linearly at a rate of 2.5 percent per annum over the design period of 20 years. It is envisaged that the system losses will be at 20 percent at inception and will rise linearly to 40 percent at the end of the design period.

i) Compute the present water demand.

ii) Compute the water delivery given that the plant will be commissioned three (3) years from now.

c) Experiments were undertaken in the Environmental Engineering Laboratory from 4th July to 16th October 2019 to establish the effectiveness of a resin collected from a softener. The experiments yielded results presented in Figure 1. The amount of resins used in the experiment was 10mL. The flow rate of water in the experiment was maintained at 20 mL/min and the hardness of the water was 340mg $CaCO_3$ /L. Assuming water is considered treated if and only if the effluent hardness is 0mg $CaCO_3$ /L, calculate how much water with a hardness of 300 mg $CaCO_3$ /L the resins of the same capacity would treat if the resin bed is now increased to 100mL.

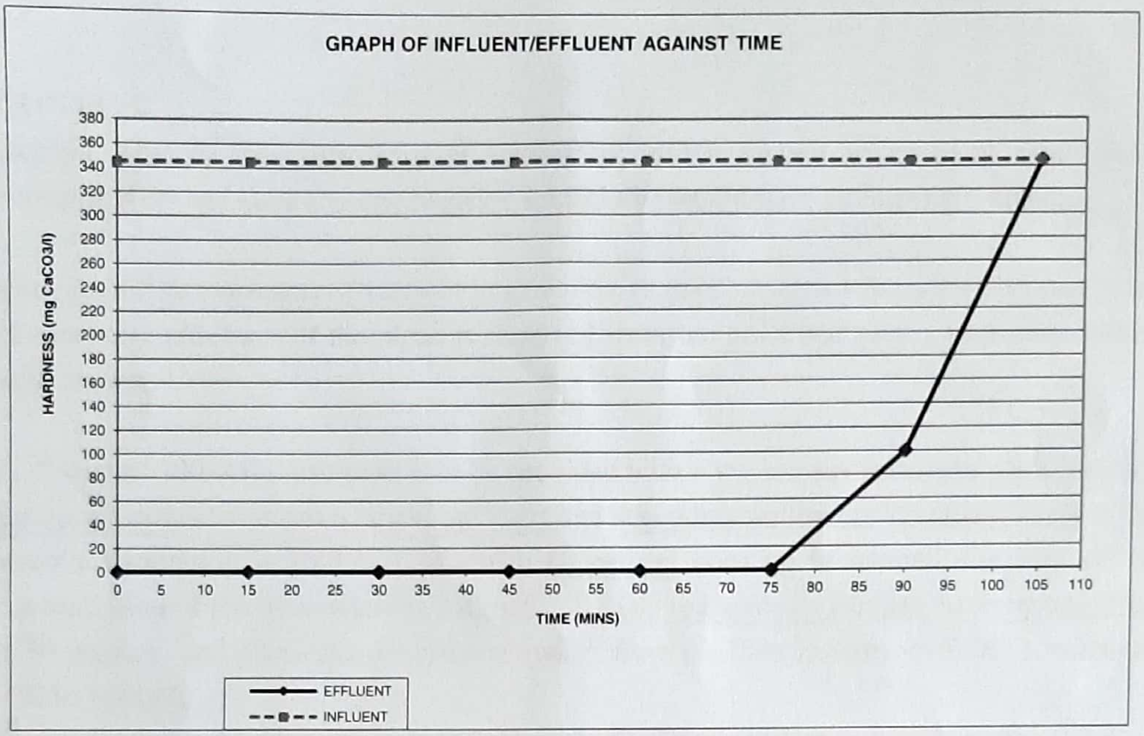

Figure 1: Graphical Results of water softening experiment.

[4 + 7 + 9]

QUESTION FOUR

a) Why is the COD test result always higher than the BOD test result if the tests are done on the same sample?

b) Explain why it is critical to have a biological treatment stage in a wastewater treatment plant if the organic matter removal is to be significant.

c) Give one advantage of small bore sewers in the collection of wastewater and explain any one critical factor for their successful operation.

d) The design of trickling filters is mainly based on empirical formulae one of which is the Rumpf equation given as:

BOD removal efficiency (%) = 93 – 1.1 OSLR

For a wastewater treatment plant receiving wastewater with a BOD concentration of 400mg/L, at a flow rate of 10 liters per second, compute the required surface area of the trickling filter given that: 25 percent of the BOD will be removed by the primary sedimentation tanks upstream of the trickling filters; and that the effluent should have a BOD concentration of 50mg/l.

[4 + 4 + 4+ 8]

QUESTION FIVE

a) Explain why the discharge of raw wastewater into a surface water body would lead to eutrophication and state any one negative impact this would have on the environment.

b) With respect to wastewater treatment in a facultative pond, discuss what would happen in terms of treatment efficiency if the algae is removed from the pond and give a probable reason for your answer.

c) A district of 100,000 inhabitants is to be provided with a wastewater treatment plant employing primary sedimentation tanks, trickling filters and secondary sedimentation tanks. The per capita water consumption is 100L/day of which 80 percent ends up in sewers. The average BOD concentration of the wastewater is 340mg/L. If BOD reduction in primary sedimentation tanks is 30 percent, and given that the effluent quality from the filter in terms of BOD concentration will be 40mg/L:

i) Compute the total mass of BOD the trickling filters remove on a daily basis.

ii) Given that there are four primary sedimentation tanks in the treatment plant to which the influent is equally distributed, compute the Hydraulic Surface Loading Rate for each sedimentation tank if the tanks have a diameter of 30m and an effective depth of 3.5m.

iii) Given that eight trickling filters each with a diameter of 28m and an effective depth of 2m are provided for the treatment of this wastewater, computer the Volumetric Organic Loading rate to each filter on a daily basis assuming each filter gets an equal quantity of wastewater.

[4 + 4+ 12]

QUESTION SIX

a) Discuss why an on-site sanitation system would not be appropriate in an area with soil that has a very high infiltration rate.

b) Give a distinction between faecal sludge and excreta.

c) A non conventional wastewater treatment plant to handle $100m^3/h$ of domestic wastewater needs to be designed. The plant layout will be such that there will be an anaerobic pond, a facultative pond and three maturation ponds all arranged in series. The BOD concentration in the influent is 360mg/L. Given that the lowest average ambient temperature for the coldest month is 15^0C, compute the required length and width of the facultative pond if the length to breadth ratio of the pond is 3.

[4 + 4 + 12]

✓ **QUESTION SEVEN**

a) State how the problem of flies which is inherent with conventional pit-latrines has been addressed in VIP latrines.

b) Give and explain any two reasons why knowing the composition of solid waste is cardinal in the design of an effective solid waste management system.

c) A septic tank is designed to service a household with 10 inhabitants. The water per capita consumption is 200 liters per day. Assuming that 80 percent of the water supplied ends up as wastewater and that the sludge accumulation rate is $0.05m^3$ per capita per year,

  i) Determine the effective depth of the septic tank given that the required retention time of the wastewater in the tank at inception will be 10 days and the tank will have a length and breadth of 4.0m and 2.0m respectively.

  ii) Given that this septic tank needs to be desludged when the solids take up 50 percent of the tank volume (when the tank is half full), compute how long it will take before the tank needs to be desludged.

[5 + 5 + 10]

END OF EXAMINATION

GOOD LUCK

JMT /EXAM/CEE 4412/2019

ANNEX: GLOSSARY OF EQUATIONS

i) $Q_a = dACq$

ii) $Q_a = ACq_a$

iii) $Q_a = A\sum_{i=1}^{n} d_i q_i p_i C_i$

iv) $Q_a = A\sum_{i=1}^{n} q_a p_i C_i$

v) $Q_{i+n} = Q_i * (1 + n * \frac{a}{100})$

vi) $Q_{i+n} = Q_i * (1 + \frac{a}{100})^n$

vii) $Q_d = (Q_a * pf_o)/(1-L/100)$

anaerobic eques 1

viii) Design volumetric organic loading rates for anaerobic ponds as a function of the monthly average ambient temperature.

Minimum monthly ambient temperature (^{0}C)	Volumetric organic loading rate λ_v (in g BOD_5/m^3.d)	BOD_5 removal (%)
< 10	100	40
10 - 20	20T – 100	2T + 20
> 20	300	60

Where T is the monthly average ambient temperature

ix) Equation for determination of anaerobic pond area

$$A = \frac{S_i Q}{\lambda_v D}$$

where

Q = hydraulic loading (m^3/d)

S_i = influent BOD_5 concentration (mg/l)

λ_v = Volumetric organic loading rate (g BOD_5/m^3.d)

D = Average pond depth (m)

A = Surface area of anaerobic pond (m^2)

Facultative equation 2

The organic surface loading rate λ_s

$$\lambda_s = \frac{LQ(g/m^3 * m^3/d)}{A(m^2)} = BOD(g/m^2.d)$$

Where

L = BOD influent (mg/l)

Q = Sewage flow (m^3/day)

A = Pond area (m^2)

Also λ_s = 2T – 12 (g/m^2.day) where T is the mean monthly ambient temperature of the coldest month in ^{0}C.

maturation equ. 2

Equation for the design of maturation ponds

$$\frac{N_e}{N_i} = \frac{1}{\left[1 + K_b \frac{\tau}{n}\right]^n}$$

Where N_i and N_e = number of faecal coliforms in the effluent and influent respectively

τ = hydraulic retention time

K_b = the die off rate coefficient (in day^{-1}) which is temperature dependent and is given by

$K_b = 2.6(1.19)^{(T-20)}$ Where T is temperature in ^{o}C.