Effects of Temperature & Salinity on Density & Stratification

Overview:

Stratification refers to the arrangement of water masses in layers according to their densities. Water density increases with depth, but not at a constant rate. In open ocean regions (with the exception of polar seas), the water column is generally characterized by three distinct layers: an upper mixed layer (a layer of warm, less-dense water with temperature constant as a function of depth), the thermocline (a region in which the temperature changes rapidly with increasing depth), and a deep zone of dense, colder water in which density increases slowly with depth.

Stratification forms an effective barrier for the exchange of nutrients and dissolved gases between the top, illuminated surface layer where phytoplankton can thrive, and the deep, nutrient-rich waters. Stratification therefore has important implications for biological and biogeochemical processes in the ocean. For example, periods of increased ocean stratification have been associated with decreases in surface phytoplankton biomass. In coastal waters, prolonged periods of stratification can lead to hypoxia (low oxygen), causing mortality of fish, crabs, and other marine organisms.

This activity compares salt and fresh water, demonstrating that fluids arrange into layers according to their densities.

Materials:

- Rectangular tank with a divider (can be ordered from sciencekit.com)
- 2 Beakers (preferably with pour spouts)
- 2 contrasting colors of food coloring
- Tap water (warm and room temperature)
- Ice
- Bottle containing pre-made salty water solution: Combine approximately 75 grams (g) salt dissolved in 1 liter (L) of water:
    - Note: Kosher salt yields a clearer solution than table salt, but either can be used

Instructions – Part One - Salinity:

1. With the divider placed in the tank, fill one side of the container with the fresh water.
2. Fill the other side of the tank with the prepared salty water.
    a. Note: You may need to shake the salt-water container to make sure the solution remains mixed before adding it to the tank.
3. Add a few drops of food coloring to each side of the tank.

    Question: What do you predict will happen when you remove the divider between the compartments? Explain your reasoning.

4. Calculate the approximate density of both water masses.

    The density of regular fresh water is 1 g/cm^3. If you began with a liter of fresh water and added 75 g of salt, what is the density of the salt water?

5. Test your prediction by removing the tank divider (try not to disturb the tank as you do this).

    Questions: What happens? Which water mass travels to the bottom of the container? Why?

Instructions – Part Two - Temperature:

1. Empty the tank chamber and put the divider back between the two sections.
2. Fill one side of the tank with warm tap water.
3. Fill the other side of the tank with water cooled by ice (do not pour any ice into the tank).
4. Add a few drops of food coloring to each side of the tank.

   Question: What do you predict will happen when you remove the divider between the compartments? Explain your reasoning.

6. Test your prediction by removing the tank divider (try not to disturb the tank as you do this).

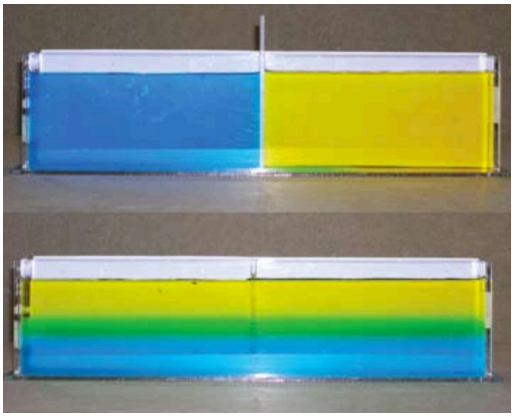
   Questions: What happens? Which water mass travels to the bottom of the container? Why?

7. Place your fingertips on top of the fluid surface and slowly move your hand down toward the bottom of the tank.

   Question: Can you feel the temperature change as you lower your fingers into the tank?

Explanation:

This activity demonstrates that fluids arrange into layers according to their densities. The two "water masses" (see image at right)—salt (blue) vs. fresh (yellow), or cold (blue) vs. warm (yellow)—are initially separated by the tank's divider. When the divider is removed, the denser water (salty water or cold water) sinks to the bottom of the container and the less-dense water (fresh or warm water) floats above, forming a stratified column. This density-driven motion is what drives ocean circulation across the Earth's ocean.



Tank before (top) and after removal of divider (bottom).

Extension:

Given what you have learned about salinity, temperature and stratification, consider the following scenario:

Question: How might the effects of climate change, such as warming and melting of sea ice, affect the vertical structure of the water column? Discuss possible scenarios with your group.

Activity adapted from:
Karp-Boss, L., E. Boss, H. Weller, J. Loftin, and J. Albright (2009). Teaching Physical Concepts in Oceanography: An Inquiry Based Approach. Oceanography 22(3), supplement, 48 pp.
Available for download at: http://www.tos.org/hands-on/teaching_phys.htm