CE102: Environmental Studies

Problem Set II: *Water Quality Parameters*

Q.1 pH of Soft Drink: The pH of a popular soft drink is about 3.8, and the sucrose ($C_{12}H_{22}O_{11}$) concentration, C_{SU}, of this same drink is about 40000 mg/L. Calculate: (i) the hydronium ion [H_3O^+] concentration in mol/L, and (ii) p[C_{SU}].

Q.2 Solids in Wastewater: A laboratory runs a solid test on a wastewater. The weight of the empty crucible = 48.6212 g. A 100 ml wastewater sample is placed in the crucible and the water is evaporated. The weight of the crucible and dry solids = 48.6432 g. The crucible is placed into a 550^0C muffle furnace for 30 minutes and subsequently cooled in a desiccator. The weight of the cooled crucible and residue i.e. unburned solids = 48.6300 g. Calculate the total (TS), volatile (VS), and fixed (FS) solids present in the wastewater sample. Report the solids concentrations in mg/L.

Q.3 Alkalinity and Hardness of Wastewater: (a) A wastewater sample contains 118 mg/L of bicarbonate ion, 19 mg/L of carbonate ion and has a pH of 9.5. What is the alkalinity of this wastewater expressed as mg/L of $CaCO_3$?

(b) A wastewater sample has the following chemical composition: [Ca^{2+}] = 15 mg/L; [Mg^{2+}] = 10 mg/L; [SO_4^{2-}] = 30 mg/L. What is the total, calcium and magnesium hardness of the wastewater sample in units of mg/L as $CaCO_3$?

Q.4 Theoretical Oxygen Demand (ThOD) and Chemical Oxygen Demand (COD) of Wastewater:
(a) Assuming complete oxidation to CO_2 and H_2O, compute the theoretical oxygen demand (ThOD) for: (i) 1000 mg/L of Glucose ($C_6H_{12}O_6$) solution, (ii) 500 mg/L of Phenol (C_6H_5OH) solution, and (iii) 250 mg/L of Ethanol (C_2H_5OH).

(b) Determine the theoretical oxygen demand (ThOD) for 1000 mg/L of glycine [$CH_2(NH_2)COOH$] solution using the following assumptions: (i) In the first step, the organic carbon and nitrogen are converted to CO_2 and NH_3, respectively, (ii) In the second and third steps, the ammonia (NH_3) is oxidized sequentially to nitrite and nitrate, and (iii) The ThOD is the sum of the oxygen required for all three steps.

(c) Compute (i) chemical oxygen demand (COD) and (ii) the total organic carbon (TOC) concentration of a synthetic wastewater that contains the following chemical compounds: Glucose ($C_6H_{12}O_6$) = 200 mg/L and Benzene (C_6H_6) = 25 mg/L. Assume ThOD is equivalent to the COD of the wastewater.

Q.5 Biochemical Oxygen Demand (BOD) of Wastewater: (a) Change in concentration of organic matter, L, with time, t, is given by –

$$\frac{dL}{dt} = -kL$$

Calculate the organic matter remaining after 3 days if the initial concentration was 200 mg/L. Assume $k = 0.4\ day^{-1}$.

(b) A 2% solution of a wastewater sample is incubated for 5 days at 20^0C. The dissolved oxygen (DO) concentrations of the diluted sample before and after the incubation were 8 and 4 mg/L, respectively. Calculate the BOD_5 of the wastewater sample.

(c) The following observations were made on a 3% dilution of wastewater sample at 20^0C: (i) Initial and final DO of blank = 8.5 and 8.2 mg/L, respectively, and (ii) Initial and final DO of diluted sample = 8.0 and 2.1

mg/L, respectively. Calculate the 5-days (BOD_5) and ultimate BOD (BOD_u) of the wastewater sample assuming that the BOD reaction constant (*k*) at test temperature is 0.1 d^{-1}.

Q.6 BOD Conversions of Wastewater: (a) The 5-days 30^0C BOD of a wastewater sample is 110 mg/L. Calculate its 5-days 20^0C BOD. Assume the BOD reaction constant (*k*) at 20^0C is 0.1 d^{-1}.
(b) Calculate 1-day 37^0C BOD of a wastewater sample whose 5-days 20^0C BOD is 100 mg/L. Assume the BOD reaction constant (*k*) at 20^0C is 0.1 d^{-1}.
(c) The BOD_5 of a wastewater has been measured as 600 mg/L. If the BOD reaction constant (*k*) at test temperature is 0.1 d^{-1}, what is the ultimate BOD (i.e. BOD_u) of the wastewater? What proportion of the BOD_u would remain unoxidized after 20 days?

Q.7 Nitrogen in Wastewater: A wastewater sample contains following nitrogen species: 60 mg/L of NH_3, 1.2 mg/L of NO_2^-, 5 mg/L of NO_3^- and 25 mg/L of organic nitrogen. What is the total nitrogen (TN), total Kjeldahl nitrogen (TKN) and total inorganic nitrogen (TIN) concentration of the wastewater sample in mg of N/L?

Q.8 Ion Balance and Bar Diagram in Water/Wastewater Quality Analysis: Results are shown below from a routine water quality analysis being run on a water sample:

Constituents	Concentration (mg/L)	Constituents	Concentration (mg/L)
Ca^{2+}	60.0	HCO_3^-	65.0
Mg^{2+}	20.0	SO_4^{2-}	200.0
Na^+	68.0	Cl^-	39.0
pH: 7.5			

Perform the ion balance based on the analysis results and estimate and check the permissibility of the percent error induced in the analysis. Also, construct a representative bar diagram of the ion balance.

Q.9 *Mixed Bag*: A synthetic wastewater sample of water is prepared by adding 500 mg coarse sand, 200 mg glucose ($C_6H_{12}O_6$), 300 mg glycine ($C_2H_5NO_2$), 168 mg sodium bicarbonate ($NaHCO_3$), 120 mg magnesium sulphate ($MgSO_4$) and 111 mg calcium chloride ($CaCl_2$) in one liter distilled deionized water. The pH of the sample is 7.0. Assuming that the complete dissociation of the salts occur leading to presence of Na^+, Mg^{2+}, Ca^{2+}, Cl^-, SO_4^{2-} and HCO_3^- species in addition to H^+ and OH^- ions, compute:
(a) total solids, total suspended solids, volatile suspended solids, fixed suspended solids, total dissolved solids, volatile dissolved solids and fixed dissolved solids in mg/L;
(b) total alkalinity, hydroxyl alkalinity, carbonate alkalinity, and bicarbonate alkalinity in mg/L as $CaCO_3$;
(c) total hardness, calcium hardness, magnesium hardness in mg/L as $CaCO_3$; and
(d) COD, BOD, ammonical nitrogen (NH_4^+-N), total Kjeldahl nitrogen (TKN), NO_3^--N.

Assume ThOD, COD and BOD terms are equivalent to each other for the synthetic wastewater sample. Ignore nitrogenous oxygen demand for glycine.