



NATURE HARMONY FOUNDATION

NATURE FARM LESSON PLAN – BIOFILTRATION: CLEANING WATER WITH ENGINEERED WETLANDS

INTRODUCTION

Topic/Unit of Study: Pollution & water quality

Instructor: TBD

Age group: 8 years – adult

Date: TBD

Lesson Objective(s)

1. To understand the global problem of water pollution.
2. To observe how different filtration methods clean water in an aquaponics system.
3. To extend understanding of biofiltration to other kinds of water pollution.

Materials

2-L bowl or bottle
Coffee filter
5 x elastic bands
5 x 2 L clear soda bottles
1 cup each of filtering materials (recommended: biochar/charcoal, gravel, sand, cotton balls)
1 cup of filtering substrate from Engineered Wetland (or home prepared)
2 cups of water from the Aquaponics Module (or home fish tank or pond)
Half-liter container
Plastic cling film
Dissolved oxygen meter or test kit
Magnifying glass
Pencil & paper

Key terms

Biofiltration
Substrate
Nitrification

CONTENT TIME

Identify (~5 min)

- The need for clean water is shared by all living things on Earth
- Organisms and ecosystems have adapted to rely on freshwater from lakes, rivers, and ponds. This water has a delicate chemical balance of essential minerals and low nutrient contents, and a biological balance of few pathogenic organisms
- Rapidly growing human populations have upset the balance by polluting waterways both near and far from cities.



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- There are three types of waste that threaten the ecological integrity of water on the planet:
 - **Organic waste** - When we flush our toilets or raise animals, we produce organic waste (urine and feces). This waste is full of nutrients like carbon, nitrogen and phosphorus that are useful to some organisms, such as bacteria, but harmful to plants and animals in high concentrations.
 - **Pharmaceuticals and household chemicals** – Household chemicals, such as cleaning agents, make our lives more convenient but are washed into the sewer system. Many pharmaceuticals like pain killers also end up in waterways to affect fish, insects and more after passing through our bodies.
 - **Industrial waste** – Chemicals from many of the clothes, construction materials and technologies we rely on leave a legacy when they leach into water through the ground or in rain and snow. These include so-called *forever chemicals* like PFAS, that can harm wildlife and people and stay unchanged in the biosphere for thousands of years.
- One of the greatest challenges facing the planet is how to clean waterways of these various kinds of wastes

Understand (~10 min)

- There are a few basic ways that polluted water can be cleaned:
 - **Mechanical filtration** – A first step to cleaning water is to remove the sediment and clumps of organic matter from the water. This is done by letting the pieces settle and/or filtering the water through a material, like gravel, sand, or something else coarse.
 - **Biological treatment** – This kind of treatment using living organisms – usually bacteria – to break down organic material and transform it into molecules that can be more easily disposed of. Nitrogen compounds in sewage treatment plants, for instance, get transformed into nitrogen gas by microbes to then return to the atmosphere.
 - **Chemical and/or light treatment** – Waste molecules can also be broken down into simpler forms by chemicals like hydrogen peroxide or energy like ultraviolet light.



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- When our sewage is treated, it undergoes the above steps to get a product that is drinkable by humans. But fewer steps may be needed for other applications.
- One of these applications is aquaponics, where we need to keep water clean enough for fish to live in but not for humans to drink it.
- But what kind of water pollution do we need to clean in an aquaponics system? Fish waste and any leftover fish food are the main culprits. Both are high in protein and so put a lot of nitrogen into the water.
- Aquaponics is the process of transforming this pollution into a form that is harmless to fish and optimal for the growing of hydroponic plants
- One of the most toxic pollutants from fish waste is *ammonia*, which kills fish and other organisms at high concentrations. Fortunately, a natural process called *nitrification* is able to convert this compound into *nitrate* - a less toxic form of nitrogen that is readily used by hydroponic plants for growing.
- The Engineered Wetland of the Nature Farm does this water-cleaning through two of the steps introduced above: Mechanical filtration and biological filtration. The water does not need further chemical or light treatment because it is for growing fish and plants and not for human drinking.
- In our activity, we are going to see these two modes of water filtration in action through two small experiments.

Process - (20 – 30 min)

Part 1. Mechanical filtration of simulated polluted water

Objective: To observe how different substrates remove larger particles of pollution, but not smaller ones that give the water its colour.

1. In a 2-L bowl or bottle, mix tap water with a handful of dirt, pieces of leaves, coffee grounds and a few tablespoons of vegetable oil. This sample mimics water polluted by particulate and organic matter, such as fish waste.



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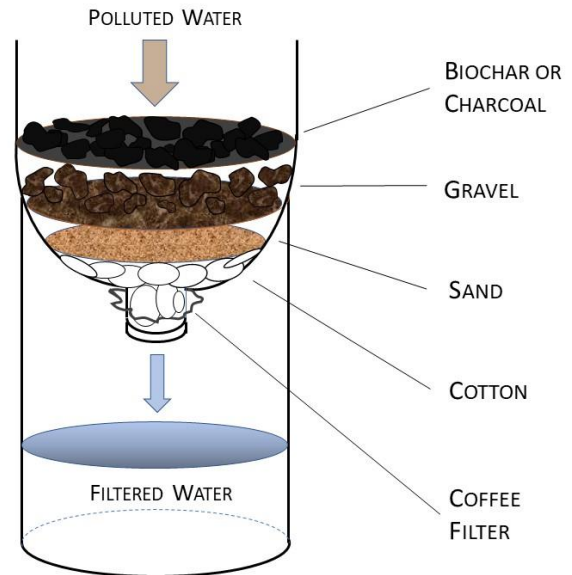
2. Cut the five 2-L soda bottles two-thirds up from the bottom. Invert the top so that it fits into the bottom as shown at right. It will be filled with filtering material kept in place by a piece of coffee filter, fastened over the bottle opening with an elastic band.

3. Set up five filters filled with:

- a. Biochar or charcoal with no coffee filter
- b. Gravel with no coffee filter
- c. Sand with a coffee filter
- d. Cotton with a coffee filter
- e. All five filter materials layered as shown

Note: Students may try any other filtering material they can think of, from shredded newspaper to straw.

4. Pour one cup (250 mL) of polluted water sample through each filter. For each filter, have students record:
 - a. How long it takes for all the water to travel through the filter.
 - b. How the appearance of the water has changed. To facilitate this comparison, students can place the filtered water next to the polluted water sample in front of a white sheet of paper. They may be prompted to look for differences in (i) the amount of debris or particulate, (ii) the colour of the water and (iii) the presence of any vegetable oil seen as a surface film.
 - c. Any changes seen in the filter itself, such as debris sitting in a particular layer or a change in colour of the cotton layer.



Part 2. Biological filtration of fish tank water

Objective: To observe the activity of microbes in filtering substrate as they transform organic pollutants from one form into another



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5. Obtain one cup of filtering substrate (biochar) from the Engineered Wetland of the Nature Farm, along with two cups of water from the Aquaponics Module. If doing this activity from home, you can soak any porous material (e.g., sand, wood chips, sawdust, charcoal) in water from a fish tank or a neighbourhood pond for one week to culture an army of waste-filtering microbes.
6. *One hour before the start of the lesson*, place the fish tank water and filtering substrate into a half-liter or larger container. Measure the dissolved oxygen concentration. This is best done with an electronic meter but can also be done with a chemical aquarium test kit. Record the oxygen concentration of the water for later comparison.
7. Cover the surface of the water with plastic cling film to prevent oxygen from the atmosphere dissolving into the water.
8. This time with the students, measure and record the dissolved oxygen concentration again. It should be noticeably lower than the initial measurement.
9. Students may also look closely at the filtering substrate with a magnifying glass to see any films or slimy coatings covering it.

CLOSING

Analyze and Communicate (~10 min)

We saw two ways of filtering water, one that relied on the physical properties of filtering materials and the other the microbes that lived on materials. For a discussion of water cleaning, ask students:

1. What happened to the appearance of water when poured through the different filters? Which material seemed to work best? What kinds of pollution did not get cleaned well by our homemade filters? Hints: Students will find that coarse substrates like gravel let larger debris through the filter. Finer substrates, like sand and cotton, are needed to remove finer particles like coffee grounds. Oils are more likely to stick (adsorb) to these fine substrates too, which may be seen in greasy cotton.
2. Did filtering get rid of all the colour in the water? What does remaining colour tell us about the limits of mechanical filtration? Hints: Students will likely note that filtered water was still slightly discoloured (brown), especially if there were a lot of coffee grounds in the water sample.



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3. Remaining colour reminds us of those small molecules like natural organic matter (NOM) and humid substances are not affected by purely mechanical filtration. Removing these substances usually requires biological filtration (metabolizing by microbes) or chemical/light treatment (e.g., UV light).
4. What happened to dissolved oxygen levels in water containing filtering material from the Engineered Wetland? What consumed the oxygen to reduce its concentration in the water? Could you see any biofilms on the substrate? Hints: Dissolved oxygen levels go down as bacteria and fungi on the substrate (and a smaller amount in the water) use oxygen to convert resources into energy for living. This includes all bacteria using oxygen to break down of carbohydrates AND special nitrifying bacteria using oxygen to convert ammonia into nitrate.
5. What do you think this filtering action means for the quality of fish tank water? Hint: It will have less organic matter and ammonia than if it was not filtered.

Conclude (~5 min)

For discussion, ask students:

1. Why do you think it is important to have more than one kind of filtering for cleaning water? Hints: Students will have seen that mechanical filtering removes pollutants that form clumps, such as raw plant and animal waste. But it does little to transform pollutants at the molecular level, which biological filtering and chemical/light treatment do. Both are important to treat the wide range of pollutants that threaten waterways.
2. Can you think of other situations where filtering could be used to solve the many problems of water pollution in our world? Hints: Many answers are possible, ranging industries (e.g., remediation of mine waste), agriculture (e.g., treatment of winery waste), rivers (e.g., flow through constructed wetlands) and homes (e.g., treatment of greywater in gardens). These and many others will be an important part of our sustainable future.