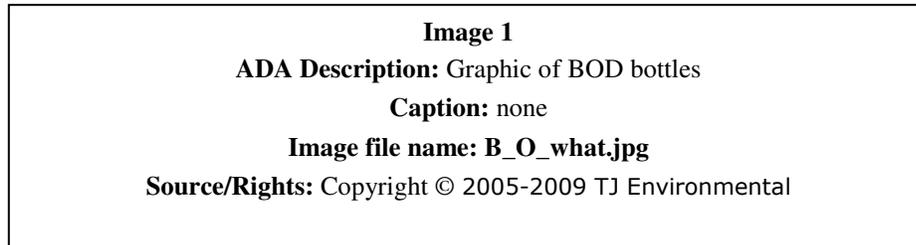




B. O. What?

Subject Area(s) Life Science, Biology
Activity Title B.O. What? (Biological Oxygen Demand – B.O.D.)
Header



Grade Level 5 (6-8)
Activity Dependency None
Time Required 45 minutes
Group Size 2
Expendable Cost per Group US\$1

Summary

Students use a simple experiment, activating yeast in a bottle to simulate biological oxygen demand (BOD), a water quality indicator that uses a chemical procedure for determining how fast biological organisms use up oxygen in a body of water to establish how polluted it is. Students measure by how quickly a balloon capping the bottle inflates and make observations until it stops inflating. Yeasts require oxygen for cellular respiration, the process in which they metabolize energy from nutrients (sugar) and then waste products including carbon dioxide – the gas that blows up the balloon.

Engineering Connection

Environmental engineers use science and engineering principles to protect human and environmental health. One way they do this is by managing hazardous waste released into the environment. Wastewaters are generated by many industrial processes. Before they can be released into a receiving stream, where animals may live or humans may use for water or food, they must be treated and tested. Engineers use BOD as an indicator of water quality to determine

whether or not a treated wastewater will adversely affect fish or aquatic plant life, which need oxygen to live.

Engineering Category

(1) relates science concept to engineering

Keywords

Water quality, BOD, oxygen demand, dissolved oxygen, wastewater, yeast, carbon dioxide, respiration

Educational Standards

State science: 3.1.7.A p. 18,
3.7.7.B p. 68,
3.3.7.A p. 36,
4.1.7.C p. 86,

Pre-Requisite Knowledge

Students should be aware that aquatic plants like duckweed, elodea and algae provide oxygen for animals in the water through photosynthesis.

Learning Objectives

After this activity, students should be able to:

- Explain one way that engineers protect aquatic environments
- Identify the physical characteristics of a stream and how these characteristics determine the type of organisms found in an aquatic environment
- Explain the flows of energy through an aquatic ecosystem
- Use evidence to explain how diversity affects the ecological integrity of natural systems – pond of slow moving stream

Materials List

Each group needs:

- 1 Packet of dried yeast
- Teaspoon
- Warm water
- Sugar
- Clear plastic bottle (an empty soda or water bottle)
- 1 or more balloons

Introduction / Motivation

Where do we get our water? [Allow students to give answers like the tap, a water treatment plant, etc] Most of the source water used by a large city comes from streams and rivers. Many

industrial plants exist along the banks of rivers and streams too and after they treat there wastewater they discharge it into the receiving waters. Environmental engineers test this water to determine it's oxygen depleting potential using a BOD test. In this test they use microorganisms to measure how much oxygen is used in a certain amount of time. This informs them about how much oxygen-demanding material is in the wastewater. Too much oxygen demanding material poses a threat to aquatic life and humans using the water or the stream for food.

Today we're going to use yeast (a primarily aerobic microorganism) to perform a similar test. Through the process of respiration yeast use oxygen and excrete carbon dioxide and other waste products. In order to get energy, all organisms (i.e. plants, bacteria, animals, yeast, etc.) respire. They internally burn sugars back into carbon dioxide gas which is then released into the atmosphere. We can use yeast in a solution of sugar and water to show this.

Vocabulary / Definitions

Word	Definition
aerobic	requiring the presence of air or free oxygen for life
BOD	biochemical oxygen demand; a water quality indicator that uses a chemical procedure for determining how fast biological organisms use up oxygen in a body of water to establish how polluted it is
respiration	the act of respiring; inhalation and exhalation of air; breathing.

Procedure

Background :

Biochemical Oxygen Demand or Biological Oxygen Demand (BOD) is a chemical procedure for determining how fast biological organisms use up oxygen in a body of water. It is used in water quality management and assessment, ecology and environmental science. BOD is not an accurate quantitative test, although it could be considered as an indication of the quality of a water source.

BOD can be used as a gauge of the effectiveness of wastewater treatment plants. It is listed as a conventional pollutant in the U.S. Clean Water Act.

Most pristine rivers will have a 5-day BOD below 1 mg/L. Moderately polluted rivers may have a BOD value in the range of 2 to 8 mg/L. Municipal sewage that is efficiently treated by a three-stage process would have a value of about 20 mg/L or less. Untreated sewage varies, but averages around 600 mg/L in Europe and as low as 200 mg/L in the U.S., or where there is severe groundwater or surface water infiltration. (The generally lower values in the U.S. derive from the much greater water use per capita than in other parts of the world.)

BOD measures the rate of oxygen uptake by micro-organisms in a sample of water at a temperature of 20°C and over an elapsed period of five days in the dark.

There are two recognized methods for the measurement of BOD.

Dilution method: To ensure that all other conditions are equal, a very small amount of micro-organism seed is added to each sample being tested. This seed is typically generated by diluting activated sludge with de-ionized water. The BOD test is carried out by diluting the sample with oxygen saturated de-ionized water, inoculating it with a fixed aliquot of seed, measuring the dissolved oxygen (DO) and then sealing the sample to prevent further oxygen dissolving in. The sample is kept at 20 °C in the dark to prevent photosynthesis (and thereby the addition of oxygen) for five days, and the dissolved oxygen is measured again. The difference between the final DO and initial DO is the BOD. The apparent BOD for the control is subtracted from the control result to provide the corrected value.

The loss of dissolved oxygen in the sample, once corrections have been made for the degree of dilution, is called the BOD₅.

BOD can be calculated by:

- Undiluted: Initial DO - Final DO = BOD
- Diluted: ((Initial DO - Final DO) - BOD of Seed) x Dilution Factor

Since all natural waterways contain bacteria and nutrient, almost any waste compounds introduced into such waterways will initiate biochemical reactions. Those biochemical reactions create what is measured in the laboratory as the Biochemical Oxygen Demand (BOD).

Yeasts are eukaryotic microorganisms classified in the kingdom Fungi, with about 1,500 species currently described. Yeasts are eukaryotic microorganisms classified in the kingdom Fungi, with about 1,500 species currently described; they dominate fungal diversity in the oceans. Most reproduce asexually by budding, although a few do so by binary fission.

The yeast species *Saccharomyces cerevisiae* has been used in baking and fermenting alcoholic beverages for thousands of years. It is also extremely important as a model organism in modern cell biology research, and is the most thoroughly researched eukaryotic microorganism. Researchers have used it to gather information into the biology of the eukaryotic cell and ultimately human biology.

Yeasts are chemoorganotrophs as they use organic compounds as a source of energy and do not require sunlight to grow. The main source of carbon is obtained by hexose sugars such as glucose and fructose, or disaccharides such as sucrose and maltose. Some species can metabolize pentose sugars like ribose, alcohols, and organic acids. Yeast species either require oxygen for aerobic cellular respiration (obligate aerobes), or are anaerobic but also have aerobic methods of energy production (facultative anaerobes). Unlike bacteria, there are no known yeast species that grow only anaerobically (obligate anaerobes). Yeasts grow best in a neutral or slightly acidic pH environment.

Yeasts will grow over a temperature range of 10 °C (50 °F) - 37 °C (99 °F), with an optimal temperature range of 30 °C (86 °F) - 37 °C (99 °F), depending on the type of species (*S. cerevisiae* works best at about 30 °C (86 °F)). Above 37 °C (99 °F) yeast cells become stressed and will not divide properly. Most yeast cells die above 50 °C (122 °F). If the solution reaches

105 °C (221 °F) the yeast will disintegrate. There is little activity in the range of 0 °C (32 °F) - 10 °C (50 °F). The cells can survive freezing under certain conditions, with viability decreasing over time.

(Wikipedia, 2009)

With the Students:

1. Gather the materials needed from the materials station.
2. Stretch your balloon out.
3. Write your name on the bottle with a permanent marker.
4. Open and pour the packet of dried yeast into the clear plastic bottle
5. Fill the bottle $\frac{1}{4}$ with warm water.
6. Add a teaspoon of sugar to the bottle and swirl the bottle around until it is dissolved.
7. Cap the bottle with a balloon by stretching the mouth of the balloon over the mouth of the bottle so that it's fully covered and there are no leaks.
8. Place the bottle with the balloon on it on a warm windowsill or place it into a large basin of warm water.
9. Have the students observe the balloons as they inflate measuring the circumference of the balloons every 5 minutes for about 30 minutes until the balloons appear to stop inflating.
10. Leave a few of the bottles on the window sill for several days (at least 5). Have the students make daily observations.
11. At the end of 5 days, remove the balloons and allow the students to smell the bottles. There will be a very malodorous gas scent that smells like methane and sulfur.

Image



Figure 1

ADA Description: Photo of a plastic water bottle capped with a balloon, with a mixture of yeast, sugar and water. The balloon is being inflated by the carbon dioxide produced by the yeast.

Caption: Figure 1: Example of the experimental bottle made by students.

Image File name: B_O_What_figure1.jpg

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Troubleshooting Tips

If balloons are not inflating in a reasonable amount of time, they may need to be stretched.

Investigating Questions

1. What do you think causes the balloon to inflate?
2. Are the yeasts alive? How do you know?
3. What do you think is happening in the soda bottle? Why?
4. Why do you think is happening during the initial 30 minutes? After several days?

Assessment

Pre-Activity Assessment

None

Activity Embedded Assessment

Have the students answer the investigating questions in their science journals. Have them make a table of the circumferences at each time interval.

Post-Activity Assessment

Have the students graph the circumferences versus the time interval. Ask the students what it means when the graph begins to level off (the balloon is no longer inflating rapidly.) Have them explain what the yeast is doing at this time. Have the students explain what affect a wastewater would have on an ecosystem if they were testing a wastewater instead of sugar water.

Activity Scaling

None

References

See Wikipedia, *Yeast*, <http://en.wikipedia.org/wiki/Yeast> (optional description here) (as of <citation>Apr. 14, 2009, 18:25</citation> GMT).

Wikipedia contributors. Biochemical oxygen demand. Wikipedia, The Free Encyclopedia. April 15, 2009, 00:17 UTC. Available at: http://en.wikipedia.org/w/index.php?title=Biochemical_oxygen_demand&oldid=283896837. Accessed <citation>April 15, 2009</citation>.

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