Problem 1: An industry discharges its liquid waste into a river that has a minimum flow rate of 10 m$^3$/s. The major pollutant in the waste is a nonreactive organic material. The waste discharge stream has a flow rate of 0.1 m$^3$/s and an organic concentration of 3000 mg/L. Upstream pollution has caused an organic concentration of 20 mg/L in the river upstream of the industrial discharge under the minimum flow rate conditions. The state regulatory agency has set a maximum limit of 100 mg/L for the pollutant in the river. Assume complete mixing occurs in the river at the point where the waste enters. Will the industry be able to discharge the waste without treatment?

Ans: yes (C$_{river}$ mixed w/waste = 49.5 mg/L)

Problem 2. As illustrated in the figure below, a river flows into a reservoir that is being used to irrigate farmland. The river inflow is $Q_i = 25,000$ m$^3$/year, and the salt concentration in the river is $C_i = 300$ g/m$^3$. The reservoir can be modeled as being completely mixed with a uniform salt concentration. The volume of water in the reservoir is constant. The farmland needs irrigation water to flush salts out of the soil and for use by plants. Water used by plants is lost by evapotranspiration and the amount of this loss, $Q_E$, equals 10,000 m$^3$/yr. For purposes of this problem assume the farmland is at steady state with no accumulation of salt, and that loss of water by infiltration into the soil can be neglected.

Salty water from the farm is returned to the reservoir. The salt concentration in the return flow is $C_R = 2,500$ g/m$^3$. Find: (a) the water flow rate out of the reservoir, $Q_{out}$; (b) the salt concentration in the reservoir, which is the same as the concentration in the flow out of the reservoir, $C_{out}$ (since the reservoir is completely mixed); and (c) the flow rate for the irrigation water, $Q_{irr}$.

Ans.

$Q_{out} = 15,000$ m$^3$/yr
$C_{out} = 500$ mg/L
$Q_{irr} = 12,500$ m$^3$/yr
Problem 3: [adapted from Environmental Science and Engineering by Henry and Heinke; Prentice Hall (1996)] A settling tank is used to remove suspended solids from wastewater at a municipal treatment plant. The influent to the tank has a flow rate of $Q_i = 10$ L/s and a suspended solids concentration $X_i = 200$ mg/L. The solids removal efficiency for the tank is 60%. The settled solids removed from the bottom of the tank have a concentration of $X_s = 3\%$. Note that the solids in wastewater can be assumed to have a density of about 1 g/cm$^3$, so it doesn’t matter if this is 3% by weight or 3% by volume. On a weight basis 3% solids = 3 g solids per 100 g suspension or \[ \frac{3 \text{ g solids}}{3 \text{ g solids} + 97 \text{ g H}_2\text{O}}. \] Calculate the flow rate of the concentrated solids waste stream ($Q_s$), and the mass removal rate of solids from the tank (in kg/day).

The magnitude of $Q_s$ is sometimes considered negligible relative to $Q_i$ (i.e., $Q_e = Q_i$). Do not make that assumption in solving this problem, but comment upon how reasonable it might be.

Ans: $Q_e = 9.96$ L/sec (99.6% of $Q_i$) $Q_i = 10$ L/s $X_i = 200$ mg/L $Q_e = ??$ L/s $X_e = ??$ mg/L

Problem 4. The settled solids removed in problem 3 (with a flow rate of $Q_s$ and concentration $X_s$) must be disposed of. One option is incineration. To be able to efficiently burn the solids they must be “dewatered” to remove water and increase the solids concentration. This is accomplished by a thickener which accomplishes an additional gravity-driven separation of the solids and produces a thickened “underflow” solids concentration of $X_u = 8\%$. The thickened sludge is then concentrated further in a vacuum filter that will remove 75% of the remaining water. What are the values for the volumetric flow of thickened solids, $Q_u$, the flow of solids free solution returned to the treatment plant from the thickener $Q_e$, the flow of filtrate produced by the vacuum filter, $Q_f$, and what final solids concentration, $X_{fc}$, (%) and flow $Q_{fc}$ is achieved for the material to be incinerated; i.e., the “filter cake”? You may assume that the density of the wet sludge is approximately equal to that of water (as in problem 3 above) and that the water removed by the gravity thickener and vacuum filter has 0% solids. A schematic of the treatment process sequence is shown below.

Ans: $Q_u = .015$ L/sec; $Q_e = .025$ L/sec; $Q_f = .0103$ L/sec, $Q_{fc} = .0047$ L/sec; $X_{fc} = 25.8\%$
Problem 5: [Adapted from Introduction to Environmental Engineering by P.A. Vesilind; PWS Publishing Co. (1997)] In wastewater treatment, microorganisms are often used to convert dissolved organic compounds to more microorganisms, which are then removed from the flow stream by processes such as sedimentation. One such operation is known as the activated sludge system shown below. Since the activated sludge system converts dissolved organics to suspended solids, it yields excess solids. The solids that are produced come from the growth of the microorganisms that perform the conversion from dissolved solids to biomass. Unfortunately, the process is so efficient that some of these microorganisms (solids) must be wasted. The slurry of these solids removed from the activated sludge system is called waste activated sludge.

Suppose an activated sludge system has an influent (feed) of 8 mgd (millions gallons per day) at a suspended-solids concentration, $X_o$, of 60 mg/L. The waste activated sludge flow rate, $Q_W$, is 0.2 mgd at a solids concentration, $X_W$, of 1%. The effluent (discharge) has a solids concentration, $X_E$, of 20 mg/L. What is the yield of waste activated sludge in kilograms per day? (Restated: what is the rate of solids production in the system?) Assume steady-state conditions (i.e., no mass is accumulating in the activated sludge reactor or the settling tank).

\[ \text{Ans: } 6,340 \text{ kg/day} \]

Problem 6: Pick two substances that are regulated by primary standards under the Safe Drinking Water Act. Using the internet, do a search to find a site that gives information on the human health effects for each of the selected materials. Print out one page for each substance from the web site(s), and specify its location (i.e., give the URL for each site). On your printout, underline or highlight what you consider to be the information that is most relevant to the health effects of the selected materials.

Problem 7: Do STELLA Exercise 1. Please turn in the STELLA part of your homework separately from the rest (and attach a separate letter of transmittal).