HOW FAST DO SEDIMENT GRAINS OF DIFFERENT SIZES SETTLE?

(teacher's guide)

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Level: Junior high to senior high

Anticipated Learning Outcomes

- Students will define rate, turbidity, and settling rate and explain the relation between settling rate and turbidity.
- Students will make semi-quantitative observations of turbidity and make a graph showing change in turbidity against time.
- Students will explain how and why settling rate varies with grain size.
- Students will interpret change in turbidity with time as a function of settling rates of sediment of different grain sizes.
- Students will predict how the clarity of water in a stream or in the ocean will differ during periods of flood vs. low water, or during a storm vs. between storms, and explain the basis for this prediction.

Materials and Procedure

See student handout sheet. Results will vary depending on sediment type used. Any relatively fine-grained, poorly sorted sand will yield satisfactory results.

Background

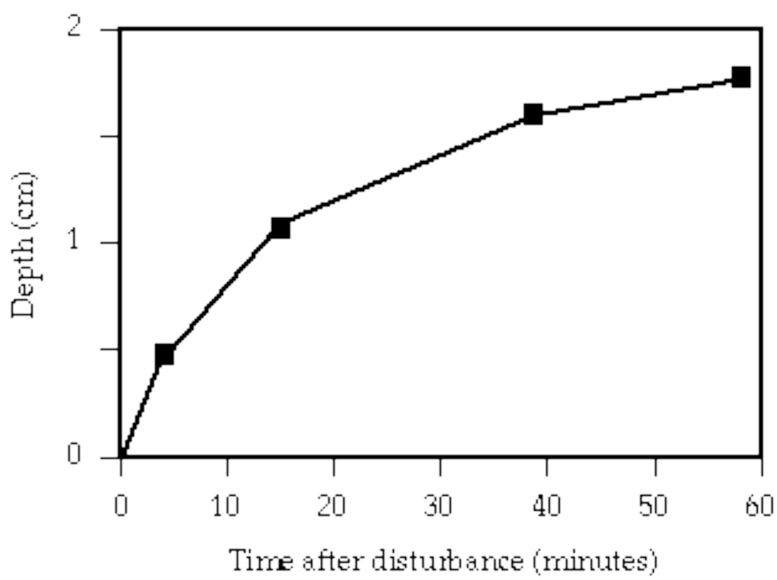
1. The settling rate of a grain depends on its size, shape and density as well as on the viscosity of the fluid through which it is settling. Some generalities include:
   - Smaller grains have a larger surface area to mass ratio and thus their settling rates are slowed more by frictional drag than are larger grains.
   - Given two grains of equal size, the denser will settle at a faster rate.
   - Given two grains of the same mass, the flatter one will settle at a slower rate because the flat shape will give a large surface area on which frictional drag will act.
2. Turbidity is cloudiness caused by sediment in suspension. Sediment may be put into suspension by disturbance such as caused by waves or currents, or, in this case by shaking. After quiet water conditions are re-established, the sediment grains will settle, but not all at the same rate. In general, large grains settle faster than smaller. This means

that the record of one event such as a storm will be a single graded bed characterized by largest grains at the bottom (settled fastest) and smallest on top (settled slowest).

3. Turbidity can be measured by lowering an object into the water and noting at what depth it disappears from sight as viewed from the top. The more turbid the water, the shallower the depth at which it disappears.
4. Turbidity in a stream generally increases with velocity. As the rate of flow increases both the size of particles in suspension increases and the amount of material in suspension increases. Stream velocity is greatest during periods of high discharge which occur during floods.

Results and Discussion of Results

1. Results of Tennessee River sand are shown below.
2. Depth at which paper clip goes out of sight increases with time. This is because fewer grains are in suspension as time goes on, and more have settled to bottom. Those still in suspension are lower.
3. The rate of settling is not constant. This is because large grains settle very fast, resulting in rapid initial removal of the grains from the water column, and rapid decrease in turbidity.
4. Rate of change in turbidity becomes quite low. This is because the small grains remaining in suspension have large surface areas and settle slowly.



Time vs. depth of paper clip visibility using Tennessee River sand

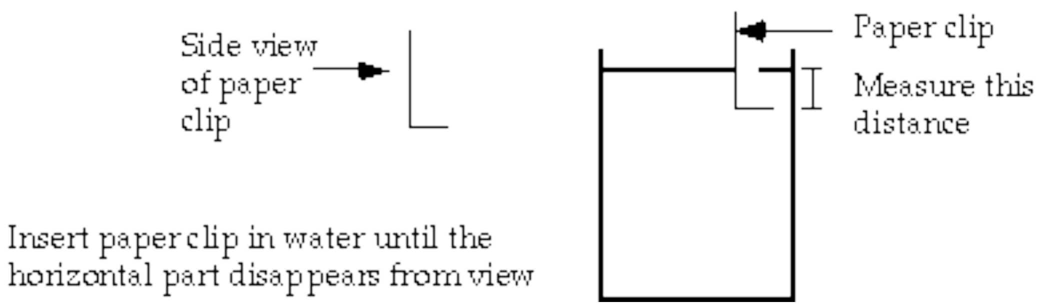
Note: Students may not be be familiar with interpreting graphs showing rates. An exercise on graphing and interpreting rates follows the student handout on the settling rates experiment. This exercise can be done either before the settling experiment or between observations while the experiment is in progress. Students might also benefit from tabulating the data before constructing the graph.

Name______________________

Sediment Settling Worksheet

Materials

- Clear glass jar preferably 10 cm high, filled 1/3 full with sediment and filled to the brim with water
- Paper clip bent as illustrated below
- Pencil
- Metric plastic ruler



Procedure: (see diagram above)

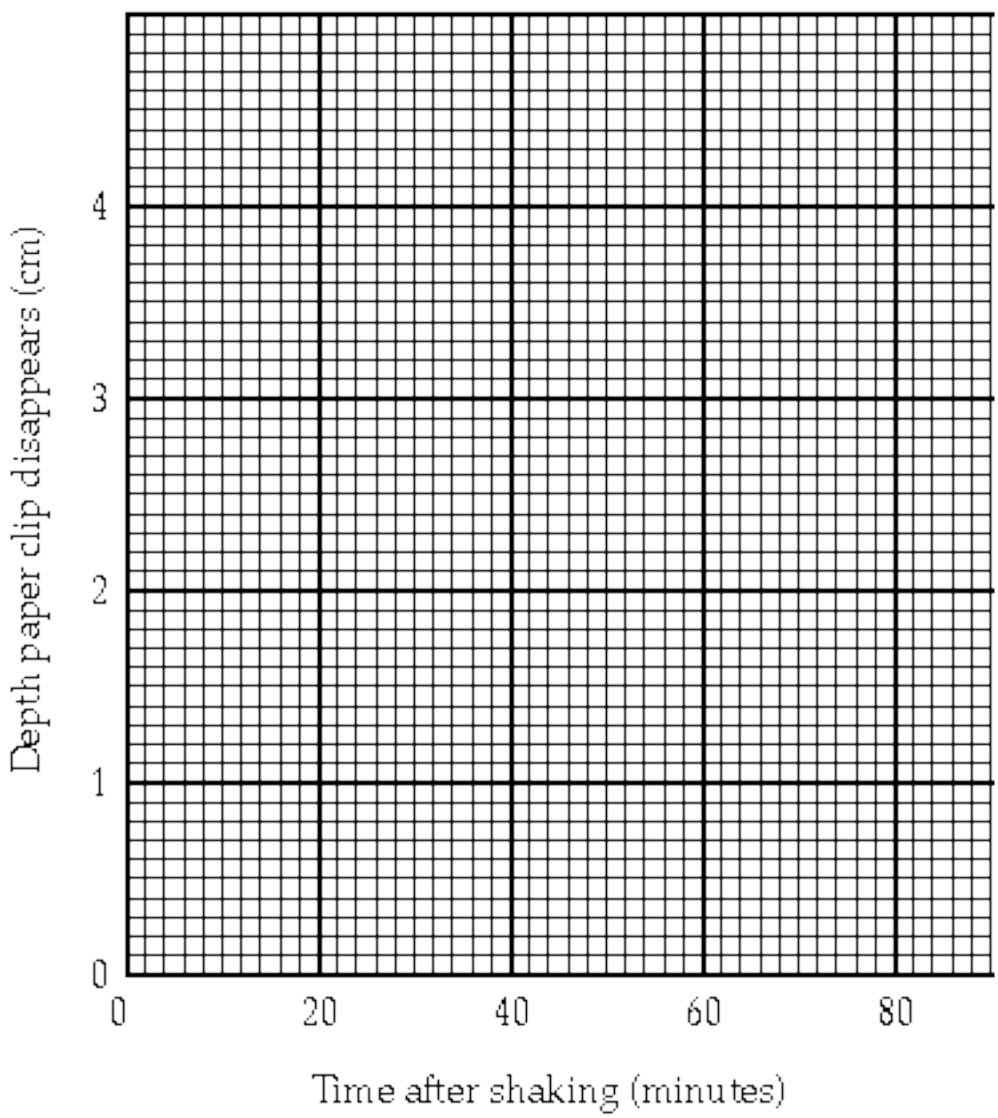
1. With lid on tightly, shake jar vigorously. Let the jar sit for 5 minutes. Note how much the water has cleared. Predict how long it would take for the sediment to settle completely. Shake the jar again and proceed.
2. Quickly set jar down and open lid.
3. Make observations as follows (two people are needed):
    a. One person lowers paper clip into water to level where it disappears from view as observed from the top and holds it there. The paper clip must be lowered next to the edge of the jar so it can be seen through the glass.
    b. The other person measures the depth beneath the water surface at which the paper clip disappears from view as observed from the top.
    c. Record the observation on a table with two columns on it - one labeled "time after shaking", the other labeled "depth of disappearance". Plot the point on the depth vs. time graph.
    d. Repeat every 5 minutes for the time your teacher tells you; the optimal time of observation depends on the size distribution of the sediment used.

Questions

1. Explain what is meant by "rate", "turbidity", and "rate of settling".
2. Summarize your observation of how the rate of change in turbidity changes with time after shaking.
3. Explain the observed trend in rate of change in turbidity as a result of different settling rates.

4. Explain the relation of grain size to settling rate. Then explain the change in turbidity as a result of settling of different grain sizes.
5. How and why does turbidity of a stream change with water flow, season?
6. How long would it take for the paper clip to be visible on the surface of the sediment?
7. Does this time approach your predicted time?

Time after shaking	Depth of disappearance



Name___________________________

Rate of Scoring Worksheet

Background

Data from the sediment settling experiment will be plotted on a graph which will show how the turbidity changed with time. From this graph you will be able to determine the rate of change in turbidity: was it constant, or did the turbidity change faster at the beginning of the experiment or at the end of the experiment? Interpreting changes in rates from graphs takes some experience as you will gain from this exercise.

The 3 tables on the attached data and graph sheet show a basketball team's score through 3 different games (Games A, B, C). In the score column is listed the team's score after so many minutes of play (listed in the column "minutes") since the start of the game. For example, in Game A, 10 minutes after the game had started, the team had scored 10 points. By the end of the game (40 minutes) they had scored 24 points. The scoring rate is the number of points per unit of time. For example, in the first 10 minutes the scoring rate was 1 point per minute. (They scored 10 points in 10 minutes.) In the last 26 minutes of the game (from 14 to 40 minutes after the start) the team scored 9 points, increasing the score from 15 to 24. The scoring rate was 9 points per 26 minutes or 0.35 points per minute.

Directions

Plot the data from game A on the graph paper and connect the points to make a line graph. Label the line "A". Repeat for games "B" and "C". (Graph paper is on attached data and graph sheet).

Questions

Fill in the blank or circle the correct answer.

1. In which game did the team score a lot of points early in the game and few later?_______ In this game, the scoring rate was (high, low) in the beginning of the game and (high, low) toward the end of the game. The line on the graph at the beginning is (steep, flat); the line representing the rate at the end of the game is (steep, flat).
2. In which game did the team have a bad start, scoring little at first, but coming on strong toward the end of the game?_______ In this game the scoring rate was (high, low) toward the beginning and (high, low) toward the end of the game. Describe how the slope of the line (that means its steepness or flatness) shows this change in rate.
3. In which game did the team play consistently, scoring evenly throughout the game? _______ Did the scoring rate change through the game?_____ Does the line graph change its slope from steep to flat, or flat to steep in this game? _________
4. Compare the graphs of scoring in Games A,B, and C with the graph showing turbidity vs. minutes after shaking from the sediment experiment. Which game's scoring pattern does the experimental data most closely resemble? ________ Explain what this means about the change in turbidity and rate of settling of particles.

Game A	
minutes	score
10	10
14	15
40	24

Game B	
minutes	score
13	3
23	5
30	7
38	22

Game C	
minutes	score
3	2
17	8
29	14
40	20