Gold, Pollution, and Farmland—Partitioning Lab--Walkthrough

Earth Science Essentials-Advanced
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An example report (minus pictures of me doing the experiments) is given below.

Materials: You will need to get some materials for this lab that aren't in your lab kit, including 9 small bathroom-sized paper cups, cornstarch, some clean sand, a teaspoon measure, and red food coloring in a dropper dispenser. You will also need your measuring cups and syringe from your lab kit. Also, don't forget one brain—not provided in your lab kit--and a partner to work with you.

Goal: Measure the partition coefficient for a pollutant between sand and water and between clay and water (we will use cornstarch as a proxy for clay and red food coloring as a substitute for the pollutant).

Outline of tasks:

1) Do 2 experiments

2) Create standard solutions whose concentrations are known

3) Compare the water in each of the 2 experiments (after equilibration) with the standards to determine the concentration of food coloring in them

4) Calculate the amount of food coloring that must remain in the sediment, and calculate the concentration that results

5) Using the concentration in both water and sediment, calculate the partition coefficient determined in each of the 2 experiments

Details of tasks:

<u>Do two experiments</u>.

Our goal is to measure the partitioning of red food coloring between water and either cornstarch or sand. Therefore, you have to do 2 experiments, one with sand, water, and red food coloring and the other with cornstarch, water, and red food coloring.

Put 5 drops of red food coloring in 50 ml water and mix in one of your small paper cups. Add 20 ml of cornstarch (simulating clay) and stir until mixed (1 teaspoon is about 5 ml). Let this sit for 30 minutes without disturbance

Put 5 drops of red food coloring in 50 ml water and mix in one of your small paper cups. Add 20 ml of sand and stir until mixed (1 teaspoon is about 5 ml). This mixture will settle out much quicker than the cornstarch, so << 30 minutes.

Create Standard Solutions:

In order to calculate partitioning coefficients, this experiments needs to be quantitative, meaning that you need to get a real number. A number has to have units (concentration of food coloring). We are going to use rather unconventional units for this lab--drops of red food coloring per 50ml. Note that this does not mean you have to use 50 ml sand or cornstarch in your experiment! In fact, if you check above, we don't! You need to understand how to determine concentration and what it means mathematically. How can you calculate the concentration in drops per 50 ml if you only have 20 ml of material? Also, you don't have to have 50ml of water to have a concentration of 4 drops per 50 ml. In fact, we will only use 20 ml of water. But recognize that if you add one drop to 20 ml, the concentration will be 2.5 drops per 50 ml, not 1 drop per 50 ml!

You will also need to measure the concentration of red food coloring in the water after the experiment. Most quantitative chemical work involves comparing what you want to analyze against a standard solution, or a series of standard solutions, whose concentrations you know (in this case, you know them because you made them). Comparisons can be visual and still be considered quantitative. For example, you could make a series of standards solutions with different numbers of drops of food coloring, and compare these to your unknown solution. Take note: Clearly, the standards must be made using the very same bottle of food coloring as you use in the experiments!

HINT: get organized first, figure out what you want to do. I am not giving a detailed recipe for what to do! You are the scientist! If you want to understand science, then you have to figure out what makes sense and what will work!

HINT: your standard solutions need to be in the same range of concentration as your experiments. The concentration of food coloring can't be so low as to be undetectable with your eye, nor so high as to make variations in concentration undetectable. (e.g. you may want to have standard solutions whose concentrations range from 1 to 5 drops per 50ml water). Also, you probably want only about 20 ml or thereabouts of standards solution, so that you don't need so much of the unknown solution to compare against.

HINT: adding one drop of food coloring to 20 ml of water is not at all the same thing as adding 1 drop to 50 ml water and then only using 20 ml of it!!!

Analyze the concentration of red food coloring in experimental water samples

After your experiments have equilibrated and the sediment has settled (a few minutes for the experiment with sand and 30-45 minutes or longer for the experiment with cornstarch), extract some amount of water from one of the experiments and put it into a small bathroom paper cup. (I suggest about 20 ml, which can be removed from the experiments without disturbing the sediment) To analyze the water sample, compare this sample to your standards (which much have known concentrations and have water depths and same color to the bottom of the cup, otherwise you are comparing apples to oranges.)

Do the same with the second experiment.

HINT: When you remove the 20ml water sample from your cornstarch-water experiment, you must take care not to stir the cornstarch back in or your experiment will be ruined. I suggest using your syringe to carefully extract a water sample—keep the end of the syringe well away from the sediment.

<u>Calculate the concentration of red food coloring in the sediment of each experiment</u>

HINT: you can calculate the amount of food coloring in the water by measuring the concentration, then scaling to an amount of water. Then you can calculate the amount in the sediment by difference with the amount you started with.

<u>Calculate the partition coefficients</u>

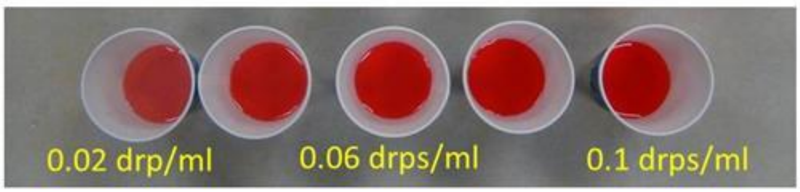
Partitioning for sand/water (drops of red coloring per 50 ml sand/drops of red coloring per 50ml water)

Partitioning for clay/water (drops of red coloring per 50 ml clay/drops of red coloring per 50ml water)

Partitioning Experiments: Making Standards

All geochemical analyses involve comparing an unknown sample to a standard sample whose composition is known. Here we make 5 standards for red food coloring by adding 1 - 5 drops of red food coloring to 50 ml of water.

After stirring, 30 ml of red water are removed from each cup to leave 20ml. The amount of standard is now less, but the concentration remains the same. For example, 5 drops per 50ml = 0.1 drops/ml regardless of the amount.



Concentrations of unknown samples can be compared to the standards by putting 20 ml unknown sample in an identical cup and comparing the intensity of the red color visually.

Partitioning Experiments

Using red food coloring as our proxy for the pollutant, and using cornstarch as a proxy for clay, we can do two experiments to equilibrate water + sediment + pollutant and measure the partition coefficients that result.

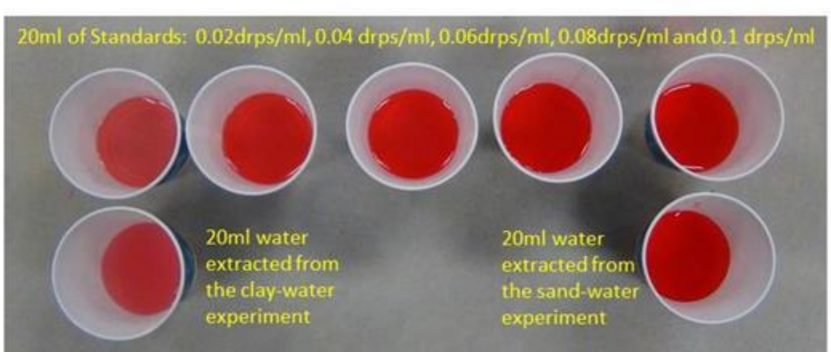
5 drops red food coloring stirred with 20ml loose clay and 50 ml water

After sediment settles, extract 20ml of water from each experiment

5 drops red food coloring stirred with 20ml loose sand and 50 ml water

Concentration in clay (cornstarch) calculated by difference:

There is 1 drop of red food coloring in 50ml of water, leaving 4 of the original drops in 20ml of clay, for a concentration of 4drps/20 ml or 0.2drps/ml.



Concentration in sand calculated by difference:

There are 5 drops of red food coloring in 50ml of water, leaving 0 of the original drops in 20ml of sand, for a concentration of 0drps/20 ml or 0drps/ml.

Report:

Your report should include pictures of you doing your experiment, your experimental set up and procedures, any problems you encountered and how you solved them, and of course your results (including measured concentrations in the water, calculated concentrations in the cornstarch or sand, and calculated partition coefficients). You should also include your interpretations.

Walkthrough:

Doing the Experiments

The experiments themselves were done as described above, using the syringe to measure 50ml of water into a small paper cup. 5 drops of red food coloring were added to each experiment. This was mixed before adding the sediment. The sediment—either sand or cornstarch—was added as 4 teaspoons full (about 20 ml). If you compacted the cornstarch or not should be reported as this makes a difference in the actual amount that you added. I did not compact. I stirred the mixture thoroughly for about 3 minutes to maximize the chance of equilibrium.

Making the standards

I made the standards while the sediment settled in the two experiments. You can make more than 5 standards if you want, but 5 provides a good range on concentrations to compare against. I added 50 ml of water to each of 5 small paper cups.

I then added one drop of red food coloring to the first cup, two to the second, and so on up to 5 drops in the fifth cup. A used a marking pen to label each cup to avoid confusion: 1 drop per 50 ml, 2 drops per 50ml, and so on. I mixed the food coloring thoroughly in each cup, otherwise the food coloring may settle and generate a heterogeneous standard, which means that its concentration varies from one place to another in the solution—a bad thing for a standard. I then used the syringe to extract 20ml of each solution, threw away the remaining 30ml, and put the 20ml back in the cup. Notice that the amount of food coloring was then different in each cup, but the concentration was still the same. It is the concentration that we use as a standard.

Analysis of experimental results

I extracted 20 ml of water from the sand-containing experiment using the syringe (leaving the cornstarch experiment to settle more). I put this 20 ml into a fresh paper cup with identical properties to the cups holding the standards (my cups have white bottoms, I think a dark bottom would diminish my ability to compare the unknown solutions to the standards).   I compared the unknown sample from my experiment with the sand to the known standards and found that it was most like (in darkness and color) the 5 drops per 50 ml standard. I therefore concluded that the concentration of red food coloring in the water after equilibration with sand was 5 drops per 50 ml.

I used the same methodology with the experiment with cornstarch. There was a film on the top of the water in the cornstarch experiment (possibly a residue that didn't sink due to surface tension effects). I punched through this with the end of the syringe to try to get clear water underneath. I was careful to keep the end of the syringe as far from the cornstarch as possible and I drew in the water very slowly (less than 40ml per minute) so as not to slurp cornstarch into my syringe. Even so, the water was slightly milky. Again, I put the 20 ml into a cup identical to the cups holding the standards.

The milky character made comparison more difficult than for the water from the sand experiment, but the water in the cornstarch experiment was clearly less 'red' than that from the sand experiment. I found it most like the standard 1 drop per 50 ml. I therefore concluded, subject to the uncertainty caused by the slight milkiness, that the concentration of red food coloring in the water after equilibration with the cornstarch was 1 drop per 50ml.

Calculating concentration in the sediment

The concentration of red food coloring in the water from the sand experiment was 5 drops per 50ml. Since I knew that I had added 50ml of water to that experiment, I knew that the amount of red food coloring in the water was 5 drops. That is how much I added to begin with—so all of the red food coloring was present in the water, leaving none to be in the sand. I concluded that the concentration of red food coloring in the sand was 0 drops in 20 ml of sand or 0 drops per 50 ml concentration.

The concentration of red food coloring in the water from the cornstarch experiment was 1 drop per 50 ml. Since I knew that I had added 50ml of water to that experiment, I knew that the amount of red food coloring in the water was 1 drop. Originally, I had added 5 drops--that left 4 drops to be present in the sediment. I concluded that the concentration of red food coloring in the cornstarch was 4 drops in 20ml of cornstarch or 10 drops per 50ml concentration.

Calculating the partition coefficients

The partition coefficient between sand and water = Concentration in sand/concentration in water = 0 drops per 50 ml / 5 drops per 50 ml = 0 (a dimensionless quantity since all my units cancel). **Dsand/water = 0**

The partition coefficient between cornstarch and water = Concentration in cornstarch/concentration in water = 10 drops per 50 ml / 1 drop per 50 ml = 10 (again, a dimensionless quantity). **Dcornstarch/water = 10**

Interpretations

The partition coefficient between sand and water is much less than 1, indicating that the red food coloring is incompatible in sand. In fact, in these experiments, any red food coloring in the sand was below the detection limits of the analytical technique. We might expect that a sandy sediment would not do well in absorbing or attenuating a migrating pollutant (at least if the pollutant acted like red food coloring).

The partition coefficient between cornstarch and water is much greater than 1, indicating that the red food coloring is compatible in the cornstarch. In-so-far as red food coloring acts like a pollutant, and the cornstarch is a proxy for clay, we can conclude that clay-rich soil will do a good job of absorbing and attenuating the movement of pollutants.