WHAT HAPPENS TO OCEAN WATER WHEN IT FREEZES?

Background:

The freezing temperature of water depends on the amount of dissolved salts (salinity). Normal ocean water, with a salinity of about 3.4%, begins to freeze when temperatures reach about -1.9°C. At its maximum extent in the winter, sea ice covers about 19 million square kilometres of the Southern Ocean near Antarctica. Approximately 80% of this ice melts each summer, contributing to the global mixing of ocean water.

Vertical mixing of ocean water, known as ‘o overturning circulation’ or ‘thermohaline circulation’, is an important aspect of the global current system that is driven primarily by rising and sinking of water masses at high latitudes in both the northern and southern hemispheres.

The seasonal formation and melt of sea ice is the dominant factor controlling the salinity and density of surface ocean waters in the polar regions. Salt is expelled as the ocean water freezes to form sea ice. This creates dense brine that sinks and flows down the continental shelf of Antarctica to form Antarctic Bottom Water – the densest water in the open ocean. This water flows outward from the Southern Ocean and through other ocean basins as part of the global ocean circulation ‘conveyor belt’ that distributes heat, nutrients and gases around the world. There are only a few areas in the world where this dense water is formed.

Sea ice extent in the Arctic has been declining rapidly over the past few decades. Although there are currently no clear trends in the extent of Antarctic sea ice, with the exception of the area around the Antarctic Peninsula, numerous climate models agree that Antarctic sea ice will decline in the future. A decrease in the amount of sea ice may slow the overturning circulation, decreasing the ocean’s ability to absorb atmospheric carbon dioxide and affecting the distribution of heat around the globe.

Activity time: 20-30 minutes + freezing time
Part I: MAKING SEA ICE

Materials Needed:
- plastic soft drink bottle with the top part cut off
- insulated soft drink cooler or other insulation to wrap around bottle
- fresh water
- salt water (use 2 tsp salt per litre of water)
- hydrometer¹ or multi-meter
- thermometer
- freezer

¹see below for directions to make your own hydrometer

Procedure:
1. Fill the soft drink bottle 2/3 full with plain water at room temperature.
2. Measure and record the water temperature.
3. Test the salinity of the water using either the hydrometer* or the multimeter* and record the results.
4. Add 2 teaspoons salt per litre of water and stir until dissolved. Test the salinity again and record.
5. Put the bottle in the insulated cooler or other insulator and place in the freezer.
6. Leave the bottle in the freezer until about 2 centimetres of ice has formed on the top of the water. Freezing time will vary, but should take between 4-6 hours.
7. Remove the bottle from the freezer, squeeze slightly and remove the ‘sea ice’. Place the ice in a separate container.
8. After you remove the ice, allow the remaining water to warm to room temperature. Test the salinity and record the results.
9. Allow the ice to melt, warm to room temperature and test the salinity of the resulting water.

Discussion Questions:
1. To represent the formation of sea ice, why did you need to insulate the container from the bottom and sides before you put it in the freezer?
2. Why did you have to have all your water samples at room temperature when you tested them?
3. Which sample had the highest salinity? Which had the lowest? Why?
*NOTE: Neither the hydrometer nor the multimeter measures salinity directly.

A **hydrometer** measures the *density* of a liquid. Density is a measurement of the quantity of matter contained in a given volume and is usually expressed as grams per cubic centimetre. When salt is dissolved in water, the volume of the water does not change, but the density increases. **Buoyancy** is a function of density – it is the ability of an object to float on a liquid because of the greater density of the liquid. The higher the salinity, the denser the liquid and the higher the hydrometer will float. You can purchase hydrometers in stores that sell aquarium equipment.

![Hydrometer Image]

A **multimeter**, set on the ohm scale, measures *electrical resistance*, which is a measurement of properties that limit the ability of a substance to conduct electricity. Salt in water decreases the resistance, which results in a lower reading on the scale. Therefore, the more saline the water, the lower the reading on the meter. Keep the two probes an equal distance apart when making comparative measurements and hold the probes still until the numbers on the scale stop moving. Inexpensive multimeters are available at electronics supply shops.

![Multimeter Image]

**Making a hydrometer:**

Attach a small piece of modelling clay or plasticine to one end of a drinking straw. Make sure the clay completely seals the straw so that no water can get in. Adjust the amount of clay so that the hydrometer floats upright with about 5 cm out of the water. If it sinks to the bottom, remove some clay. If it tilts to one side, add more clay.

![Hydrometer Clay Image]

To calibrate your hydrometer, place it in a deep clear container (such as the bottom of a 2-litre soft drink bottle) of fresh water. Grab the straw at the water line and pull it out of the water Draw a line on the straw at this point with a permanent marker. This represents the density of fresh water. Use the same volume of liquid, at the same temperature, when you test your other samples.
Part II: CREATING CURRENTS

Materials Needed:

☐ aquarium tank or clear plastic box
☐ water and salt
☐ food colouring
☐ water remaining after you made your sea ice in Part I

Procedure:

1. Fill the clear plastic container or aquarium about 2/3 full with salt water (the salinity should be the same as the salinity of the water you used in Part I).
2. Add 3-4 drops of food colouring to the brine that was left after you made your ‘sea ice’ in Part I.
3. Pour this coloured water slowly and gently down the side at one end of the plastic container or aquarium and observe what happens.

Questions:

Other things to try:

1. Try pouring coloured fresh water into the container and see what happens.
2. Try changing the temperature of the brine and see what happens.

Find other fun activities through the sea ice link at www.ipy.org.