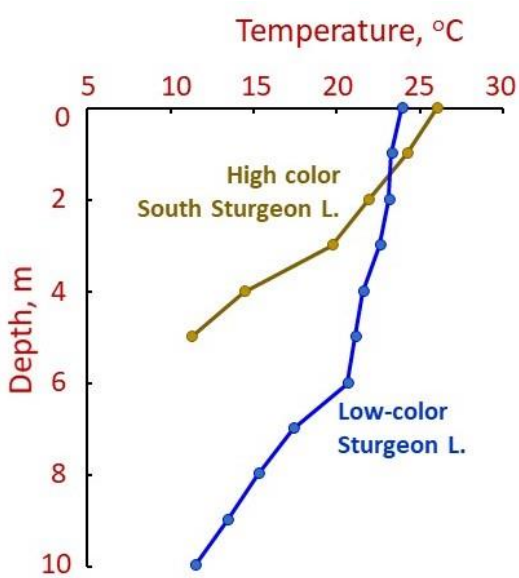
Color Dissolved Organic Matter (CDOM)

Background information

Colored (or chromophoric) dissolved organic matter (CDOM) is the portion of organic matter that absorbs light in the blue and UV part of the electromagnetic spectrum, staining water a “tea-like” color. CDOM plays a major role in controlling freshwater ecosystem processes, determining physical and chemical conditions, the suitability of water for various species of aquatic organisms, and water quality in freshwater ecosystems. Dissolved organic matter occurs in all natural waters, and CDOM is the most abundant DOM fraction in many natural waters, especially in forested watersheds with wetlands.

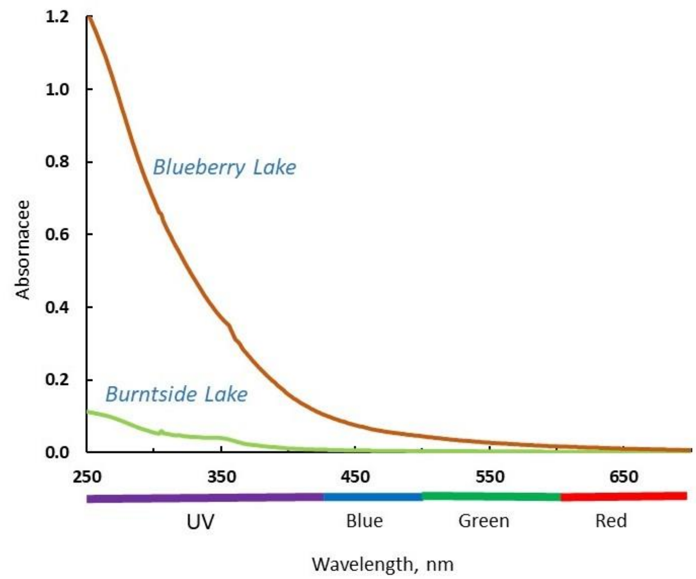
Aquatic dissolved organic matter (DOM) is derived from two types of natural sources: autochthonous production by aquatic organisms and allochthonous inputs from terrestrial plants. DOM also is derived from anthropogenic sources, including wastewater (effluent OM, EfOM) and urban and agricultural runoff. DOM differs chemically depending on its source. Although algae and aquatic macrophytes produce DOM with low levels of yellow-brown color, high levels of CDOM are derived primarily from terrestrial or wetland plants. CDOM is the most abundant DOM fraction in many natural waters.

CDOM strongly attenuates solar radiation, with major implications for physical, chemical, and biological processes in surface waters. CDOM, has significant impacts on surface water quality through its ability to (i) affect pH, (ii) mobilize metals and hydrophobic organic chemicals and (iii) serve as a source of reactive intermediates in aquatic photochemistry. CDOM also regulates heat transfer to water, controlling lake temperatures, mixing and stratification. By reducing light, CDOM decreases the depth to which photosynthesis can occur in lakes, and overall, it suppresses primary productivity. UV impacts on biota are attenuated by CDOM. In addition, CDOM increases heterotrophic activity and shifts the metabolic balance in nutrient-poor lakes toward heterotrophy, stimulating carbon burial. CDOM also affects nitrogen, phosphorus, and sulfur cycling through effects on microbial metabolism and redox status.



DOM is an important source of reactive intermediates in aquatic photochemistry. UV absorption by DOM or visible light by CDOM excites molecules and transforms some into excited triplet states, $^3DOM^*$, which react with contaminants by electron or energy transfer or hydrogen abstraction. Quenching of $^3DOM^*$ by dissolved O_2 forms singlet oxygen, $^1O_2$, a more reactive form of oxygen. Electron transfer from $^3DOM^*$ to O_2 forms superoxide radical anions, $O_2^{\cdot-}$, which react further to form hydrogen peroxide, H_2O_2, and other $^3DOM^*$ reaction pathways form hydroxyl radicals, ·OH. These so-called reactive oxygen species ($^1O_2$, O_2^-, H_2O_2, and ·OH) are important in the indirect photolysis of organic contaminants. Photobleaching of CDOM itself occurs on time scale of weeks to months and is important in transforming recalcitrant CDOM molecules into bioavailable forms.

Although not directly harmful to human health, CDOM negatively affects production of safe drinking water. DOM, and especially CDOM, increases the consumption of water treatment chemicals, reacts with chlorine to form potentially harmful disinfection by-products, stimulates bacterial growth, and fouls filtration membranes.



CDOM is easily measured in the lab on a filtered water sample as the absorbance, A_λ, of light at specific wavelength λ using a spectrophotometer. Today, CDOM is commonly reported as the absorption coefficient, a_λ, at wavelength λ. There is no standard wavelength for absorbance measurements; oceanographers use 412 nm, but freshwater scientists usually use 420 or 440 nm. A few other wavelengths are used less commonly. The relationship between a_λ and A_λ is: $a_\lambda = 2.303A_\lambda/\ell$ (units of m^{-1}), where ℓ is light path length in meters (m). The range of a_{440} values we have observed in Minnesota lakes is from near zero to ~ 30 m^{-1}. An a_{440} value of ~ 3 m^{-1} can be considered an approximate upper limit for low-colored waters. Lakes with $a_{440} > 3\ m^{-1}$ appear visibly brown-stained even to casual observers. For context, Blueberry Lake and Burntside Lake, ocated near Ely, MN and whose absorbance spectra are in the graph above, had a_{440} values of 19.6 and 1.2 m^{-1}, respectively.

CDOM's role in regulating biogeochemical cycles, food webs and water quality is a paradigm that has emerged from research of the past two decades. We now know that DOM functions as one of a small number of "master variables", including pH, redox status and phosphorus, that control important aspects of how aquatic ecosystems work and respond to environmental change, and determine the quality of the water resources. Knowledge of the sources and cycling of CDOM in ecosystems thus is of great importance for management and prediction of the outcomes of ongoing environmental change.

CDOM can be measured by satellite imagery, and a variety of retrieval equations, most based on band-ratio models, have been reported. CDOM levels in surface waters exhibit considerable spatial and temporal variability, and as a result, remote sensing is likely to play an important role in improving our understanding of the spatial distribution and temporal dynamics of CDOM in coming years.