K-12 IYS Activity

Soil Science Society of America

Reuse of Degraded Water on Different Soils

Summary

This exercise serves to provide examples of how different soil textures can affect typical wastewaters. The focus is on seeing how these different soils with varying textures affect the wastewater as they move (or percolate) through the soils. The participants will be presented effects of particle size by filtering eutrophic water through sandy and clay bearing soils. Filtering grey water through sandy and clay-bearing soils will demonstrate the effects of adhesion. Participants will see differences in the "soapiness" of the final percolated grey water. Participants are encouraged to consider real-world soils and degraded waters in the natural environment and to consider what may be the positive and negative impacts on the soil and waste water.

Key Words

grey water, eutrophic/eutrophication, adhesion, percolate, deionized, texture, sand-sized particle, clay-sized particle, bentonite clay, degraded water reuse, blue-green algae, cyanobacteria

Learning Objectives/ Outcomes

1. Students will be able to provide examples of how different soil textures can affect typical wastewaters. The focus is on seeing how these different soils with varying textures affect the wastewater as it moves (or percolates) through the soils.
2. Students can state the effects of particle size on the filtering of water through sandy and clay bearing soils. Filtering degraded water through the sandy and clay bearing soils will demonstrate the effects of adhesion and particle size.
3. Participants are encouraged to consider real-world soils and degraded waters in the natural environment and to consider what may be the positive and negative impacts on the soil and waste water.

Materials (per student, group etc.)

All materials are readily available in retail outlets (e.g., *Home Depot*, *WalMart*, or any supermarket). For this exercise two experiments (i.e., green water experiment and grey water experiment) are executed approximately simultaneously. The materials listed are per individual participant or small group. For a small class setting it is possible to do one set of experiments for the whole group. One scale could easily be shared among many participants or groups.

- Clear-plastic cups (at least 8 to run all experiments simultaneously)
- 1 thumb tack
- Plastic spoons (for mixing soils)
- Inexpensive weighing scale < can be obtained from *Walmart*
- Deionized water (at least 850 mL) < can be obtained from the bottled water section of any supermarket
- All purpose sand - washed by participant (about 500 g for all experiments) < can be obtained from *Home Depot*
- Bentonite clay (about 4g for all experiments) < can be obtained from *Home Depot*
- Spirulina (Capsules or Powder) < can be obtained from a drug store
- Bubble solution (at least 20 mL) < can be obtained from a toy store
- 9" × 13" pan
- Test tubes with caps (or clear identical plastic bottles – 6 total) < can be obtained from *Walmart*
- Box(es) – with holes cut by participant to hold extraction cups

Many items can be found in the home (e.g., plastic cups, thumb tack, plastic spoons, pan, and boxes). The total cost of all other items will be $20-30.

Ages of Audience

1. Middle School, High School
2. Adults

Recommended group size?

1. Less than 20
2. 20-50

Where could you offer this?

1. Local school
2. Other, please specify: Any place with participants interested in very basic water reuse with the ability to accommodate several small countertop experiments.

Type of Lesson

1. Hands-on (participants touch the stuff)
2. Indoor
3. Demonstration (scientist or teacher demo, outside professional)
4. Experiment (follow procedure, get results, interpret results)
5. Small group exercise/discussion critical thinking

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Time Needed

Most of the prep time will be acquiring the supplies. The leader of the experiment may want to pre-wash a significant amount of sand to save participant time. Pre-washing of sand should take about 20 minutes of rinsing, and a couple hours for the sand to dry.

The experiments require two sessions of about 45 minutes broken up as follows: one session to prepare extraction cups, fluids, and set up the experiment; another session is needed the following day to study the results of the experiments. Discussion questions can be addressed in the second session or during a third session if preferred.

The fluids passing through the clay-bearing samples will take quite a while to percolate through, so this needs to be done over two sessions preferably waiting overnight. *Note:* even with sitting overnight, the fluids for the grey and green water experiments may not completely filter through the clay soil but there should be sufficient sample to evaluate the results (at least 5mL). Clean up time is minimal since the plastic cups could be emptied, rinsed and recycled by participants.

Background Information

Soil consists of a mixture of three different particle sizes, which define its texture. These particle sizes are sand, which has a coarse texture or large particle size; silt, which is medium in particle size; and finally clay, which has a fine texture or small particle size. Different textural compositions cause soil to have different properties, so a sandy soil will have different properties than a clay soil.

Water has a variety of uses for agriculture, home, and industrial purposes. Each time water is used it is degraded, which means that pollutants are added to the water thus degenerating its quality. There are a variety of different degraded waters that are created when fresh or clean water is used. For instance, water is used in the household for washing clothes or cleaning. Crops are irrigated with water in many agricultural areas of the world. There are countless industrial uses for water such as cooling, heating, and paper manufacturing to name a few. These activities all produce degraded waters which are often simply called wastewaters. Not all degraded water is the same so the wastewater industry uses different terminology to describe the type of wastewater.

Degraded water generated from wash hand basins, showers, and baths is sometimes referred to as “grey water.” This wastewater can be recycled in the home for uses such as toilet flushing or watering plants in the yard. Grey water is sometimes used in gardens to provide water for crops. This type of degraded water usually contains soaps, detergents, greases, oils, and inorganic chemicals.

Agriculture consumes very large volumes of water for the irrigation of plants. Irrigation water applied to crops results in drainage water, or rather water that the plant does not consume. When plants are irrigated (or watered), the water is consumed and any salts that were originally in the irrigation water are left behind in the water that drains past the roots (referred to as drainage water). The resulting drainage water contains salts.

During heavy rains water comes into contact with farmland and household lawns containing fertilizer. The runoff water carries some of the fertilizer, which ultimately ends up in lakes and streams where the excess nutrients can cause algae to form. This is known as eutrophication. The algae usually give the eutrophic water a green color. Other uses of water are recreational, such as in lakes for fishing, swimming, boating, and industry. These are some of the most common uses of water and some of the most common degraded waters that result from those uses.

The demand for clean freshwater is constantly increasing, which is primarily due to the ever increasing world population. As freshwater supplies become stretched to their limits, alternate sources of water, such as degraded water, are needed to meet increased demand. Agriculture is the largest consumer of freshwater supplies, and subsequently it is a large potential user of degraded water, particularly in geographical areas of recurring drought. However, it is of great concern what happens when degraded water is applied to agricultural land because it will determine its sustainability, or rather how long the reuse of the degraded water can continue before detrimental impacts occur. The following experiments were designed to illustrate what happens when different types of degraded water are applied to different types of soil varying in particle size (sand, silt, and clay) and to see what the beneficial and detrimental effects can be on the soil and on the degraded water.

Experimental

Multiple cups with small holes in the bottom are filled with soils of different textures and placed over collection cups. About 75 mL of “green water” (water containing spirulina) and “grey water” (water containing a bubble solution) are poured over the soil and allowed to pass through the soil. The excess water is collected and compared to evaluate the effects of the different soil textures.

The green water test primarily illustrates the ability of soil with different particle sizes to filter the algae (spirulina) from the green water. Water containing spirulina (a blue-green algae scientifically referred to as cyanobacteria) is a good representation of eutrophic water. The filtering of the spirulina is primarily due to the physical size of the spirulina exceeding the size of the pores in the soil. Since sandy soil has larger pores than a clay soil, more of the spirulina will pass through the sandy soil.

Since soap is dissolved in grey water, the physical size of the soil pores will not be a factor in filtering soap. Rather, the grey water test primarily illustrates adhesion, which causes soap to bind (or adhere) to the soil particle surfaces. Since clay is a smaller particle than sand, clay soil has more soil surface than an equal volume of sandy soil. Consequently, more of the soap will be removed as the grey water passes through the clay soil.

Methods/Procedures

1. Pre-experiment Preparation
   a. Fill the 9 × 13” pan about 3/4” deep with the all-purpose sand. Rinse the sand with tap water until the run-off water is clear. Allow the sand to dry.
   b. Prepare extraction cups by piercing the bottom of 4 plastic cups (refer to Figure 2) with about 30 holes using the thumb tack. Reserve 4 cups as collection cups to collect percolated fluids.
   c. Make an extraction rack: using scissors make holes in the box so that the extraction cups can be held above collection cups (do not make the holes too big or the cups will fall through). Depending on the size of the cups and boxes this may require several boxes. See Figure 3 for an example.

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2. Green (Algae) Water Experiment
   a. Prepare the “green water” by adding the contents of one spirulina capsule to 200 mL of deionized water and mix thoroughly. (Refer to Figure 4)
   b. Prepare the sandy soil cup: Place 100 g of washed sand into a cup and wet the sand with deionized water (refer to Figures 5 and 6). Place the sand into one of the extraction cups. Lightly press the soil into the cup so that most of the airspace is eliminated. Allow excess fluid to drip into a sink or basin before placing in the extraction box over a collection cup. Gently pour about 75 mL of the test fluid (i.e., green water or grey water) onto the soil.
   c. Prepare the clay soil cup: Place 98 g washed sand into a cup, add 2 g bentonite clay and mix the sand and clay (refer to Figures 7-9). Thoroughly mix with deionized water to moisturize the soil. Place the mixture into one of the extraction cups. Lightly press the soil into the cup so that most of the airspace is eliminated (refer to Figure 10). Allow excess fluid (if any) to drip into a sink or basin before placing in the extraction box over a collection cup (refer to Figure 11). Gently pour about 75 mL of the test fluid onto the soil (refer to Figure 12 and 13).
   d. The following day: Stir the collected fluid and collect equal volumes of each fluid for comparison. The fluid should be collected into clear identical containers with lids (i.e. plastic bottles or test tubes with caps). Shake the fluid in the containers to compare results—remember to compare with an equal volume of the original solution (refer to Figure 14).
3. Grey Water Experiment
   a. Prepare the “grey water” by mixing 20 mL of bubble solution and 180 mL of deionized water.
   b. Follow the procedure from 2.b
   c. Follow the procedure from 2.c
   d. Follow the procedure from 2.d (refer to Figure 15)

Discussion Questions

1. Based on the results of your experiment compare the filtering ability of sandy and clay bearing soils. Did the sand or clay soil filter the best?
2. How would the results of the green water experiment be different if the clay content was increased?
3. The fabricated soils in these experiments were relatively simple compared to natural soils – what differences would you expect if you carried out these experiments on your local soil? Describe sources of wastewater in/near your community.
5. Some landfills use clay layers to protect drinking water aquifers from contaminants—based on these experiments do you think this is sustainable? Why or why not?
6. Based on this experiment discuss potential long-term effects of disposing of grey water on the soil surface.
7. Real topsoil is sometimes rich in organic matter—how might the green and grey water experiments differ if the soil used was real topsoil. (Hint: organic matter has a large surface area and readily takes up organic chemicals.)
8. BONUS ACTIVITY: Using local soil, repeat each experiment. Use the results to determine if your soil is more typical of clay-rich or sandy soils. Explain how your results compare to the classroom experiment and how these results support your conclusion.

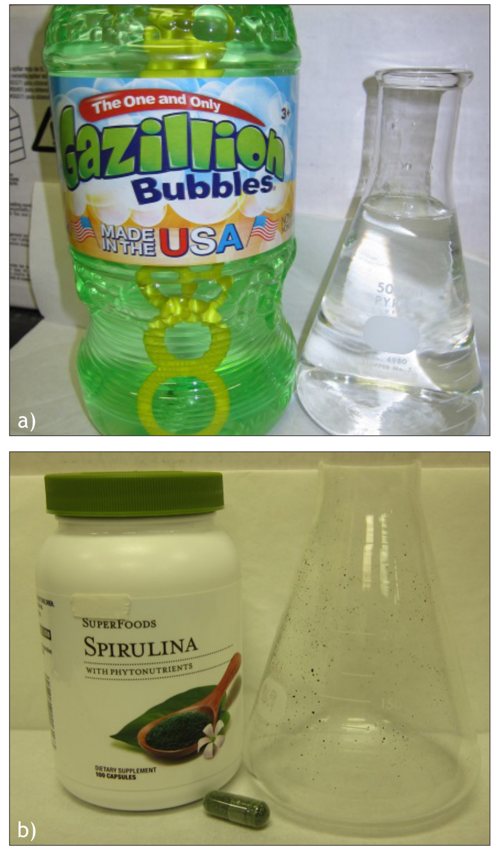

Figure 1. a) Photos of sand, bubble solution, and b) spirulina capsules used in the experiment.

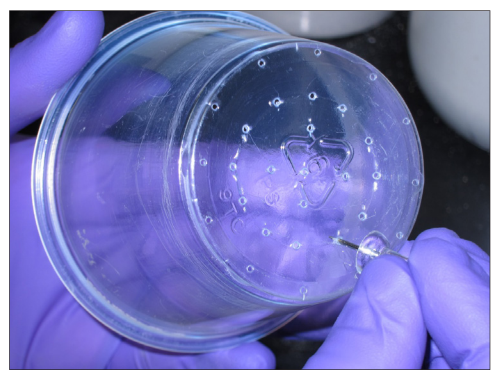

Figure 2: Perforated extraction cup.

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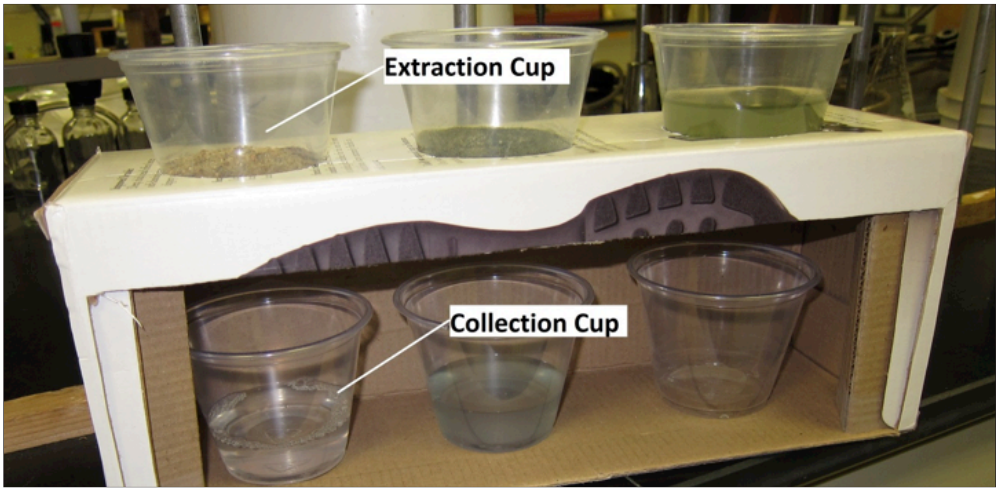

Figure 3: Cardboard extraction rack setup.

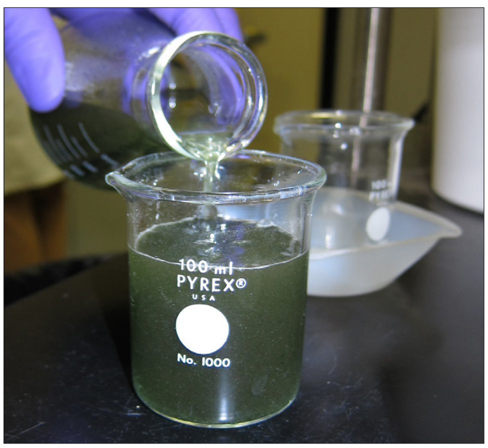

Figure 4: Spirulina solution.

Figure 5: Weighing 100 g of washed sand.

Figure 6: Wetting the sand.

Figure 7: Weighing 98 g of washed sand.

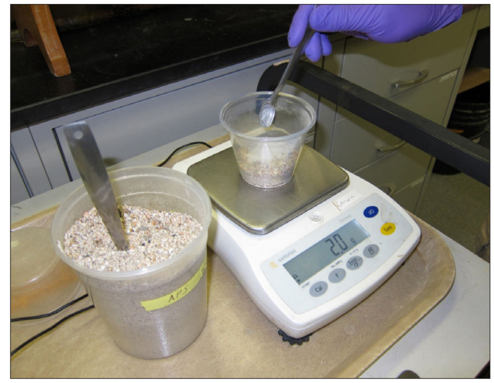

Figure 8: Weighing 2 g of bentonite clay.

Figure 9: Wetting the sand/clay mixture.

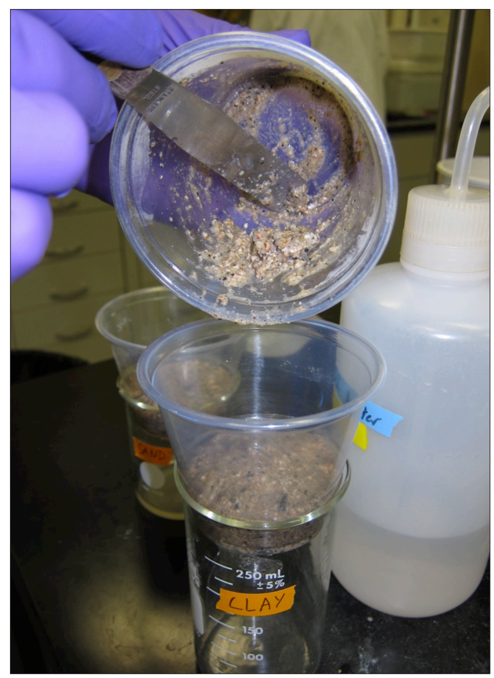

Figure 10: Placing sand/clay mixture into extraction cup.

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Figure 11: Allowing water to percolate though soil before adding solutions.

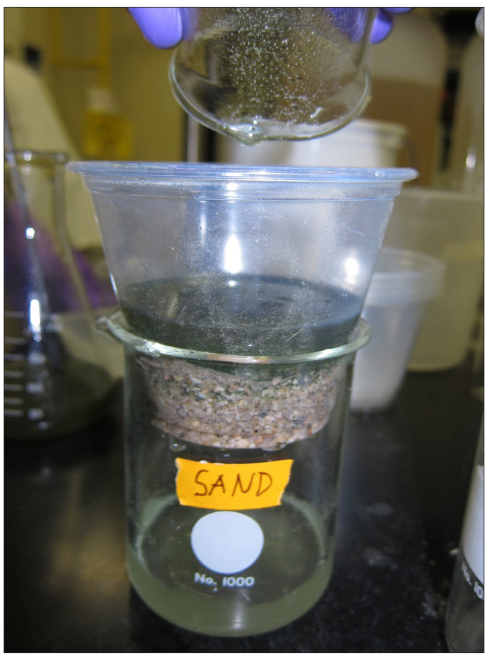

Figure 12: Adding 75 mL of the spirulina solutions to soil.

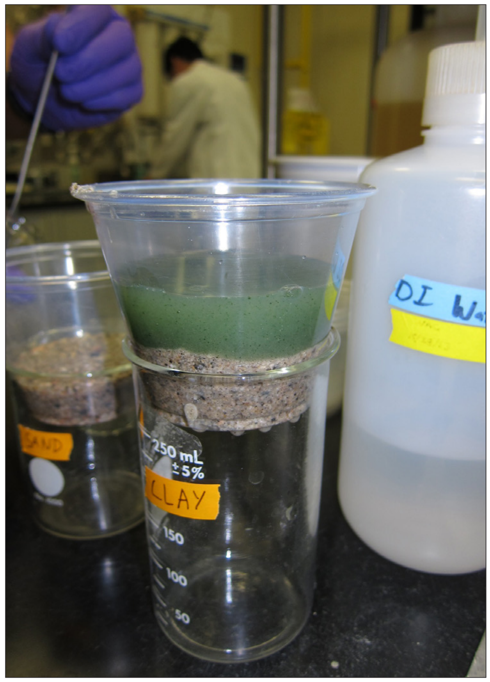

Figure 13: Waiting for spirulina solution to filter through sand/clay soil.

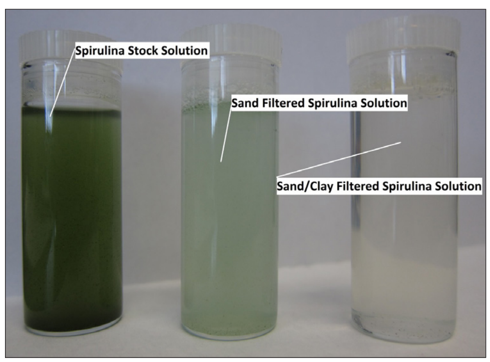

Figure 14: Spirulina end results.

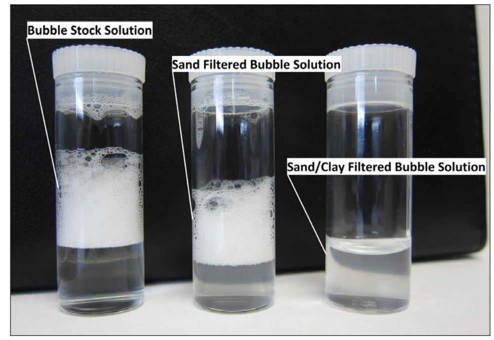

Figure 15: Bubble solution end results.

Additional Resources

WaterWorld—Water Reuse and Recycling.
http://www.waterworld.com/waste-water/reuse-recycling.html

8 Ways to Recycling Water Around Your House.
http://www.care2.com/greenliving/8-ways-to-recycle-water-around-your-house.html

Recycling Water—Benefits of Recycling.
http://www.benefits-of-recycling.com/recyclingwater/

Water Reuse—Issues, Technologies, and Applications by T. Asano, F. L. Burton, H. L. Leverenz, R. Tsuchihashi, and G. Tchobanoglous. 2007. McGraw Hill, New York, NY.