1. (10 points) A company has to dispose of 1.30 kg/day of a certain chemical, which may not be released directly into a nearby stream. On their property is a 8,500 m³ pond fed by a 500 m³/day clean stream and which empties in the nearby stream. The plan is to dump the chemical into the pond while the pond is being flushed by the passing stream. A laboratory analysis has revealed that under that scenario, the chemical would decay at a rate of 0.10/day. Evaporation is deemed negligible. The permitted value for release into the nearby stream is 0.50 mg/L. You are an environmental engineer hired to help the company comply with the regulation pertaining to the permitted release value.

(a) (4 points) Show based on calculations that the company’s plan is not meeting the regulation.

(b) (6 points) To comply with the law, you suggest to the company that it should provide a longer retention time. This can be accomplished in two ways, either by augmenting the volume of the existing pond or by passing the effluent into a second pond before release into the nearby stream. Either way, some excavation and earth removal must be done and paid for. Because the company is cost conscious, it wants to minimize the amount of excavation. Which option do you recommend to the company? And, what volume (in m³) will it have to excavate?

2. (10 points) A bankrupt chemical company has been taken over by new management. On the property they found a 20,000 m³ brine pond containing 25 g/L of salt and they propose to flush it through a discharge pipe leading to the Atlantic Ocean, which is nearby and which has a salinity of 30 g/L. What flow rate of freshwater (in L/s) must they use to reduce the salinity of the pond to 500 mg/L within one year?
3. (10 points) Aside from trending upward, the atmospheric concentration of carbon dioxide fluctuates over the seasons. The latest monthly data from the Mauna Loa Observatory in Hawai‘i (depicted below) reveal that the last low point was 403 ppm in late 2017 and the last peak was 411 ppm in mid 2018. While such a swing occurs in the atmosphere, the amount of carbon dioxide in an open-surface body follows.

Assuming that the CO₂ concentration in the water of Lake Erie responds in equilibrium with the partial pressure of CO₂ in the atmosphere, that the local CO₂ partial pressure is the same globally (and hence the same over Hawai‘i as over Lake Erie, a very good assumption), and that the 468 x 10⁹ m³ volume of Lake Erie is well mixed, calculate the following:

(a) (4 points) The amount of carbon dioxide (in metric tons) that was exchanged between Lake Erie and the atmosphere when the atmospheric CO₂ concentration rose from 403 to 411 ppm;
(b) (6 points) The change in the pH of the Lake Erie water.

4. (5 points) (Mines & Lackey, Problem 6.10, page 152, modified) Calculate the volume of an ideal plug flow reactor that must remove 95% of a contaminant present in a 650 m³/day liquid flow. This contaminant decays according to a first-order law with decay constant estimated at K = 9.0/day.
5. (5 points) (Mines & Lackey, Problem 6.3, page 151, edited) A certain contaminant was studied in the laboratory by measuring over time the concentration in a sample placed in a closed container. The values of the observed concentrations are given below. Determine the reaction order and the decay rate for this contaminant.

<table>
<thead>
<tr>
<th>Time (hours)</th>
<th>0</th>
<th>1.0</th>
<th>3.5</th>
<th>6.5</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration (mg/L)</td>
<td>100</td>
<td>80</td>
<td>50</td>
<td>26</td>
<td>10</td>
</tr>
</tbody>
</table>

**The extra thinking question**
(10 points)

Find in a news outlet on the web or elsewhere, a 2018 article dealing with an environmental issue in which a certain physical domain is involved, such as the interior of a building, an estuary, or other body of water, and take the perspective of an environmental engineer who is called to investigate the problem.

What control volume will you choose for the study? And, for this control volume, will you assume that it behaves as a continuously mixed flow reactor or as a plug flow? Justify your answers.