Science Lesson 18:
Building a Tabletop Bioremediation System (TBS)

Hawaii DOE Content Standards:

Science standards: All* (See "A Note to HCPSIII Science Standards" at end of lesson.)

Key concepts:

Cycles of Mater and Energy, Community Structure, Diversity, Health.

Performance indicators: After completing this unit, the students will . . .

- build and populate four tank environments with fish, plants, mud, rock and water
- connect the tanks with silicone tubing and use an aquarium aerator to circulate the water through the system.

Note to the Student:

"When you have completed this lesson you will be able to build and maintain a sustainable aquarium habitat."

Activity at a glance:

Four tanks will be used to model the different ecosystems in a watershed. The tanks will be connected with tubing. An aquarium aerator and the force of gravity will circulate the water through the system. One tank will contain fish, the other three will clean the water using plants and microorganisms.

Time: Building the TBS should take one to two class periods, maintaining and monitoring the system can take five to ten minutes a day.

Prerequisite skills: Students should be familiar with water quality parameters and water quality testing procedures. Also, it is helpful to understand nutrient cycles in particular the nitrogen cycle.

Skills to be introduced:

Students will learn the process of design and will be challenged to monitor and keep a good record of the life of their system.

Assessment:

Students can be assessed on the success of the TBS as well as their response to any challenges or failures. Student data logs and life log journal entries and reflections will play a large part in the evaluation of the learning accomplished through this activity.

Vocabulary:

Ecosystem, water quality, biosphere, interdependence, ecological engineering, nitrogen, phosphorus, dissolved oxygen, dynamic equilibrium.

Materials:

Two to four tanks, silicone sealant, tubing, aquarium aerator, water quality monitoring equipment, plants, mud and rock, fish, log book.

Activity Overview

1. The Tabletop Bioremediation System is built by connecting four tanks of similar shapes and sizes together with silicon tubing and sealant.

   The tanks are filled as follows:

Table 1. TBS Tanks

Tank number	TBS tanks are used as follows:
Tank one	fish
Tank two	one third soil and floating aquatic plants or plants growing hydroponically on a floating raft
Tank three	under gravel filter with air lift and emergent plants
Tank four	additional media and plants or an algae clarifier with screened pipe back to tank one

2. The four tanks are connected by tubing or pipes with the circulation of the system perpetuated by the air lift in tank three. It is also important to connect at least tank four and one with a stand pipe drain to prevent back flow of the system. Stand pipes can be used in the other connections as well but it is not necessary. A stand pipe consists of a drainpipe with a ninety degree angle that will maintain water levels through the system.
3. As the water travels through the system, the nutrients from tank one are processed by the aquatic ecology of bacteria, microorganisms and plants in the following tanks. The water quality improves with the introduction of oxygen and through contact with the biofilm and plant roots which are literally eating the fish waste, or nutrient pollution, dissolved in the water. Because the filtration is biological it will take some time for the system's populations to mature. This beginning phase is very important to the balance of life and may require the removal of some water and or solids, particularly from the fish tank, which should have a drain valve near the bottom of the tank. Smaller mosquito fish should be used in low numbers in all of the tanks for mosquito control.
4. An airlift is built by inserting a compressed air hose into a vertical pipe below the water level where the pipe is suspended in the tank. The pipe should be open on both ends. The top turns ninety degrees and continues at a down slope into the next tank. As the air enters the pipe, it lifts the water in the pipe up over the ninety degree turn and down the gravity run.

The water will lift in bursts and bubbles adding oxygen to the tank. The air line should enter the lift pipe about 6 to 3 inches below the water surface.

5. Once the tanks are connected and populated and water is flowing through the system the performance of the system can be monitored using data sheets or log box that track the following water quality parameters:

Table 2. Water Quality Parameters and their Effects

Water Quality Parameters w/ Ranges	Effects to Ecology of TBS
Temperature 20-30 degrees Celsius	Higher temperature increase microbial and slow fish growth rates.
pH 6-8 pH	An acid or base system indicates a high nutrient level or algae growth.
Dissolved Oxygen 2-8 mg/l or 10-200%	Dissolved oxygen is required for fish, bacteria and microbe respiration.
Turbidity 0-100 NTU or ATF	Turbidity is an indicator of water clarity and suspended solids.
Nitrogen 0-25 mg/l	A primary nutrient is fish waste composition and plant growth.
Phosphorus 0-10 mg/l	A primary nutrient is fish waste composition and plant growth.

6. A measure of water flow rates through the system can be collected by timing the fill rate of a known volume container and using the equation: flow in units per second is equal to unit volume divided by time in seconds. Log books should also detail observations of each tank and note any water changes or refill volumes. To determine the detention for the system and the circulation rate it is important to derive the volume of water held by each tank in the system. Changes in detention and flow will affect water quality.

Cultural Values

Malama
Respect, reciprocity, relationships, and responsibility
Pono
Correct doing
Laulima
Work together for success
Kokua
Taking initiative, service, clean up, maintenance, care taking
Lokahi
Unity, harmony, leadership skills

Adaptations/ Extensions

The scale of the system is entirely up to you. Some individuals have miniaturized the process in a single two liter bottle with no circulation other than evaporation and condensation. Others have expanded the system to include large fish tanks and hydroponics gardens with the circulation run by industrial blowers.

Airlift optimization is another fun aspect of designing the systems. Variation of pipe diameter, depth of air introduction and height of lift are all variables that can be adjusted to change flow. Measurements of flow and drawings of different designs that include specifications can be used for a friendly design competition between students with the goal to maximize flow rates through the TBS tanks.

Connections to other curricula or lessons:

The modeling of the TBS relates to the nutrient, energy and water cycles seen through out the watershed. Connections can be made to the Aquaculture of the Fish ponds, the Hydroponics of the Taro Loi, and the Health of the near shore coral reef and estuarine ecologies.

Background, teaching suggestions, and resources:

The background for this experiment is the aquarium experience. In short, the water gets dirty and green when algae grow from nutrients introduced by the fish and fish food. The goal of this lab is to create your own fish tank filter using the natural systems of the Earth, soil filters, wetland aquatic ecologies and higher plants to capture and process the nutrients and out compete the algae.

The best thing to do is just build it and try to make it work. Adjustments in fish numbers and feed amount will greatly reduce the rate of pollution. In contrast not circulating the water will result in a quick algae bloom. See if the system is responsive enough to deal with changes in these variables and time its return to equilibrium. You can always change the water and start fresh, but remember to detail everything in the log book especially the date of major changes and developments.

The more technical resources for this project include the book Dynamic Aquaria and other guides to recirculation aquaculture.

Safety

The mix of water and electricity is always to be treated carefully. Ideally many systems can be run from a single industrial air compressor with each student receiving a compressed air line to run their experiment. If single aerators are to be used make sure to warn students of the risk of electrical shock and prevent spills and contact of water to the aerators or electrical outlets. Also, make certain that the TBS are well supported or preferably built on the floor as they become quite heavy with the addition of water.

A Note to HCPSIII Science Standards Addressed in
"Building a Tabletop Bioremediation System (TBS)"

Standard 1: **Scientific investigation**: Discover, invent, and investigate using the skills necessary to engage in the scientific process.

In this activity the students build aquarium systems that allow innovation, discovery, and scientific modeling. The operation of the aquariums will allow monitoring and experiment design.

Standard 2: **Nature of Science**: Understand that science, technology and society are interrelated.

The natural and engineered systems that clean and maintain water quality are essential to the preservation of life. As students operate the aquariums they will observe the changes, from tank to tank, in water quality.

Standard 3: **Organisms and the Environment**: Understand the unity diversity and interrelationships of organisms including their relationships to cycles of matter and energy in the environment.

The forms of life that inhabit the aquariums are interdependent for both food and waste processing. The waste of the fish becomes the food for the bacteria, microorganisms and plants that in turn provide food for the fish. Creating a delicate balance between ecosystems that models the natural world.

Standard 4: **Structure and Function in Organisms**: Understand the structures and functions of living organisms and how organisms can be compared scientifically.

Fish and plants are the macro organisms that students will work with to maintain organism health through environmental maintenance. In addition a compound microscope can be used to investigate the micro-organism community. An island environment can be added to include terrestrial invertebrates.

Standard 5: **Diversity and Genetics and Evolution:** Understand genetics and biological evolution and their impacts on the unity and diversity of organisms.

The evolution of the aquarium ecology is the opposite of the Earth, where you will start with a maximum population of higher organisms and wait for the micro community to develop and mature. But the idea that niches, resources and habitats, create opportunities for organisms to fit into, survive and reproduce, is central to the idea of evolution.

Standard 6: **Nature of Matter and Energy**: Understand the nature of matter and energy forms of energy including waves and energy transformations and their significance in understanding the structure of the universe.

The energy required to sustain life comes from the sun and is conserved and cycled as chemical bonds that are created through the metabolism of life. There are many energy paths in the TBS to be investigated.

Standard 7: **Force and Motion**: Understand the relationship between force mass and motion of objects and know the major natural forces gravitational, electrical, and magnetic.

The aerator introduces technology and the engineered part of the project and represents the Earths stored solar energy in natural systems, wind, rivers, ocean, and rain, as it provides the circulation of the system. The use of compressed air in an airlift to pump the water is a low energy way of circulating water within an engineered system.

Standard 8: **Earth and Space Science**: Understand the Earth and its processes, the solar system and the universe and its contents.

The maintenance of the dynamic ecological balance of the film of life that inhabits the planet is modeled by the interaction and interdependence of the life and chemistry in tanks of the Tabletop Bioremediation System.