Project 3

Water Treatment - Maintaining the Quality of our Natural Waters

At first glance, the blue planet, Earth, seems to be a gigantic ball of water. Much of the "blue" seen in photos from space however, is saltwater oceans which cover 70% of the earth's surface. Of all the freshwater on earth, almost 26% is tied up in glaciers and polar ice caps, and 11% is groundwater lying between 0.8 and 40. km below the surface of the earth. Unfortunately, sewage waste has for centuries been dumped into the available bodies of fresh water such as lakes and streams. As a result, treating waste water is a critical task facing countries around the world.

Waste water treatment occurs in three stages. Primary treatment involves removing suspended solids, while secondary treatment removes dissolved organic compounds. The material removed in these treatments is call sludge, which then undergoes a separate treatment process. After moving through the first two treatments, the water is placed in a settling tank in preparation for tertiary treatment, which removes phosphorus, nitrogen and resistant organic compounds. After the tertiary treatment, the water is released back into the environment.

Tertiary treatment is a very costly procedure, and one considered a luxury by most cities and towns. Fortunately, environmental engineers have developed a reasonable alternative. They noticed that the water at the top of the settling tank after the secondary treatment is fairly clean, but grows progressively contaminated towards the bottom of the tank. With careful analysis of the density of contaminants in the tank, cities can release water from the top of the tank directly into the environment without tertiary treatment.[1]

You have been hired by the city of Highland Falls to monitor the city waste water treatment facility and determine the level at which water in the settling tank can be safely released into the Hudson. The council wants to release as much water as possible, but New York State requires water contaminants of less than 720 PPM (parts per million) for water released into the environment. Due to your limited equipment, you convert this requirement into quantities you can measure and simplify matters by assuming that the mass of contaminants at any level in the tank is constant. You then conclude that water released from your tank cannot exceed a density of 0.63 kg/m.

The formula for mass with constant density and a given height is $m = \rho \cdot h$ where m = mass, ρ = density, and h = height.

Requirement One: Using the data from Table 1, calculate the **average** density for each interval in the tank. Estimate the depth (measured from the top of the tank) of water that can be released.

Requirement Two: A local conservation group collected more data. Using the data in Table 2, calculate the average density for each interval in the tank and give an estimate for the depth of water that can be released.

Requirement Three: As you analyze the data, you notice the mass is changing with the depth of the tank (measured from the top). Plot the mass against the depth. What is happening to the density? How would you model the change in mass as the change in depth gets infinitely small?

Requirement Four: After months of sampling, you model the mass as a function of depth and conclude that $m(y) = y^3$ where m=mass and y=depth (measured from the top of the tank). Determine the density at a depth of exactly 46.2 cm. Is the water clean enough to release? At exactly what depth can you release the water? Compare this with your earlier estimates.

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[1] Penelope ReVelle and Charles Revelle, The Global Environment, (Boston: Jones and Bartlett Publishers, 1992), p.390-404.

Requirement Five: How well does your model reflect reality? What assumptions did you make, and what are the implications of those assumptions?