Laboratory Demonstration No. 1

Purpose:

1. to investigate the role of volume and flow rate in the "cleansing" of a contaminated water body
2. to determine the residence time
3. to apply the residence time principle to the prediction of processes

Overview:

You will create a 1-liter pond and a 0.5-liter pond "contaminated" with saltwater. You will then investigate the response of the ponds to fast and slow flow rates of freshwater and determine "cleansing" times.

Equipment:

- table salt
- water
- food coloring
- 1000-ml vacuum Erlenmeyer flask w/ #7 rubber stopper and inserted tube
- 500-ml vacuum Erlenmeyer flask w/ #6 ½ rubber stopper and inserted tube
- 1-liter plastic beakers
- 100-ml plastic beakers
- 50 ml graduated cylinder
- rubber/tygon tubing
- stopwatch
- TDS meter
- TDS meter stand/reservoir
- Masterflex L/S compact drive w/ 7018-21 pump head
- magnetic stirrer
- stir bar

Procedures:

1. Make some salt water with a concentration of about 10 ppt by adding ~40 grams of table salt to 4 liters of water in a suitable container. Stir until all the salt is dissolved. Color the saltwater with food dye.
2. The pocket TDS meter has an inherent measurement error when it switches from the 'ppt' scale to the 'ppm' scale. Determine the calibration factor for the ppm scale as follows.
   - 2.1. Measure out 10 ml of the 10-ppt salt water and add to a 100-ml plastic beaker
   - 2.2. Add 40 ml of distilled (or fresh) water to the plastic beaker and stir
   - 2.3. Measure the salinity of the solution with the TDS meter. Reading should be ~2 ppt.
   - 2.4. Add 50 ml of distilled (or fresh) water to the plastic beaker to bring total volume to 100 ml. Measure the salinity with the TDS meter and record.
   - 2.5. Repeat steps 2.1-2.4 two more times.
   - 2.6. Calculate the calibration factor for the ppm-scale based on what the ppm reading should be (after 50% dilution).

NOTE: The pocket TDS meter shuts off automatically after a few minutes. Watch it carefully during the test runs. If the meter turns off, turn it back on.

3. Fill the 1000-ml Erlenmeyer flask with freshwater to the bottom of the vacuum nipple. Set up the experimental system according to the attached diagram.
4. Set the pump speed to fast (~500 ml/min).
5. Start the pump by placing the swith to the clockwise position and pump freshwater through the system until all of the tubing and the TDS stand/reservoir is filled.
6. Measure the flow-rate through the system by collecting and recording the amount of water collected in a 1-liter plastic beaker in one minute using a stop-watch. Collect the water from the drain of the TDS meter stand/reservoir.

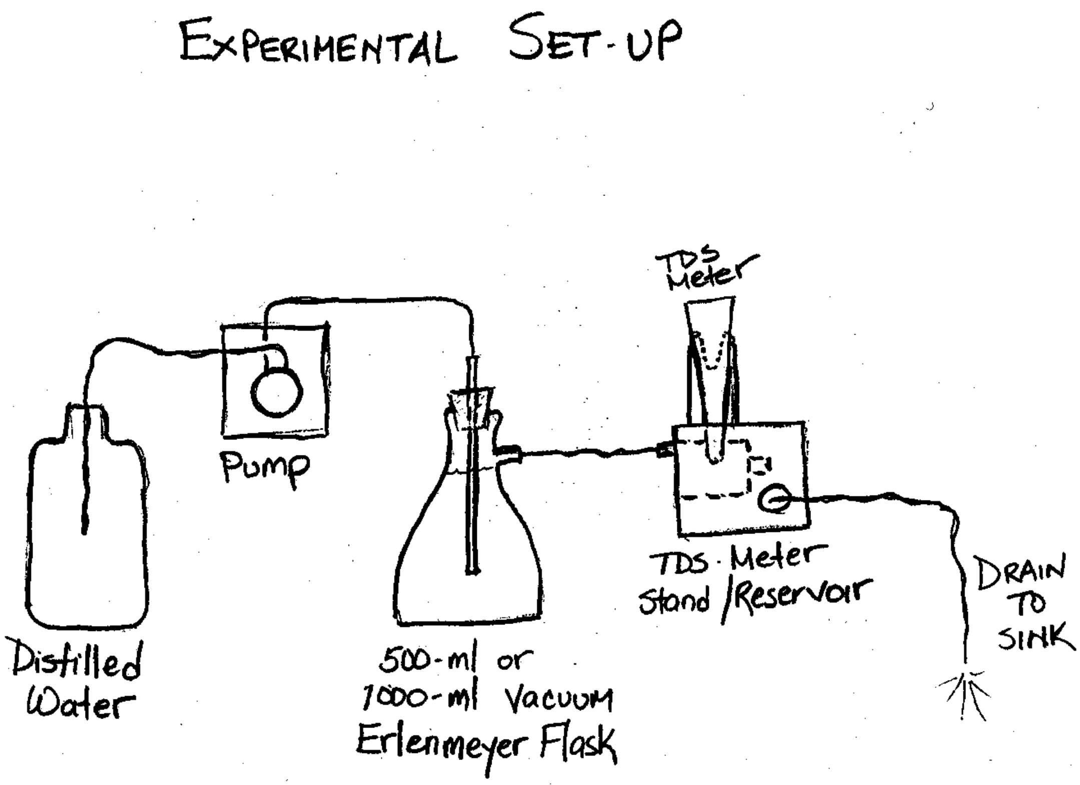
NOTE: After measuring the flow-rate, be careful that you don't accidently change the speed setting on the pump.

7. Stop the pump.
8. Measure the total volume in the 1000-ml Erlenmeyer flask using 1-liter plastic beaker and graduated cylinder.
9. Measure and record the salinity of the salt-water in the plastic beaker. Then fill the 1000-ml Erlenmeyer flask with the 10-ppt salt water.
10. Calculate the residence time of the water in the "pond" based on your volume measurement and flow rate measurement. How much time do you think it will take for the salinity of the "pond" to reach ~0 once we start pumping freshwater through it? How often should you record the salinity of the outflow in order to describe the response of the system? Decide before the next step, and assign tasks (data recorder, TDS-meter reader, timer, flow-rate determinations).
11. Start the pump in the fast speed to pump freshwater into the "pond'.
12. Start the stopwatch and record salinity readings at the time-interval determined from step 10. Readings should be taken for a minimum of 10 minutes. **(As the outlfow changes from fresh to saline immediately after starting the pump, the TDS meter might initially display a higher reading than the measured value of the salt water. This is ok, because we already know the initial salinity reading at t=0.)**
13. Periodically (at least three times), determine the flow rate as in step 6.
14. After a minimum of 10 minutes, stop the pump.
15. Determine the volume of the 500-ml Erlenmeyer flask by filling it to the bottom of the vacuum nipple with freshwater and pouring it into a graduated cylinder.
16. Fill the 500-ml Erlenmeyer flask with 10-ppt salt water. Remove the 1000-ml flask from the system and replace with the 500-ml flask.
17. Calculate the residence time of the water in the "pond" based on its volume and the average flow rate from step 13. How much time do you think it will take for the salinity of the "pond" to reach ~0 once we start pumping freshwater through it? How often should you record the salinity of the outflow in order to describe the response of the system?
18. Repeat steps 11-14, except, run the pump for a minimum of 5 minutes.
19. Empty the 500-ml flask and refill with 10 ppt salt water.
20. Set the pump speed to slow (~250 ml/min).
21. What effect should reducing the pump speed by one half have on the residence time of

water in the “pond”?

22. Repeat steps 11-14 with the pump in slow speed. Run the pump for a minimum of 10 minutes. **(Ensure that you determine the flow-rate at least three times during the run.)**
23. Fill the 1000-ml flask with 10-ppt salt water. Replace the 500-ml flask with the 1000-ml flask.
24. Repeat steps 11-14 with the pump in slow speed, except, once the salinity reaches its initial value, adjust the pump speed to fast. Ensure that you measure the new flow rate at least three times after changing the pump speed.

At this time you should have run four experiments with four different values of residence time. For each experiment you will have salinity (C) measured as a function of time (t). For each experiment you should have several measures of the flow rate. For each calibration of the TDS meter you should have several checks of the calibration.



CALCULATIONS FOR THIS EXPERIMENT

Use Excel for all calculations and graphing.

1. **Plot** the raw uncorrected data for all experiments (use Microsoft Excel or Quattro Pro) as concentration (C) (y-axis) vs time (x-axis). PLOT ALL THE DATA ON ONE GRAPH.
2. **Calculate** the correction factor for the TDS meter when it shifts from the 'ppt' to 'ppm' scale (show calculations). **Apply** the correction to the data. Why is this correction necessary? (Hint: if we didn't tell you beforehand about the problem with the TDS meter, what feature of the uncorrected data plots would have indicated a problem. Is this feature physically possible?)
3. **Plot** the corrected data for all experiments as in step 1.
4. **Determine** the time required for the concentration in each lake to be reduced by one-half. Do this by picking a value on the data sheet and then finding another value that is ~1/2 the first value. Subtract the two times. For each experiment, make several estimates and use the average time to half concentration.
5. **Determine** the time required for the concentration in each lake to be reduced by 95% in the same manner as above.
6. **Plot** time to reduce the concentration by half versus the residence time calculated from V/F for all experiments. When you have completed Task 9, plot also the time to reduce the concentration by half versus the residence time calculated from the data for all experiments. What is the graphical relationship between these two times (i.e. is it linear? exponential? what's the slope?) Can you generalize from this experiment? What is the expected relationship?
7. **Plot** the time to reduce the concentration by 95% versus the residence time from V/F for each experiment. When you have completed Task 9, plot also the time to reduce the concentration by half versus the residence time calculated from the data for all experiments. What is the graphical relationship between these two times? Can you generalize from this experiment? What is the expected relationship?
8. **Explain** how you can use the residence time to predict/estimate the time it would take to clean a contaminated water body?
9. Using an appropriate normalization of the concentration data, **plot ln (normalized C) vs. time**. Normalized C means $(C_t - C_f)/(C_o - C_f)$. What is the relationship between the slopes of these lines and residence time? **Calculate** the residence time in the flasks using the information provided by the plots. (THERE IS USUALLY A LEAST SQUARES FIT FOR A STRAIGHT LINE IN ANY SPREADSHEET PROGRAM. USE IT IF YOU CAN.) Compare the residence times calculated from the graphs with the residence times calculated from the flow rates and the volumes, and comment on the differences and similarities.
10. Normalize the time for each experiment by dividing time (in minutes?) by the residence time (τ) for that experiment. **Plot ln (normalized C) vs normalized time (t/τ)**; PLOT ALL FOUR RUNS ON ONE GRAPH. Explain the differences and/or similarities.

11. If the only thing you could see and measure was the concentration in the flask (you did not know the there were inflows and outflows), you could still calculate a rate constant for the disappearance of salt from the system (flask). **How would you determine if the change in salinity was governed by flow or by a reaction that consumed salt? What investigations would this prompt?**