Demonstrations and laboratory exercises in aquaculture. I. Pond soil

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Introduction to Pond Soils

A great deal of commercial aquaculture takes place in earthen ponds. Because the soil affects the chemistry of the water, and the ability of the pond to hold water, soil is considered an important topic for most culturists.

The chemistry of soils is somewhat complex. Not only does soil affect the pH of the water and the nutrients available to plants and phytoplankton, but soils may also affect the water chemistry because of their cation exchange capacity. Soils that are high in organics usually have a very high exchange capacity, soils with expanding clay minerals are intermediate, while those soils dominated nonexpanding minerals have a very small cation exchange capacity. Because soil chemistry is complicated and variable, in this article we will only concentrate on some of the physical properties of soils and their relationships to ponds, not on soil chemistry.

Soils are made up of many particles. If the particles are all about the same size, the soil is referred to as being "well sorted". To analyze a soil for its particle-size classes, a soil sample is taken, dried, and passed through a series of sieves with different size meshes, so the fraction that each size particle contributes to the whole soil is determined. These classes of soil particle sizes can be classified; the UDSA system is in Table 1.

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Soils themselves are often named according to their mix of size particles, such as "sandy clay" or "silty clay." When a soil is called a **loam**, it is a medium textured soil that is roughly equally influenced by the sand, silt, and clay. If, for example, the sand becomes more important than it might be in a simple loam, that soil can be termed a "sandy loam" or, if the sand becomes *even more* important, the soil can be referred to as a "loamy sand." For more details about what constitutes specific differences, students should see a general soils textbook.

Soils are often layered in horizons so before a site is selected for pond construction, a **core** should be taken. This can be used to determine not only what soil is at the surface, but what types of soil layers are below that may affect the pond, and how deep each of these layers extend.

Because some soils are less stable than others, the incline of the pond's slope into the water must be adjusted according to the soil. Often, the slope of the pond wall will be about 3:1 (horizontal:vertical), but with some very stable soils this can be reduced to 2.5:1 or even 2:1. Unstable soils are not preferred since slopes of 5:1 or more mean that a lot of the pond is shallower than it needs to be, resulting in reduced growing space for the culture organism.

Series Introduction

Science educators have for a long time understood that seeing and doing science, in the form of classroom demonstrations and laboratory exercises, is critical to learning. Readings and lectures are certainly important, but carefully planned experiments make what a student sees on a blackboard come alive. Aquaculture is, however, a somewhat peculiar science. It is such an amalgam of techniques and information, that it is sometimes overwhelming even for teachers.

Like traditional agriculture, aquaculture is only really meaningful in the real world when viewed in terms of the final product — the crop. So how does an educator make a short demonstration experiment meaningful to a student? Obviously, by showing how the subject of the demonstration, from pumps to water chemistry, impacts the final outcome. During Aquaculture '98, we chaired the first all-aquaculture education session for the triennial WAS conference. It was at this meeting that we committed ourselves to producing lab exercises for aquaculture educators.

The purpose of this series of articles in **World Aquaculture** will be to present to aquaculture educators, and old hands, experiments that illustrate principles that impact aquaculture. These can be done as demonstrations or as lab exercises. We welcome comments, ideas, and submissions from the readers.

The soil along the side of a pond is subject to erosion by waves that form inside the pond as wind blows over the water's surface. The size of the waves is related to the distance over the water that the wind travels. If wave erosion is a problem, the pond wall can be protected by a layer of stones, called **riprap**, that will absorb much of the energy of the waves before they can damage the wall. Outer pond walls are often stabilized with grass, which holds the soil in place, but trees or large bushes are to be avoided since deep extensive root systems may destabilize the wall.

Earthen ponds must be able to hold the water with minimal loss to seepage into the ground. Under the worst circumstances, a farmer may line a pond with specialized liners that completely eliminate seepage, but these are expensive to purchase and ship, and for large ponds they are difficult to install. The ability of the soil to hold the water in an unlined earthen pond is related to the spaces between the soil particles, the **pores**. As porosity decreases, the soils hold the water in the pond more efficiently; farmers can alter porosity simply by compacting the soil, but just how effective that will be will depend on the size of the particles. Sands are relatively course, and no amount of compacting will make them hold water in a pond, but farmer may be able to mix clay into the sand to get a less porous soil. As the clay fills the pores between the sand grains, the ability of water to flow out of the pond is reduced. One of the preferred clays is **bentonite** because it swells as it absorbs water.

Table 1

class	Diameter limits (mm)
Gravel	>2.00
Very coarse sand	2.00-1.00
Coarse sand	1.00-0.50
Medium sand	0.50-0.25
Fine sand	0.25-0.10
Very fine sand	0.10-0.05
Silt	0.05-0.002
Clay	<0.002

Even soils with high clay contents can sometimes have unacceptable seepage rates. This is because soils don't naturally occur simply as individual particles, but more often as **aggregates**, secondary particles formed by cementing of the primary particles (sand, silt, and clay). Cementing is the result of the presence of cementing agents such as some organic molecules, mineral oxides, and polyvalent cations. Calcium and aluminum ions, for example, form electrostatic links between the clay particles. The aggregates can be broken up in order to decrease seepage. This is done by the addition of chemical dispersing agents such as sodium hexametaphosphate (sodium pyrophosphate).

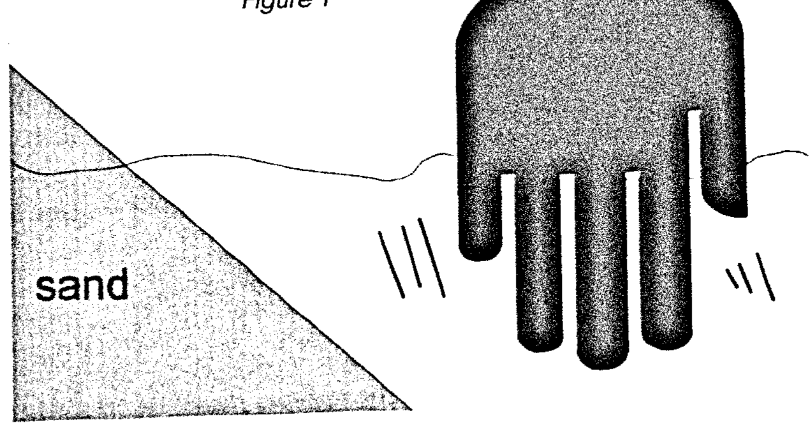
Exercise 1 – Soil Protection

This can get sloppy. Instructors should be sure that the height of the tank or shoebox is be great enough to contain the waves made by even the most enthusiastic students. Adjust the depth of the water as needed.

Use a plastic shoebox, small fish tank, or other similar vessel, to model as a pond, and fill it to about the _ level. Along one inner side of this "pond" use builder's sand to construct a pond's inner slope, as in figure 1; try to make the slope as steep as reasonably possible, then draw the profile. Using your hand, make two small waves that wash up the sand slope of the pond, then redraw the slope profile. Repeat this procedure of making two small waves and then redrawing the profile, until the profile does not seem to be changing significantly.

After the first part of this exercise is complete, rebuild the slope, but this time, cover the slope (above and below the water level) with stones about 0.5" to 1.0" in diameter. After you have covered the slope with stones, make the waves and draw the profiles like you did when the slope was uncovered.

Figure 1



Student Question - Compare the set of pond side drawings when the slope was uncovered with the changes in the stone-covered slope. Is there any difference? If so, what could the reason be?

Answer - The slope that is uncovered should quickly erode to a small hill after several sets of waves. The slope that is covered should not be affected by the waves very much, if at all. The stones on the covered slope act as "riprap", as such they absorb most of the wave energy before it reaches the sand slope. Even the wave energy that does manage to get between the stones and reach the sand will often be dissipated as it rebounds back into the covering stones

Exercise 2 – Seepage Through Soil

In practice, the flow through the bentonite-sand might be very slow. If so, the students can begin Exercise 3 while the water is seeping through. Even so, the students may have to stop this experiment when only a fraction of the water has passed; if this is the case, be sure to point out that in their question below, only the water passed through the filter is used in the calculations, not the total amount of water applied.

You will need a disposable glass pipette, which should have a little glass wool in the bottom, as shown in the figure 2. A support stand and clamps will be needed to hold the pipette. Wet the glass wool before you start the experiment.

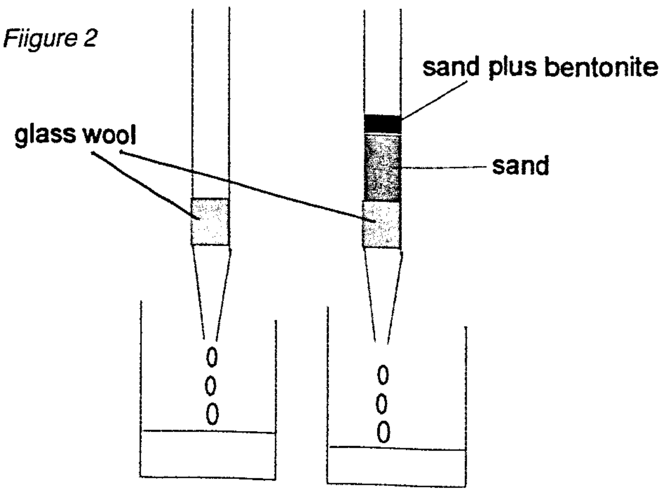
Using a graduated pipette, dispense about 3 ml of water through the wet glass wool, and time how long it takes for all the water to pass. Repeat this and record the results in table 2.

Add about 3 cm of sand on top of the glass wool, then wet it. Again, using a graduated pipette, dispense about 3 ml of water through the wet glass wool and sand, twice, and record the results. Finally, mix some sand with some bentonite clay so that the mixture is about 10% clay (by weight). Apply the sand-bentonite mixture on top of the sand in the disposable pipette; this new layer should be thin, about 0.5 cm. Wet it with a few drops of water after it's on top of the sand. Now do the experiment again to see how long the 3 ml of water takes to pass through the sand with the bentonite-sand mixture above.

Table 2

Pipet contents	Time for 3 ml to pass (1st trial)	Time for 3 ml to pass (1st trial)	Average time for 3 ml to pass
Glass wool			
Glass wool and sand			
Glass wool, sand, and bentonite			

Fiigure 2



Student Question - Calculate the velocity of the water in Exercise 2 through (a) the sand plus glass wool, and (b) for the bentonite plus sand plus glass wool. The velocity, v, is related to the flow (Q, as cm^3/second) and the cross-sectional area of the pipette (A, as cm^2). v=Q/A

Answer - Suppose that the water took 55 seconds to flow through the sand plus the glass wool. If 3 ml was used, that is 3 cm^3 of water. If the diameter of the pipette is about 0.65 cm, than the cross-section area (πr^2) is 3.14 X $(0.65/2)^2 = 0.33$ cm^2. v=Q/A v= (3 cm^3/55 seconds)∏0.33 cm^2 v=0.165 cm/second The velocity of the water through the sand that was topped with the bentonite-sand layer should have been much less than that of the sand itself.

Exercise 3 – Formation and Dispersion of Aggregates

The instructor should start to prepare for this a few days in advance. Some builder's sand and a mixture of about 80% builder's sand with 20% bentonite will be used. For each student or group, prepare and mark three glass Petri dishes, Syracuse dishes, or watch-glasses; one should have only the sand and the other two should have the sand and bentonite mix. Cover the sand sample and one of the mixed samples with just enough water what all the material is submerged, and cover the other mixed sample a 20 percent aqueous solution of $AlCl_3$-$6H_2O$. All the samples should be placed in a drying oven for about 2 days before the lab. There should also be a 2 percent aqueous solution sodium pyrophosphate prepared. Each group of students should also be given either a dissecting microscope or a good magnifying glass.

Each student or group will get the three dried soil samples. You should examine each dry sample under a microscope or magnifying glass and try to disturb it with a glass rod or other device. Consider if there was any formation of aggregates. Record your observations in Table 3.

Take a sub-sample of each of the three soil types, and place them in separate small Petri dishes, Syracuse dishes, or watchglasses. Barely cover each with water, gently agitate, and again examine under magnification and record the results in Table 3.

Table 3.

	sand	sand and bentonite	sand and bentonite (dried with $AlCl_3$-$6H_2O$
Dry			
Treated with water			

Student Question - In this part of Exercise 3, what was the effect of adding bentonite in terms of forming aggregates? What was the effect of using aluminum chloride rather than just water when preparing the soil samples?

Answer - The sand that had been dried in water probably did not form any aggregates, or aggregates that were very weak and easily broken up mechanically. When the samples were mixtures of sand and bentonite, aggregates probably formed, although the aggregates that were formed in the absence of aluminum chloride should have broken up when exposed to more water. The aggregates formed because of prior aluminum chloride treatment may also have somewhat broken up, but smaller (perhaps whitish) aggregates probably stayed intact. The soil that was treated with the aluminum chloride probably had a whitish crust upon drying.

Finally, take two more sub-samples of the sand-bentonite mixture that was dried with $AlCl_3$-$6H_2O$. Slightly cover one with water as before, and cover the other in a 2% solution of sodium pyrophosphate. Swirl each for about 10 seconds and then observe to see if the water in either has gotten "cloudy". Wait about 10 minutes and repeat this; this should be repeated every 10 minutes for half an hour. It may be easier to see the "cloudiness" if magnification is **not** used. Record your results on Table 4.

Table 4.

minutes	Water	2% solution of sodium pyrophosphate
0		
10		
20		
30		

Student Question - What was the difference between placing the aluminum chloride treated sand-bentonite mixture in water and placing it in the sodium pyrophosphate solution? There was probably little effect in the water sample. The bentonite was held together by electrostatic forces contributed by the aluminum ions, and the water did not get too cloudy even after 30 minutes. The sodium pyrophosphate, a chemical dispersing agent, should have disrupted the electrostatic links between the clay particles resulting cloudiness as the clay particles separated.

Notes

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