Dissolved Oxygen

Dissolved oxygen (DO) refers to the volume of oxygen that is contained in water. Oxygen enters the water as rooted aquatic plants and algae undergo photosynthesis, and as oxygen is transferred across the air-water interface. The amount of oxygen that can be held by the water depends on the water temperature, salinity, and pressure. Gas solubility increases with decreasing temperature (colder water holds more oxygen). Gas solubility increases with decreasing salinity (freshwater holds more oxygen than does saltwater). Both the partial pressure and the degree of saturation of oxygen will change with altitude . Finally, gas solubility decreases as pressure decreases. Thus, the amount of oxygen absorbed in water decreases as altitude increases because of the decrease in relative pressure.

Once absorbed, oxygen is either incorporated throughout the water body via internal currents or is lost from the system. Flowing water is more likely to have high dissolved oxygen levels compared to stagnant water because the water movement at the air-water interface increases the surface area available to absorb the oxygen. In flowing water, oxygen-rich water at the surface is constantly being replaced by water containing less oxygen as a result of turbulence, creating a greater potential for exchange of oxygen across the air-water interface. Because stagnant water undergoes less internal mixing, the upper layer of oxygen-rich water tends to stay at the surface, resulting in lower dissolved oxygen levels throughout the water column. Oxygen losses readily occur when water temperatures rise, when plants and animals respire (breathe), and when aerobic microorganisms decompose organic matter.

Oxygen levels are also affected by the diurnal (daily) cycle. Plants, such as rooted aquatic plants and algae produce excess oxygen during the daylight hours when they are photosynthesizing. During the dark hours they must use oxygen for life processes.

Dissolved oxygen may play a large role in the survival of aquatic life in temperate lakes and reservoirs during the summer months, due to a phenomenon called stratification (the formation of layers). Seasonal stratification occurs as a result of water's temperature-dependent density. As water temperatures increase, the density decreases. Thus, the sun-warmed water will remain at the surface of the water body (forming the epilimnion), while the more dense, cooler water sinks to the bottom (hypolimnion). The layer of rapid temperature change separating the two layers is called the thermocline.

At the beginning of the summer, the hypolimnion of the lake will contain more dissolved oxygen because colder water holds more oxygen than warmer water. However, as time progresses, an increased number of dead organisms from the epilimnion sink to the bottom and are broken down by microorganisms. Continued microbial decomposition eventually results in an oxygen-deficient hypolimnion. If the lake has high concentrations of nutrients, this process may be accelerated. When the growth rate of microorganisms is not limited by a specific nutrient, such as phosphorus, the dissolved oxygen in the lake could be depleted before the summer's end.

Microbes play a key role in the loss of oxygen from surface waters. Microbes use oxygen as energy to break down long-chained organic molecules into simpler, more stable end-products such as carbon dioxide, water, phosphate and nitrate. As the organic molecules are broken down by microbes, oxygen is removed from the system and must be replaced by exchange at the air-water interface.

Each step above results in consumption of dissolved oxygen. If high levels of organic matter are present in a water, microbes may use all available oxygen. This does not mean, however, that the removal of microbes from the ecosystem would solve this problem. Although microbes are responsible for decreasing levels of dissolved oxygen, they play a very important role in the aquatic ecosystem. If dead matter is not broken down it will "pile up," much as leaves would if they were not broken down each year.

The introduction of excess organic matter may result in a depletion of oxygen from an aquatic system. Prolonged exposure to low dissolved oxygen levels (less than 5 to 6 mg/l oxygen) may not directly kill an organism, but will increase its susceptibility to other environmental stresses. Exposure to less than 30% saturation (less than 2 mg/l oxygen) for one to four days may kill most of the aquatic life in a system.

If all oxygen is depleted, aerobic (oxygen-consuming) decomposition ceases and further organic breakdown is accomplished anaerobically. Anaerobic microorganisms obtain energy from oxygen bound to other molecules such as nitrates and sulfates. The oxygen-free conditions result in the mobilization of many otherwise insoluble compounds. As sulfate compounds break down, the water may smell like rotten eggs.

Low dissolved oxygen levels may occur during warm, stagnant conditions that prevent mixing. In addition, high natural organic levels will often cause a depletion of dissolved oxygen.

Water Quality Standards for Dissolved Oxygen

Rule 64 of the Michigan Water Quality Standards (Part 4 of Act 451) includes minimum concentrations of dissolved oxygen which must be met in surface waters of the state. This rule states that surface waters designated as coldwater fisheries must meet a minimum dissolved oxygen standard of 7 mg/l, while surface waters protected for warmwater fish and aquatic life must meet a minimum dissolved oxygen standard of 5 mg/l.

Dissolved Oxygen Limitations in NPDES Permits

Dissolved oxygen limits are placed in many NPDES permits, to ensure that the minimum levels are met. These limits are developed along with limits for biochemical oxygen demand (BOD) and ammonia nitrogen. BOD is the measure of the oxygen needed to degrade organics in the water column. Ammonia is of concern because it is converted to nitrate (a nitrogen-oxygen compound) by bacteria in the water column, a process which results in the consumption of oxygen. By insuring that levels of BOD and ammonia nitrogen are sufficiently low, and levels of dissolved oxygen are sufficiently high, these limits together play an important role in protecting our surface waters.

Dissolved oxygen limits are commonly placed in permits for discharges which have the potential to exert an oxygen demand. These types of discharges include effluent from wastewater treatment plants, food processing and manufacturing operations and landfills. Dissolved oxygen limits are not necessary for all permits, such as discharges of clear noncontact cooling water, where levels of dissolved oxygen are expected to be high.

Treatment plants can keep levels of dissolved oxygen in their effluent high by proper aeration. This is accomplished by adding bubbles of oxygen, or running the water over rocks or "steps" to increase the transfer of oxygen across the air-water interface.