

## CVG2132 – FUNDAMENTALS OF ENVIRONMENTAL ENGINEERING

Homework 4:

Fall 2015

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### Question 1: Question 4.1 from the textbook.

Given chemical formula of bacterial cell =  $C_{60}H_{87}O_{23}N_{12}P_1$

#### Part a

The molecular weight of  $C_{60}H_{87}O_{23}N_{12}P_1$  :

$$MW = (60 \times 12 \text{ g/mole}) + (87 \times 1 \text{ g/mole}) + (23 \times 16 \text{ g/mole}) + (12 \times 14 \text{ g/mole}) + (1 \times 31 \text{ g/mole}) = 1374 \text{ g/mole}$$

The mass of each element is:

$$C = \frac{(60 \times 12 \frac{\text{g}}{\text{mole}}) \times 3000 \text{ mg}}{1374 \frac{\text{g}}{\text{mole}}} = 1572 \text{ mg}$$

$$H = \frac{(87 \times 1 \frac{\text{g}}{\text{mole}}) \times 3000 \text{ mg}}{1374 \frac{\text{g}}{\text{mole}}} = 190 \text{ mg}$$

$$O = \frac{(23 \times 16 \frac{\text{g}}{\text{mole}}) \times 3000 \text{ mg}}{1374 \frac{\text{g}}{\text{mole}}} = 803 \text{ mg}$$

$$N = \frac{(12 \times 14 \frac{\text{g}}{\text{mole}}) \times 3000 \text{ mg}}{1374 \frac{\text{g}}{\text{mole}}} = 367 \text{ mg}$$

$$P = \frac{(1 \times 31 \frac{\text{g}}{\text{mole}}) \times 3000 \text{ mg}}{1374 \frac{\text{g}}{\text{mole}}} = 68 \text{ mg}$$

$$\text{Total mass} = (1572 + 190 + 803 + 367 + 68) \text{ mg} = 3000 \text{ mg}$$

#### Part b

First, calculate what mass of bacterial cells could be produced based on the 25 mg N/L of ammonia.

$$25 \frac{\text{mg N}}{\text{L}} \times \left( \frac{3000 \text{ mg bacterial cells}}{367 \text{ mg N}} \right) = 204 \frac{\text{mg cells}}{\text{L}}$$

Second, calculate what mass of bacterial cells could be produced based on the 5 mg P/L of orthophosphate.

$$5 \frac{\text{mg P}}{\text{L}} \times \left( \frac{3000 \text{ mg bacterial cells}}{68 \text{ mg P}} \right) = 221 \frac{\text{mg cells}}{\text{L}}$$

**Nitrogen** is limiting cell growth since less cells can be produced based on the ammonia (N) present (204 mg/L bacterial cells) than based on the orthophosphate present ( 221 mg/L bacterial cells).

**Part c**

**204 mg/L** of bacterial cells could be produced.

**Part d**

Bacterial cell mass production if nitrogen source was cut to 15 mg/L:

$$15 \frac{mg\ N}{L} \times \left( \frac{1374 \frac{g\ bacterial\ cells}{mole}}{12 \times 14 \frac{g}{mole}} \right) = 123 \frac{mg\ cells}{L}$$

**Part e**

Bacterial cell mass production if phosphorus source was cut to 4 mg/L:

$$4 \frac{mg\ N}{L} \times \left( \frac{1374 \frac{g\ bacterial\ cells}{mole}}{1 \times 31 \frac{g}{mole}} \right) = 177 \frac{mg\ cells}{L}$$

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**Question 2: Why are phosphorus levels in rivers and lakes hard to control?**

The two main reasons are:

- a) The large phosphorous contribution from uncontrolled non-point sources, such as run-off from agricultural land and lawns.
- b) Algae die and settle to the bottom of the waterway and there they are broken down by bacteria and this releases the phosphorus into solution so it is available to be used by other algae. This cycling reduces the amount of phosphorus that is washed out of the lake and river, thus perpetuating the problem. Even if all inputs into the waterway are stopped there will sufficient phosphorus available to algae because of this cycling that that the eutrophication problems will continue for a long time.

**Question 3: Describe at least three ways eutrophication impacts fish.(use a sentence or two for each)**

- Large quantities of algae consume a significant amount of dissolved oxygen for respiration which causes the dissolved oxygen levels to drop during nighttime. If the dissolved oxygen drops for too long it can kill fish.
- When algae die and settle to the bottom of a lake, bacteria there decompose the algae. The more rapid aerobic bacteria proceed first, and often consume most or all of the

dissolved oxygen there. In stratified lakes, the dissolved oxygen does not get replenished until the turnover. So this leaves little or no dissolved oxygen for fish which must either move to another area with more oxygen or die. The regions with low oxygen (or anoxic conditions, i.e.  $DO < 0.5$  mg/L) in the bottom are called dead zones.

- Note that many of the most important fish for recreational fish are cold water fish, if they move to the thermocline or the epilimnion. to get dissolved oxygen the temperatures may be too high for them.

**Question 4: Describe at least four ways eutrophication impact humans and human activities. (Use a sentence or two for each)**

- Algal blooms make water very unpleasant to swim in and in some cases can lead to rashes and gastrointestinal problems
- Algal blooms can give drinking water unpleasant tastes and odours
- Algal toxins from blue-green algae (cyanobacteria) are potentially toxic have known to kill farm animals
- Large diatoms (phytoplankton that require silica) and filamentous algae can clog water treatment plant filters and result in reduced time between backwashings.
- Extensive growth of rooted aquatic macrophytes (larger plant forms) interfere with navigation, aeration and channel carrying capacity.

**TASK 5:** Read <http://news.nationalgeographic.com/news/2014/08/140804-harmful-algal-bloom-lake-erie-climate-change-science/>

**TASK 6:** Read. <http://www.canadiangeographic.ca/magazine/so03/deadzone.asp>

**Question 5: What is a dead zone?**

A dead zone is a zone of a waterway in which the bottom of the waterway is anoxic, that is that the levels of dissolved oxygen there are below 0.5 mg/L and thus cannot support a many aquatic life species.

**Question 6: The last two articles point out that although there is significant variation in the annual input of phosphorus into Lake Erie the levels have been relatively stable. Yet in the past few years there have been an increase in the magnitude and duration of the algal blooms. List at least four reasons that are hypothesized to be behind the increase in severity of the algal blooms.**

- The removal of wetlands has resulted from the loss of a natural phosphorus removal mechanism
- Although the amount of fertilizer used per acre has decreased, there has been an increased level of corn (for biofuel production) and soy planting in the area of the Great Lakes. So the total amount of phosphorus applied in the watersheds has not decreased.
- The methods of planting of these crops have led to greater runoff

- Modern fertilizers contain more dissolved phosphorus, which is the form readily used by plants and algae.
- Global warming has resulted in more intense storms that washed away more fertilizer from the field.
- Global warming has decreased the length of winter so there is runoff for a larger fraction of the year.

**Question 7: Why are cyanobacteria important?**

Cyanobacteria (also known as blue-green algae) are photosynthetic microorganisms that grow like algae and have periods of great growth that turn the waters green. Beyond the aesthetic problems the most significant impact to humans are: a) they can cause drinking water to have taste and odour; and b) they release three types of toxins into the water (neurotoxins, hepatoxins and skin allergens). It should be noted that with global warming algal/cyanobacterial problems will increase and higher temperatures favor cyanobacteria over algae.