



The Mexican Underground: Cenotes Floating on a Halocline

by Bill Andrade

*In this episode, Jonathan dives through an underwater cavern called a “cenote” which lies below the rain forest of the Riviera Maya in Mexico’s Yucatan Peninsula. As the dive continues through the underground river toward the sea, the divers eventually reach saltwater. The transition between the fresh groundwater and the seawater create a boundary between the two known as a **halocline**. Being less dense, the freshwater floats on the more dense saltwater. This halocline phenomenon can be easily simulated in the laboratory and allows students to explore the important concept of density in an interesting way.*

Science Lesson: Floating on a Halocline - Based on Webisode 26

Grade Level: 7-8

Time: Three to four (45-50 min) class periods; Pre-lab, Lab, Follow-up Activity

Introduction

The density of water can be affected by temperature and **salinity**. Layers form in the ocean when water with different densities separates. Layers are important as they prevent the mixing of surface and bottom water. They can block the upwelling of nutrients from the bottom and prevent convection from occurring which keeps heat from being distributed to and from deeper water.

A location in the ocean where there is a sharp change in salinity as you go deeper is called a **halocline**. The term comes from the mineral “halite” which is rock salt. A halocline is a boundary between a less dense layer of water with a lower salinity on top of a layer of more dense water with a higher salinity.

*(A location in the ocean where there is a sharp change in **temperature** as you go deeper is called a **thermocline**.)*

Is it possible for an object to reach a certain depth in the ocean where it stops sinking before reaching the bottom? If its density is just right could it float on a halocline? In this activity you will attempt to float a small glass vial (bottle) in a halocline created in a graduated cylinder between two layers of water with different salinities.

Science Standards

National Science Education Standards

Physical Science:

- Properties and changes in properties of matter.

Ocean Literacy Principles

- *Principle #1:* Earth has one big ocean with many features.

Objectives

- Enhance students’ understanding of the property of density and how it is measured.
- To understand that a material’s density affects its ability to float or sink in a fluid.
- Increase students’ understanding that the ocean’s salinity can influence the physical properties of water such as density.
- To gain an understanding of how layers of different densities can form in the ocean.

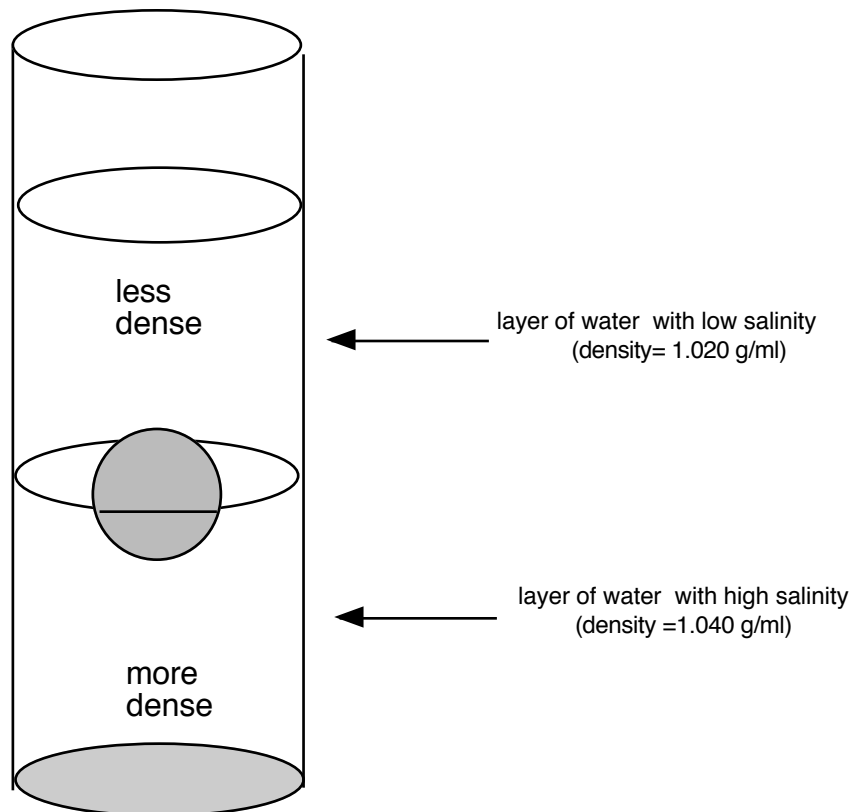


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Do the Math... Pre-Lab Calculations and Questions (continued)

- 4) What is the density of pure water? _____
- 5) In order to sink in pure water, the density of the material must be _____
- 6) A sample of seawater has a density of 1.025 g/ ml.
- a. Is it possible to have an object that would float on this seawater and yet sink in freshwater? _____
- b. What would be the density of this object? _____



In this diagram, a 20 ml ball sank through the top layer of water but it is floating on the bottom layer of water, unable to sink to the bottom of the tube.

- 7) What would be the approximate density of the ball for this to happen? _____
- 8) What would be the approximate mass of the ball? (show your work below)

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Floating on a Halocline: Lab Activity

In this activity you will attempt to float a small glass vial (bottle) in a halocline created in a graduated cylinder between two layers of water with different salinities.

Materials:

For each lab group (2-4 students):

- (2) 100 ml graduated cylinders, dropper, and a small vial (bottle with screw cap).
- Three 250 ml beakers or cups to hold the following fluids:
 - About 100 ml of concentrated saltwater solution. Kosher salt dissolves well and forms a very clear solution. Make a saturated solution.
 - About 100 ml of tapwater.
 - About 50 ml of water colored with food coloring per lab group. This will serve as “ballast water” to sink the vial.
- A gram balance or scale that measures to the nearest 0.1g.
- Optional: a 25 ml graduated cylinder measures to the nearest 0.5 ml.

A small vial floats on a layer of dense salty water after sinking through a layer of less dense water.



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Procedure

Part 1: Density of the layers and forming the halocline

The Bottom Layer... Saltwater

1. Measure the mass of the empty 100 ml graduated cylinder and record it below.

Mass of empty 100 ml grad. cylinder : _____ g

Data Table

Fill in the results from the questions that follow

	Mass (g)	Volume (ml)	Density (g / ml)
BottomLayer		60 ml	
Top Layer	N/A	N/A	1g /ml
Vial			

2. Fill your 100 ml graduated cylinder with **60 ml** of the concentrated saltwater solution.
 Determine the **mass** of this 60 ml of salty water. (show your calculation below and record this in the data table).

3. Determine the **density** of this bottom layer of saltwater (show your calculation below and record this in your data table).

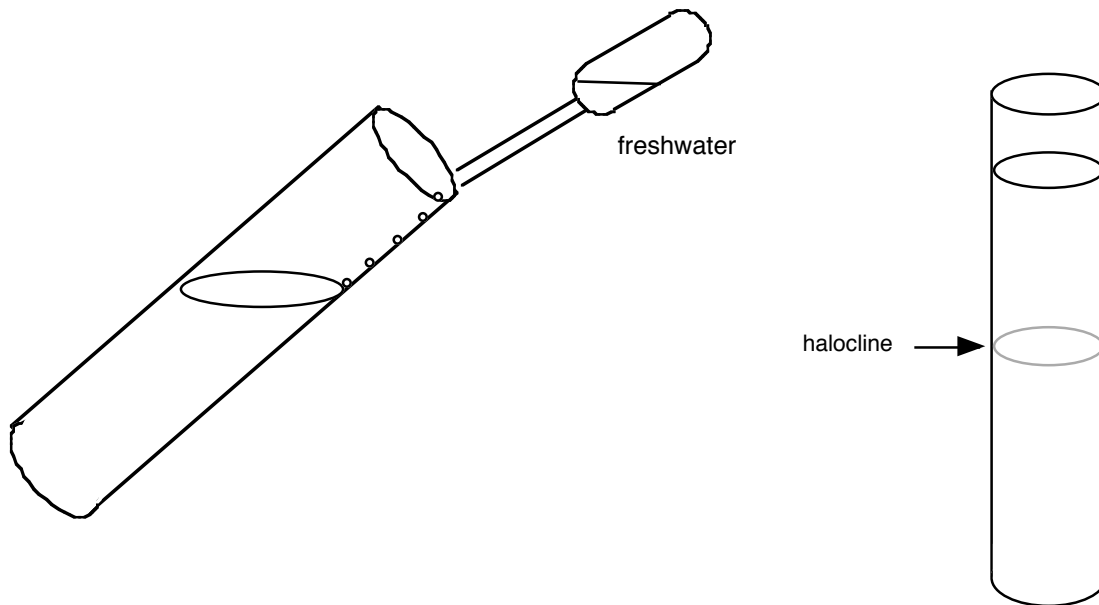
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Procedure (continued)

Forming the top layer and the halocline.

4. Next ... **very, very, VERY slowly**...USING A DROPPER.. add freshwater to the tube.

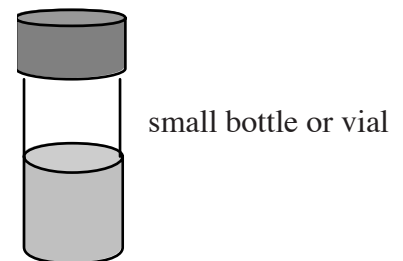
Tilt the graduated cylinder and **SLOWLY** trickle the freshwater down the side of the cylinder until it is nearly full. **THIS MAY TAKE SEVERAL MINUTES. YOU WANT TO AVOID MIXING** of the layers. Since the top layer is freshwater, we will assume a density of about 1 g/ ml.



Part 2: Setting up the vial to float on the halocline

$$\text{Density} = \text{mass} \div \text{volume}$$

Basically you will have to create a vial that has a density in between that of the two layers you formed in your graduated cylinder.



5. Determine the density that you want your vial to have so that it will sink through the top layer and float on the bottom layer, on the halocline. Record this in the data table.
6. Find the volume of the vial... **THIS NEEDS TO BE PRECISE!!!!**
To find the volume of the vial you need to fill it with colored water and determine the volume of water that it displaces in your other graduated cylinder. (If you have a 25 ml graduated cylinder, measure the vial to the nearest 0.5 ml). Record it in the data table.

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Procedure (continued)

7. Determine the mass of your vial that would give it a density that would allow it to sink through the top layer and float on the halocline. About half-way between 1 g/ml and the density of the bottom saltwater layer. Record this in the table.

Since $\text{Density} = \text{mass} \div \text{volume}$ then $\text{Density} \times \text{Volume} = \text{Mass}$
(show your calculation)

8. Place the vial and cap (don't forget the cap) on the balance. Then add or take out colored water from the vial with a dropper until you get the mass that will give you its desired density.

WHEN YOU'RE ALL SET, DROP THE VIAL INTO THE GRADUATED CYLINDER.

If calculated correctly the vial should sink through the top layer,
resting on top of the saltwater layer at the halocline.



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Follow up Lesson Activity

Optical Phenomena in a Halocline

After reviewing the Episode on Cenotes, students can simulate the blurry, optical conditions that the divers experienced as they reached the halocline on their dive. Pour saltwater into a clear container of freshwater to see this phenomenon.

Light passes through saltwater at a slightly lower speed than in the less dense freshwater, distorting the visual properties of the water.

This can be related to the wavy look in the air as less dense hot air mixes with colder air; an effect often seen above hot pavement or in the air above a flame. This is often mistakenly interpreted as “heat rising” when in actuality it is hot air rising. Mixing air of different densities distorts light, just as mixing water with different densities gives water a swirly appearance.

Haloclines and Climate

Is Global Warming Changing the Arctic? Oceanus Magazine, Woods Hole Oceanographic Institute.

<http://www.whoi.edu/oceanus/viewArticle.do?id=9206&archives=true>

A halocline below the sea ice of the Arctic is formed as salt is “squeezed” out of the water as sea ice forms. This addition of salt to the cold surface water creates a dense salty layer of water which forms a protective boundary between warmer salty water of the Atlantic and the Arctic sea ice.

With global warming, continued disappearance of Arctic sea ice may cause the Arctic halocline to shrink allowing heat from the Atlantic to reach the sea ice, thus speeding up the shrinking of the ice pack and disrupting the ecosystem of the Arctic Ocean.

Haloclines and Upwelling of Nutrients

Demonstrate how layering in the ocean prevents vertical movement such as the upwelling of nutrients from the bottom, which nourish phytoplankton and thus begin ocean food chains.

Create a halocline in a graduated cylinder as in “Floating on a Halocline.” Add food coloring to the surface water. Notice how the two layers stay separated. The freshwater layer floats on the saltwater layer, blocking any vertical mixing.

Students can experiment different ways to mix the layers (without actually inverting the cylinder). For example: what would happen if we add ice to the water? Colder water is more dense.

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Answer Guide: Do the Math... Pre-Lab Calculations and Questions

1) If a 12 ml object has a density of 1.4 g / ml . What would be its mass?

$$\begin{aligned} \text{Mass} &= \text{Volume} \times \text{Density} \\ \text{Mass} &= 12 \text{ ml} \times 1.4 \text{ g/ml} \\ \text{Mass} &= \underline{16.8 \text{ grams}} \end{aligned}$$

2) How much space would a 10 gram object up take up with a density of 2.5 g/ ml?

$$\begin{aligned} \text{Volume} &= \text{Mass} \div \text{Density} \\ \text{Volume} &= 10 \text{ g} \div 2.5 \text{ g/ml} \quad (\text{Volume} = 10 \text{ g} \times 1 \text{ ml} / 2.5 \text{ g}) \\ \text{Volume} &= 10 \text{ ml} / 2.5 \\ \text{Volume} &= \underline{4 \text{ ml}} \end{aligned}$$

3) If I needed an 8 ml object to have a density of 1.02 g/ml how much mass would it have?

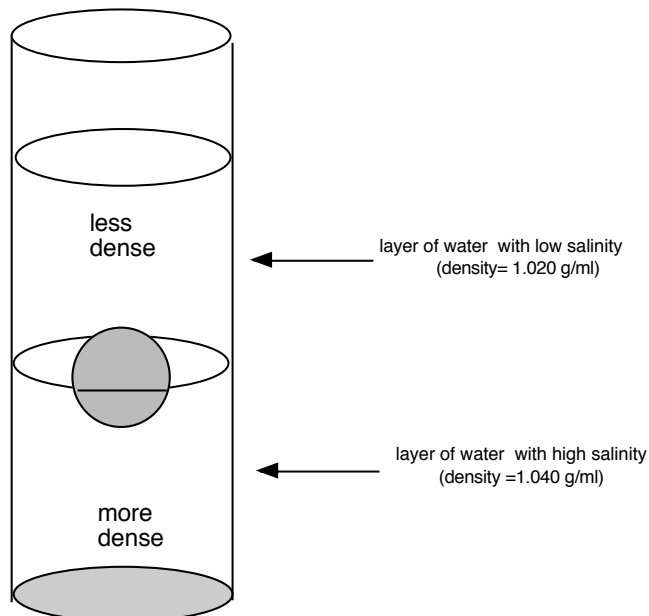
$$\begin{aligned} \text{Mass} &= \text{Volume} \times \text{Density} \\ \text{Mass} &= 8 \text{ ml} \times 1.02 \text{ g/ml} \\ \text{Mass} &= \underline{8.16 \text{ grams}} \end{aligned}$$

4) What is the density of pure water? *1 gram / ml*

5) In order to sink in pure water, the density of the material must be greater than the density of water, so greater than 1g/ml.

6) A sample of seawater has density of 1.025 g/ ml. Is it possible to have an object that would float on this seawater and yet sink in freshwater? Yes

7) What would be the density of this object? a density between 1.0 g/ml and 1.025 g/ml... approximately 1.1 g/ml.



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Answer Guide: Do the Math...Pre-Lab Calculations and Questions (continued)

7) What would be the approximate density of the ball for this to happen? 1.010 g/ml

8) What would be the approximate mass of the ball? (show your work below)

$$\text{Mass} = \text{Volume} \times \text{Density} \quad \text{Mass} = 20 \text{ ml} \times 1.010 \text{ g/ml} \quad \text{Mass} = 20.2 \text{ g}$$

Answer Guide with Sample Data: Floating on a Halodine Lab Activity

1. Measure the mass of the empty 100 ml graduated cylinder and record it below.

Mass of empty 100 ml grad. cylinder : 40.8 g

2. Fill your 100 ml graduated cylinder with 60 ml of the concentrated saltwater solution.

Determine the mass of this 60 ml of salty water.

<u>103.7 g</u>	-	<u>40.8 g</u>	=	<u>62.9 g</u>
mass of cylinder plus 60ml of saltwater		mass of empty cylinder		mass of 60ml of saltwater

3. Determine the density of this bottom layer of saltwater.

$$\text{Density} = \text{Mass} \div \text{Volume} \quad \text{Density} = 62.9\text{g} \div 60 \text{ ml} = \underline{1.048 \text{ g/ml}}$$

See the Data Table for answers to 5, 6 and 7

5. Determine the density that you want your vial to have so that it will sink through the top layer and float on the bottom layer, on the halocline. Record this in the data table.

6. Find the volume of the vial. THIS NEEDS TO BE PRECISE!!!! To find the volume of the vial you need to fill it with colored water and determine the volume of water that it displaces in your other graduated cylinder.

7. Determine the mass of your vial that would give it a density that would allow it to sink through the top layer and float on the halocline. About half-way between 1 g/ml and the density of the bottom saltwater layer.

Since $\text{Density} = \text{Mass} \div \text{Volume}$ then $\text{Density} \times \text{Volume} = \text{Mass}$

$$\text{Mass} = \text{Desired Density} \times \text{Volume of Vial}$$

$$\text{Mass} = 1.02 \text{ g/ml} \times 8 \text{ ml} = \underline{8.16 \text{ g}}$$

	Mass (g)	Volume (ml)	Density (g / ml)
BottomLayer	62.9 g	60 ml	1.048 g/ml
Top Layer	N/A	N/A	1g /ml
Vial	8.16 g	8 ml g	~1.02 g/ml