CivE 230 Assignment 3

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June 21, 2020

Assignment 3

Question 1

The biogeochemical cycle refers to how chemical elements (C,O,H,N,P), which are prerequisites for life, flow from one repository to the next. Water is tracked through analysis of the hydrologic cycle. Evaporation, transpiration, evapotranspiration, condensation, precipitation, infiltration, and runoff are all components of this analysis, which cumulatively allow one to analyze the presence of water from one reservoir to the next. The solid presence of these elements in water is calculated through filtration tests on water.

Question 2

It is shocking to see that the USA abstracts far more than Canada does, as USA is red and Canada is light yellow. While it is reassuring that Ontario is located in a nice recharge area, it is also frightening that Western Canada, as well as some parts of the USA with high abstraction rates, have a very low recharge rate. Looking at the image of the Aral Sea, I have high hopes that people can begin to monitor their consumption, as impacts are becoming more and more prevalent and awareness is becoming more and more common.

Specifically, abraction is very low across Canada and Southern African countries, while recharge is very high in these areas. This makes them highly sustainable areas. Eastern Asia and the USA are typically high abstraction and high recharge, making them somewhat sustainable. Australia has moderate abstraction rates and low recharge rates, making it somewhat sustainable.

Question 3

There are three categories of water usage:

- **Withdrawal use**: usage such that water needs to be physically removed from the source. Water in a shower is an example of this
- **Nonwithdrawal use**: usage such that water can remain in its original source. Swimming in the ocean is an example of this
- **Consumptive use**: usage such that water is physically removed but not returned to the water source. Irrigation of crops is an example of this

Question 4

The **water footprint** shows the link between water consumption from another country and local water usage to the environmental impact on the country of interest.

$$WF = W_{use} + VW_{imports} \qquad \text{(Water Footprint)}$$

Virtual Water is commonly referred to the hidden water cost embedded in a producing consumer products. It is the volume of water used to produce consumer products. This shows how dependent a country is on another's water.

A single apple requires 70 litres of water to grow. Thus, when an apple is exported, it's footprint is measured as 70 L.

264 gal/m^3

5) P, R, C, ~~E~~, I

$\frac{1\ mile}{1609.34\ m}$ $\frac{1\ ft}{0.3048\ m}$ $\frac{1\ gal}{3.78541\ L}$ $\frac{1\ m^3}{1000\ L}$ $\frac{31536000\ s}{year}$

$P = R + C + I + S$

$\frac{1}{0.264\ gall} \frac{L}{} \times \frac{1\ m^3}{1000\ L}$

$= 0.000264$

a) $P + I - O - C - E = \Delta S$

Out $= E$

b) $\frac{-1.15}{2}(9900)(1609.34)^2 = -1.474343403E10\ m^3/year \cdot \frac{1\ year}{3.154E7\ s} = 467.45\ m^3/s$

$\therefore \Delta S$ due to level decline is this figure above

c) $P = -\Delta S\ E + C + O$

$+0.85(9900)(1609.34)^2 = E - 1.474343403E10 + 45(31536000) + 115(1200000)(3.78541)(365)(\frac{1}{1000})$ $+ 5500(31536000)$

8103 0 * 0.3048 $(\frac{m}{ft})^3$ * 31536000

$E = \frac{2.314008795E10\ \frac{m^3}{year}}{9900(1609.34)^2}$

$= 0.9024729611\ m/year$

$= 902.47\ mm/year$

⑥ $k_{20} = 0.23$

$K_T = ?$, $K_T = k_{20}\,\theta^{(T-20)}$, $\theta = 1.047$

DO; eo day

① BOD_u

$BOD_t = BOD_u(1 - e^{-kt})$

$175 = BOD_u(1 - e^{-0.23(5)})$

$BOD_u = 256.086$ mg/L

② $k_T = k_{20}\,\theta^{(T-20)}$

$= 0.23 \cdot 1.047^{15-20}$

$k_T = 0.182807676$

③ $BOD_7 = 256.086(1 - e^{-0.1828(7)})$

$= 184.86$ mg/L

⑦ BOD_5?

r = dilution ratio, $\frac{V_{wastewater}}{V_{wastewater} + V_{dilution\ water} [\text{Total } V]} = \frac{2}{2+298} = \frac{1}{150}$

Initial dissolved oxygen $DO_i = (V_w DO_w + V_d DO_d) / (V_w + V_d)$

1) $DO_i = \frac{2 \cdot 0.003 (mg/mL) + 298 (0.0105)}{2+298}$, $DO_f = 6.2$

$= 0.01045\ mg/mL = 10.45\ mg/L$

2) $BOD_5 = \frac{DO_i - DO_f}{r}$

$= \frac{10.45 - 6.2}{1/150}$

$= 637.5\ mg/L$

(8) $DO_i = 9.5 \text{ mg/L}$

$DO_f = 4 \text{ mg/L}$

$r = 0.04$

$k = 0.23$

$$BOD_5 = \frac{9.5 - 4}{r} = 137.5 \text{ mg/L}$$

$$BOD_5 = L_o(1 - e^{-k5})$$

$$137.5 = L_o(1 - e^{-5 \cdot 0.23})$$

$$L_o = 201.21 \text{ mg/L}$$

9. Influent

$r_1 = \frac{5}{300} = \frac{1}{60}$ $\quad DO_i = 1000\left(\frac{5 \cdot 0.003 + 295 \cdot 0.0085}{300}\right) = 8.408$

$BOD_5 = \frac{8.408 - 6.2}{1/60} = 132.5$ mg/L required

Effluent

$r_2 = \frac{25}{300} = \frac{1}{12}$, $\quad DO_i = 1000\left(\frac{8.2 \cdot 0.025 + 275 \cdot 0.0085}{300}\right) = 8.475$

$BOD_5 = \frac{8.475 - 5.9}{1/12} = 30.9$

$\frac{(132.5 - 30.9)}{(132.5)} = 76.68\%$

∴ no, the plant only removes 76.68% of the BOD_5.

(10)

$$TS = 1000\left(\frac{85.490 - 85.337}{0.085}\right) = 1800\ mg/L$$

$$TSS = 1000\left(\frac{0.1530 - 0.1400}{0.200}\right) = 65\ mg/L$$

$TS = TSS + TDS$

$TDS = 1735\ mg/L$

TS

$$VS_{\%} = \frac{(85.375 - 85.337)}{(85.490 - 85.337)}$$

= 24.84% is fixed, 447 mg/L

∴ 75.16% is volatile, 1353 mg/L

SS

$$VS_{\%} = \frac{0.1426 - 0.1400}{0.1530 - 0.1400}$$

= 20% fixed, 13 mg/L fixed

∴ 80% volatile, 52 mg/L

DS

$VS_{\%} = 447 - 13$

fixed = 434 mg/L

volatile ∴ = 1353 − 52 = 1301 mg/L

(11) μ_w @ $20° = 1.002E-2$ Pa·s

ρ_w @ $20° = \frac{kg}{m^3}$ 998.2 , $V_s = \frac{g(\rho_s - \rho_w) d^2}{18\mu}$ $g = 9.81 \frac{m}{s^2}$

@ max V_s, particle size is maximized

1) Debris

$$V_s = \frac{9.81(1100 - 998.2)(10^{-5} m)^2}{18(1.002E-2)} = \underline{553.7026E-9} \ m/s$$

2) Clay

$$V_s = \frac{9.\cancel{81}(2000 - 998.2)(10^{-5} m)^2}{18(1.002E-2)} = \underline{5.449E-6} \ m/s$$

3) Sand

$$V_s = \frac{9.81(2650 - 998.2)(10^{-4} m)^2}{18(1.002E-2)} = \underline{898.434E-6} \ m/s$$

(12) Q, P, $k_d = 0.61/\text{day}$, $k_r = 0.76/\text{day}$ $\qquad \frac{dD}{dt} = k_d L - k_r D$

$DO_s = 8.26$ mg/L (@25°C assuming no [Cl]) $\qquad x_c = t_c u$

a) $D_{\text{deficit}} = DO_s - DO_{\text{actual}}$ $\qquad BOD_u = \frac{1(28) + 7(3.6)}{8}$

$= DO_s - \frac{Q_w \times DO_w + Q_r \times DO_r}{Q_w + Q_r}$ $\qquad = 6.65$ mg/L

$= 8.26 - \frac{7 \cdot 7.60 + 1 \cdot 1.80}{8}$

$= 8.26 - 6.875$

$= 1.385$ mg/L

b) $t_c = \frac{1}{k_r - k_d} \ln\left[\frac{k_r}{k_d}\left(1 - D_o\left(\frac{k_r - k_d}{k_d L_o}\right)\right)\right]$

$= \frac{1}{0.76 - 0.61} \ln\left[\frac{0.76}{0.61}\left(1 - 1.385\left(\frac{0.76 - 0.61}{0.61(6.65)}\right)\right)\right]$

$t_c = 1.11525$ day

$x_c = t_c \cdot V_{river}$

$= 1.11525 \text{ day} \times 0.37 \text{ m/s} \; 3600 \text{ s/hr} \times 24 \text{ hr/day}$

$= 35652.312$ m $= 35.65$ km

c) $D_{crit} = DO_s - D_c$

$= 8.26 - \frac{k_d L_o}{k_r - k_d}\left(e^{-k_d t} - e^{-k_r t}\right) + D_o e^{-k_d t}$

$= 8.26 - \frac{0.61 \cdot 6.65}{0.76 - 0.61}\left[e^{-0.61 \cdot 1.11525} - e^{-0.76(1.11525)}\right] + 1.385 e^{-0.61 \cdot 1.11525}$

$= 8.26 - 2.11 - 0.70$

$= 5.45$ mg/L

d) $t = \frac{x}{v} = \frac{16000}{0.37} = 43243.24$ s $\therefore$

$= 0.5005005$ days

$D = 8.26 - \frac{0.61 \cdot 6.65}{0.76 - 0.61}\left[e^{-0.61 \cdot 0.5} - e^{-0.76 \cdot 0.5}\right] + 1.385 e^{-0.61}$

$= 8.26 - 1.44 - 1.02$

$= 5.8$ mg/L