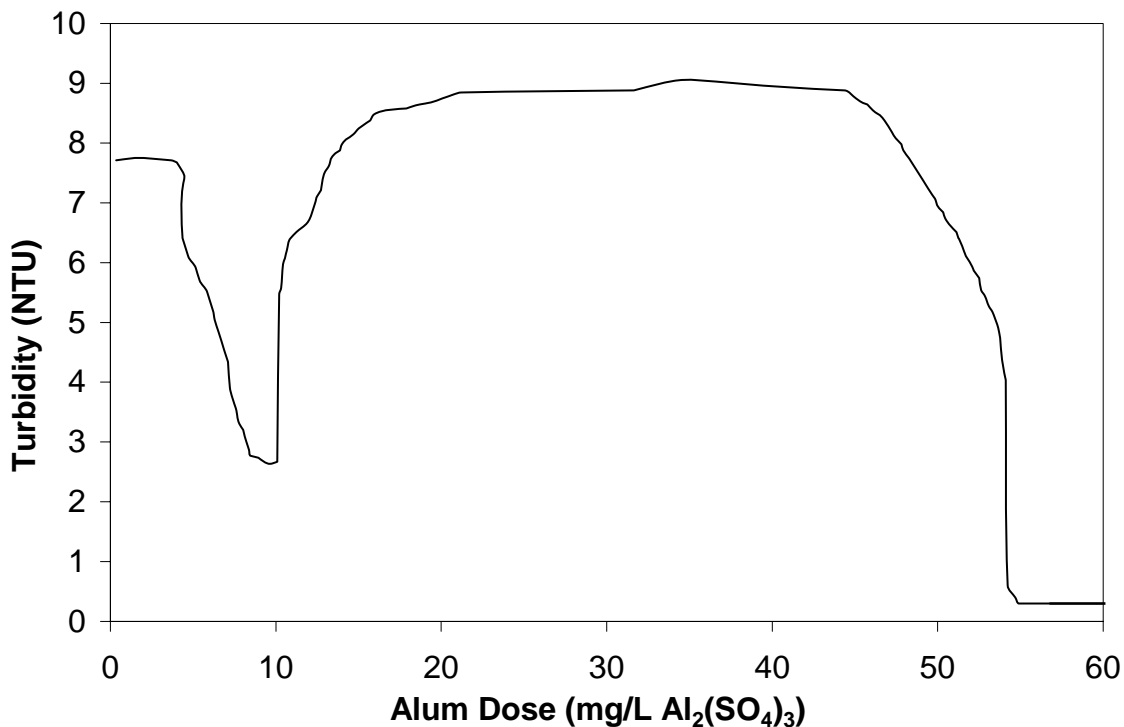


CEE 483 Winter 2006. Example exam questions and answers for Midterm #2

1. The graph below shows the results of some jar tests for coagulation of a water supply. The data are for the turbidity after adding the alum, mixing for 5 min, and allowing the suspension to settle for 30 min. As indicated, the dosages are based on a chemical formula of $\text{Al}_2(\text{SO}_4)_3$ for alum.

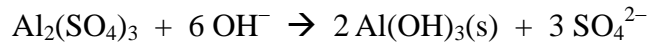
- At what alum dosages, or over what ranges of dosages, do you think the particles carry a negative surface charge?
- Two good choices for the dosage appear to be 10 and 55 mg/L. List one advantage and one disadvantage of using the higher dosage.
- A plant has been operating at the lower of the two optimal dosages, but a new operator has decided that it would be better to operate at the higher dose. How much additional sludge (mg of sludge per liter of water treated) will be produced when the switch is made?



Answer. (a) The particles are likely to be negatively charged in their natural state. Addition of alum gradually neutralizes those charges. When the charges are approximately fully neutralized, the particles coagulate. This occurs at an alum dose of ~10 mg/L. At higher doses, the particles acquire a positive surface charge and the suspension is restabilized, and at higher doses still, sweep flocculation occurs. However, at no dose greater than about 10 mg/L do the particles again become negatively charged.

(b) The higher dose is in the range of sweep flocculation, and good performance in terms of turbidity removal is pretty much assured; overdosing coagulant in this region has no adverse effects on water quality. On the other hand, the cost of the additional chemicals and the cost associated with the requirement to dispose of more sludge can be significant.

(c) The incremental addition to go from the lower acceptable dose to the higher acceptable dose is 46 mg/L of $\text{Al}_2(\text{SO}_4)_3$. When this coagulant is added to water, it precipitates as $\text{Al}(\text{OH})_3(\text{s})$; the relevant reaction is:



The molecular weights of $\text{Al}_2(\text{SO}_4)_3$ and $\text{Al}(\text{OH})_3(\text{s})$ are 342 and 78, respectively. Noting that two moles of $\text{Al}(\text{OH})_3(\text{s})$ are formed for each mole of $\text{Al}_2(\text{SO}_4)_3$ added, the sludge formation can be calculated as follows:

$$\left(\begin{array}{c} \text{Additional} \\ \text{sludge generated} \end{array} \right) = \left(46 \frac{\text{mg Al}_2(\text{SO}_4)_3}{\text{L}} \right) \left(\frac{2 \times 78 \text{ mg Al}(\text{OH})_3 \text{ formed}}{342 \text{ mg Al}_2(\text{SO}_4)_3 \text{ added}} \right) = 21 \frac{\text{mg Al}(\text{OH})_3}{\text{L}}$$

2. Indicate how the following changes would alter the performance of a sedimentation basin (improve, make worse, no effect). For each part, give separate answers for Type 1 and Type 2 suspensions. Briefly explain your reasoning.

(a) Doubling the flow rate and the length of the basin, but not changing the width or depth.

(b) Doubling the flow rate and depth of the basin, but not changing the length or width.

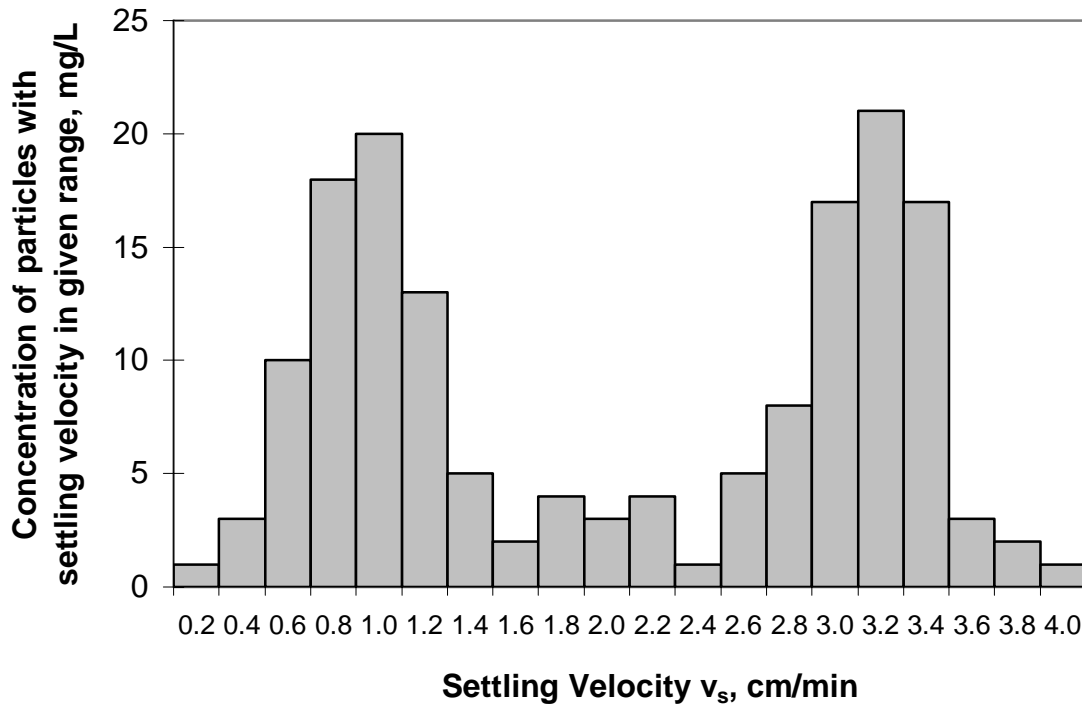
Answer. (a) Removal efficiency of discrete settling particles depends only on the overflow rate, Q/A . Doubling flow rate and length leads to a system with the same overflow rate, so the change has no effect on removal of discrete settling particles.

Removal efficiency of flocculant particles depends on the overflow rate and the residence time (t_d). Doubling flow rate and length does not change either of these parameters, so the change has no effect on removal of flocculant particles.

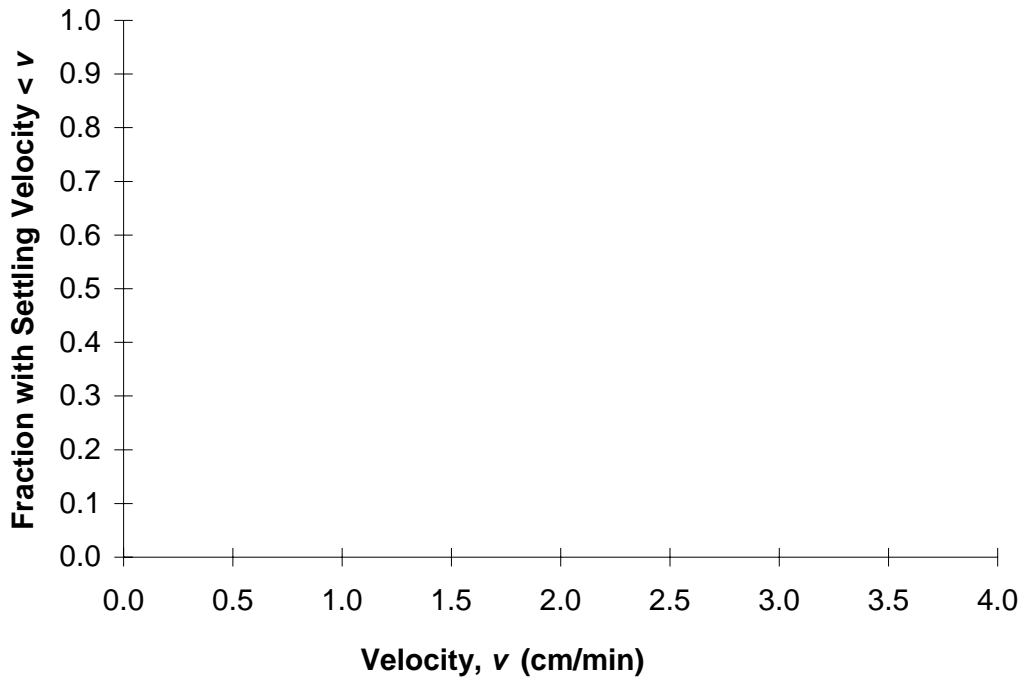
(b) As noted in part a, the removal efficiency of discrete settling particles depends only on the overflow rate, Q/A . Doubling the flow rate and depth of the basin increases Q but has no effect on A , so the overflow rate increases, causing the removal efficiency to decline.

The increased overflow rate would lead to a decline in removal efficiency of Type 2 particles, just like it does for Type 1. However, the decline would not be as severe (and in rare cases might not even occur), since increased residence time tends to increase removal efficiency for Type 2 particles.

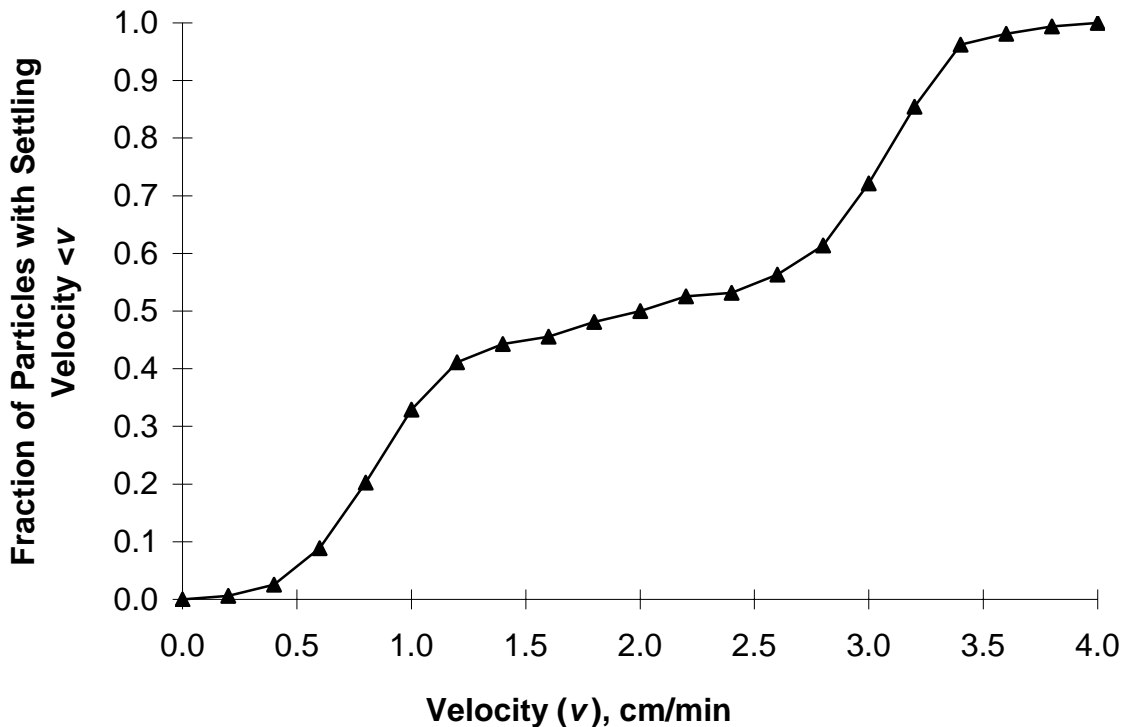
3. Shown below is a histogram describing the settling velocities of non-flocculating particles in a water supply. The number under each bar indicates the value of v_s at the end of range, *e.g.*, the first bar represents particles with settling velocities between 0 and 0.2 cm/min. As you can see, the distribution has two distinct portions; about 50% of the suspended solids are included in each portion.



- (a) On the blank graph provided (next page), sketch a plot of f (the fraction of particles with settling velocity less than v) vs. v for this system.
- (b) If you designed a settling basin with $v_{crit} = 2.0$ cm/min, would significantly less than half, about half, or significantly more than half of the suspended solids be removed? Explain briefly.

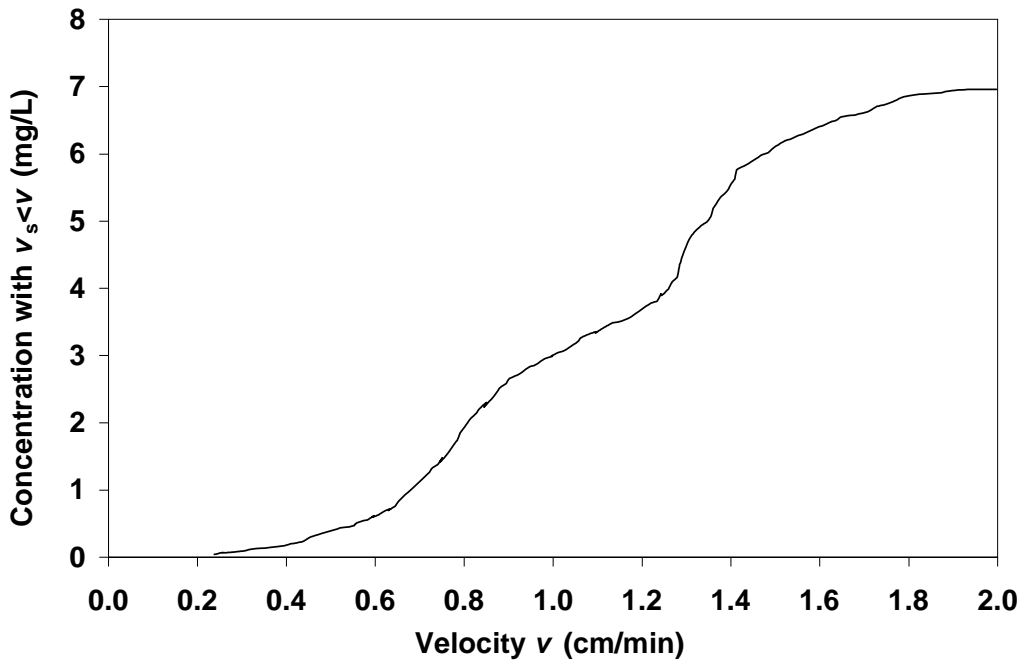


Answer. (a) The exact plot is shown below, although a rough sketch was satisfactory to receive full credit. The main features I was looking for were the two steep portions separated by a relatively flat region in the middle, reflecting the high concentrations represented by the two “humps” of the histogram, and the small number of particles in intermediate range of settling velocities.



(b) If v_{crit} is 2.0 cm/min, all particles with v_s greater than 2.0 cm/min will be removed in the basin. These particles account for about 50% of the total, so their removal accounts for 50% overall removal. In addition, a substantial fraction of the particles with velocities less than v_{crit} will also be removed (if they enter near the bottom). Therefore, the overall removal will be substantially greater than 50%.

4. A settling velocity distribution for a Type 1 suspension is shown below. This suspension is passed through a settling basin that is 30 m long and 8 m wide, and is filled to a depth of 2.8 m. The flow rate through the basin is $3.0 \text{ m}^3/\text{min}$, and the total particle concentration entering the system is 7.0 mg/L . What concentration of particles would you find in a sample that was collected at the effluent end of the tank, from a depth of 2.0 m below the water surface?

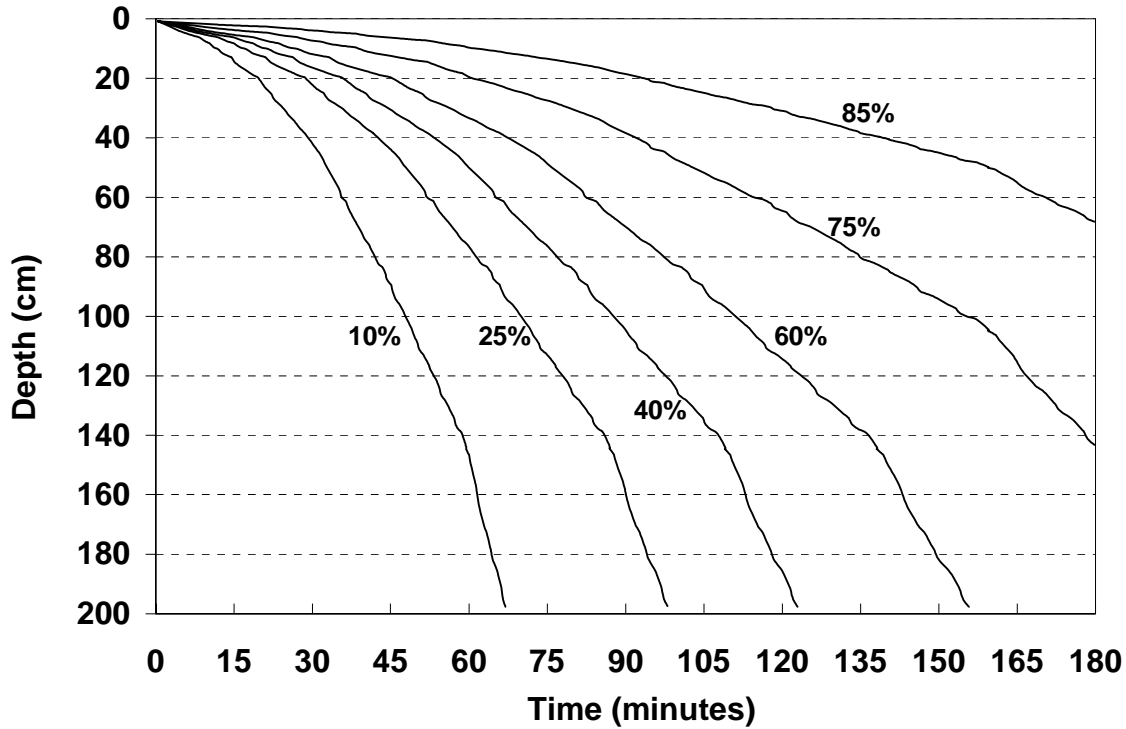


Answer. The hydraulic detention time in the settling basin is V/Q , or:

$$t_d = \frac{V}{Q} = \frac{(30 \text{ m})(8 \text{ m})(2.8 \text{ m})}{3.0 \text{ m}^3/\text{min}} = 224 \text{ min}$$

For particles to remain in a water sample taken at a depth of 2.0 m at the effluent end of the tank, they would have to fall a distance of less than 2.0 m in time t_d , i.e., less than 2.0 m in 224 min. Thus, their velocity would have to be less than $200 \text{ cm}/224 \text{ min}$, or 0.89 cm/min . From the settling distribution curve, approximately 2.6 mg/L of particles in the suspension have velocities less than this value, so that is the concentration of particles that will be present in the sample.

5. Below is a plot showing the results of a column settling test, in terms of isopleths of constant percentage removal. The test lasted 3 hours. Estimate the fraction of the particles that had an average settling velocity less than 0.5 cm/min during the first two hours of the test.



Answer. Particles that had an average settling velocity of 0.5 cm/min would have fallen 60 cm in two hours. On the graph provided, the point (120 min, 60 cm) falls just slightly above the isopleth for 75% removal. Thus, about 76% of the particles fell at average velocities greater than or equal to 0.5 cm/min, so 24% must have fallen at average velocities less than that value.