Foam on Surface Waters

Why does foam form on lakes, rivers, and streams?

Shoreline foam on Cooking Lake, AB

Surface waters naturally contain dissolved organic compounds. Some of these are surface-active agents or **surfactants** as they are commonly called. Like soap, surfactants lessen the **surface tension** of water. Diminished surface tension allows air bubbles to persist at the water's surface. Vigorous mixing of surface water by waves, water currents, rapids and even boating activity generates bubbles that persist and build up as foam. In lakes, reservoirs and ponds, foam collects along windward shores or may form long, evenly-spaced lines, called 'windrows', in open water areas resulting from water currents. In rivers and streams, foam is often found downstream of rapids, in back-currents (eddies) or below waterfalls and dams.

Where do surfactants come from?

Plants and algae inhabiting watersheds and surface waters produce many organic compounds, some of which have surfactant properties. Natural surfactants include carboxylic fatty acids derived from plant lipids and lignins from wood, to name a few. These are released into water and contribute to a large variety of soluble organic material collectively referred to as dissolved organic carbon (DOC). Though some DOC is produced within surface waters, the primary source is usually from the surrounding watershed. High DOC concentrations in lakes, wetlands and streams can impart a 'tea' color to the water. Brown-water lakes, ponds and streams occur throughout much of Alberta, but are most prevalent in areas dominated by peat or muskeg, such as in northern Alberta.

While mostly natural, some foam is caused by synthetically produced surfactants released to surface waters. Synthetic surfactants are widely used in household cleaning products (detergents), cosmetics and personal care products (shampoo and toothpaste for example). Early detergents contained branch-chained alkylbenzene sulfonate surfactants, which are non-biodegradable and resulted in extremely persistent foam accumulating below sewage treatment plants and other wastewater outfalls. Moreover, these also contained phosphate softeners to enhance the effectiveness of surfactants by reducing water hardness. Unfortunately, phosphates ultimately contributed to nutrient enrichment of surface waters (eutrophication) and the proliferation of cyanobacterial (blue-green algal) blooms and aquatic plants (macrophytes). To solve these problems, modern-day detergents were modified to limit or exclude phosphates and contain biodegradable linear alkylbenzene sulfonate surfactants, such as sodium or ammonium laureth or lauryl sulfate.

Surfactants are also used by many industries as wetting agents, dispersants, de-foamers, de-inkers, antistatic agents, and in paint and protective coatings, pesticides, leather processing, plastics and elastomer manufacturing, and oil extraction and production. Unlike modern-day detergent surfactants, many of these are very persistent in the environment, can 'bio'accumulate in organisms and humans and have various biological consequences. Alkylphenol ethoxylates for example, which continue to be widely used by industry, have been shown to have estrogenic properties eliciting reproductive effects in fish and other organisms. Similarly, perfluorooctanoic acid and perfluorooctane sulfonate, which were commonly used in the production of stain resistant and nonstick coatings including Scotchguard and Teflon, also have estrogenic and carcinogenic properties. Regardless of the new formulations, synthetic surfactants usually cause foam to accumulate near the source and not over large distances, and generally not in relation to rainstorms or windy conditions. In contrast to natural foam, fresh detergent foam will be white and may have a noticeable sweet or perfume scent. In waters receiving a range of treated wastewaters, such as downstream of our major cities and industries, both synthetic and natural compounds may be present that can contribute to the formation of foam.

Close-up view of foam

How do surfactants affect the surface tension of water?

Surface tension is an important property of water. It results from cohesion – the attraction of water molecules for one another. Cohesion gives water the ability to bead up or form droplets and contributes to the formation of waves and currents, which play an important role in the distribution of temperature, dissolved gases, nutrients, microorganisms and plankton. At the surface of a body of water (i.e. the air-water interface), cohesion creates a thin 'film' or tension. This allows insects like water striders to 'walk' on water and forms a special habitat for some aquatic organisms adapted to living on this surface film (mosquito larvae for example).

Surfactants are amphipathic molecules, that is, they contain both hydrophilic (water-attracting) and hydrophobic (water-repelling) components. The hydrophilic component can form bonds with water and competes with other water molecules as they attract one another. In this manner, surfactants reduce the overall attraction between water molecules, thus diminishing surface tension. Lower surface tension causes water to become more 'fluid' or elastic, and when air is vigorously mixed in, the resulting bubbles can persist for some time. This phenomenon is easily demonstrated by running tap water into a sink or tub. The tap water and air mix vigorously, creating bubbles that last only moments before bursting. Now add soap, a surfactant, to the tub and, instead of bursting immediately, the bubbles persist and build up as foam.

How is foam produced?

Foam below beaver dam on AB stream

A reduced surface tension due to the presence of surfactants is only one half of the recipe for the production of foam. Equally important is the incorporation of air to form bubbles. In lakes, ponds and reservoirs, wind-induced currents and waves cause turbulent mixing of air and water. Boating activity may also contribute to this turbulence. In these environments, foam will often collect on windward shores and coves where waves break. In open water, foam may form along a series of helical currents called Langmuir circulations. Langmuir circulations typically run parallel with the wind, and result in evenly-spaced and repetitive streaks, or windrows. Like shoreline foam, these usually occur during extended windy periods. In streams and rivers foam tends to collect at the end of rapids, in backwater eddies or below waterfalls and dams. Foaming will often increase during runoff from snowmelt or rainstorms that transport the surfactants to surface waters. Natural foam has a somewhat earthy or fishy aroma and at first can be white, but generally turns off-white or brown over time. Foam can persist for some time and may accumulate locally, such as downstream of beaver dams.

What is the influence of water hardness on foaming?

Water hardness may influence the amount of foam that results from water turbulence. People with hard domestic water are well aware of the ineffectiveness or foaming ability of household soaps and detergents under these circumstances. Water hardness is a result of the presence of certain minerals in water, principally calcium and magnesium (and iron and manganese, to a lesser extent). Dissolved in water, calcium and magnesium exist as positively charged ions. These out-compete water molecules for binding to negatively charged surfactants (carboxylic fatty acids for example). The harder the water, the more likely the surfactant will be bound up by calcium or magnesium and, consequently, the less likely surface tension will be reduced. Most of Alberta's rivers and many of the central Alberta lakes have moderately hard to very hard waters, meaning they have high concentrations of calcium and magnesium. As a result, foaming is not usually excessive in these waters. Lakes in the North, as well as many sodium-dominated prairie lakes in the province, often have low amounts of calcium and magnesium and, hence, reduced hardness. In these softer waters, foam may occur more frequently.

For more information call toll-free (310-0000) to a regional office of Alberta Environment, or the Environmental Monitoring and Evaluation Branch.