Acoustic Properties of Seawater (General)

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Objective:

To discover how the acoustic properties of water affect the transmission of sound.

Vocabulary Words:

Frequency - in physics, the number of waves that pass a fixed point in unit time; also, the number of cycles or vibrations undergone during one unit of time by a body in periodic motion. A body in periodic motion is said to have undergone one cycle or one vibration after passing through a series of events or positions and returning to its original state. *See also* angular velocity; simple harmonic motion.

Sound wave - a wave that is formed when a sound is made and that moves through the air, or other medium such as water, and carries the sound to your ear.

Refraction - in physics, the change in direction of a wave passing from one medium to another caused by its change in speed. For example, waves in deep water travel faster than in shallow. If an ocean wave approaches a beach obliquely, the part of the wave farther from the beach will move faster than that closer in, and so the wave will swing around until it moves in a direction perpendicular to the shoreline. The speed of sound waves is greater in warm air than in cold. At night, air is cooled at the surface of a lake, and any sound that travels upward is refracted down by the higher layers of air that still remain warm. Thus, sounds, such as voices and music, can be heard much farther across water at night than in the daytime.

SOFAR channel - in full **sound fixing and ranging channel**, zone of minimum sound speed in the oceans that occurs at depths of approximately 1,000 metres (3,300 feet). In this region, pressure, temperature, and salinity combine to inhibit the movement of sound through the water medium. If a sound is generated by a point source in the SOFAR zone, it becomes trapped by refraction. Dispersed horizontally rather than in three directions, the sound is able to travel slowly over great distances. Hydrophones lowered to this depth many kilometres from the origin of the sound are able to detect the sound pulse. The difference in arrival time of the pulse at separate listening posts may be used to triangulate the position of the pulse source.

Hydrophone (sonobuoy) - device for converting sound waves into electrical signals, similar in operation to a microphone but used primarily for detecting sound waves from an underwater source, such as a submarine. Usually an array of hydrophones is employed to pinpoint the source: the array is connected to an electrical circuit that permits the phase differences of the sound waves at the various hydrophones to be compensated electrically. Thus, the whole array can be “steered” in the direction of the sound source without actual motion of the hydrophones.

Noise pollution

Materials:

Background Information:

Water is an excellent conductor of sound, considerably better than air. The attenuation of sound by absorption and conversion to other energy forms is a function of sound frequency and the properties of water.

High-pitched sounds are absorbed and converted to heat faster than low-pitched sounds. Sound velocity in water is determined by temperature, salinity, and pressure.

In the oceans the speed of sound varies between 1,450 and 1,570 metres (about 4,760 to 5,150 feet) per second. It increases as the water gets colder, saltier, and deeper.

The greatest changes in temperature and salinity with depth that affect the speed of sound are found near the surface. Changes of sound speed in the horizontal are usually slight except in areas where abrupt boundaries exist between waters of different properties. The effects of salinity and temperature on sound speed are more important than the effect of pressure in the upper layers. Deeper in the ocean, salinity and temperature change less with depth, and pressure becomes the important controlling factor.

In regions of surface dilution, salinity increases with depth near the surface, while in areas of high evaporation salinity decreases with depth. Temperature usually decreases with depth and normally exerts a greater influence on sound speed than does the salinity in the surface layer of the open oceans. In the case of surface dilution, salinity and temperature effects on the speed of sound oppose each other, while in the case of evaporation they reinforce each other, causing the speed of sound to decrease with depth. Beneath the upper oceanic layers the speed of sound increases with depth.

If a sound wave (sonic pulse) travels at a right angle to these layers, as in depth sounding, no refraction occurs; however, the speed changes continuously with depth, and an average sound speed for the entire water column must be used to determine the depth of water. Variations in the speed of sound cause sound waves to refract when they travel obliquely through layers of water that have different properties of salinity and temperature. Sound waves traveling downward and moving obliquely to the water layers will bend upward when the speed of sound increases with depth and downward when the speed decreases with depth. This refraction of the sound is important in the sonar detection of submarines because the actual path of a sound wave must be known to determine a submarine's position relative to the transmitter of the sound. Refraction also produces shadow zones that sound waves do not penetrate because of their curvature.

At depths of approximately 1,000 metres, pressure becomes the important factor: it combines with temperature and salinity to produce a zone of minimum sound speed. This zone has been named the SOFAR (sound fixing and ranging) channel. If a sound is generated by a point source in the SOFAR zone, it becomes trapped by refraction. Dispersed horizontally rather than in three directions, the sound is able to travel for great distances. Hydrophones lowered to this depth many kilometres from the origin of the sound are able to detect the sound pulse. The difference in arrival time of the pulse at separate listening posts may be used to triangulate the position of the pulse source.

Hearing is an important sensory mechanism for marine animals because seawater is more transparent to sound than to light. Animals communicate with each other over long distances and also locate objects by sending directional sound signals that reflect from targets and are received as echoes. Information about the size of a target is gained by varying the frequency of the sound; high-frequency (or short-wavelength) sound waves reflect better from small targets than low-frequency sound waves. The intensity and quality of the returning signal also provide information about the properties of the reflecting target. Much of the world's oceans are polluted with chaotic sounds from ships, seismic tests, and oil drills, and noise pollution poses a serious problem for marine animals that rely on echolocation in seawater, such as whales and dolphins.

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Activity Instructions:

Conclusion/wrap up:

Further Investigations:

Sources:

Britannica: https://www.britannica.com/science/seawater/Acoustic-properties