Low Dissolved Oxygen in Water

Causes, Impact on Aquatic Life – An Overview

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Dissolved oxygen – oxygen molecules dissolved in water – is a major indicator of water quality. Like the air we breathe, the survival of aquatic life depends on a sufficient level of oxygen dissolved in water. When it drops below levels necessary for sustaining aquatic life, it becomes a significant water quality impairment, often referred to as low dissolved oxygen (DO).

Unlike air, which is normally about 21 percent oxygen, water contains only a tiny fraction of a percentage of dissolved oxygen. In water it usually is expressed in milligrams per liter (mg/L), parts per million (ppm), or percent of saturation. At sea level, typical DO concentrations in 100-percent saturated fresh water will range from 7.56 mg/L (or 7.56 parts oxygen in 1,000,000 parts water) at 30 degrees Celsius to 14.62 mg/L at zero degrees Celsius.

The amount of dissolved oxygen that a given volume of water can hold is a function of atmospheric pressure, water temperature, and the amount of other substances dissolved in the water. At sea level, fresh water can absorb more oxygen per volume than water at mountainous elevations because of the higher atmospheric pressure near sea level. Cool water can hold more oxygen than warm water, with variations ranging from seasonal to time of day or night. Water with high concentrations of dissolved minerals such as salt will have a lower DO concentration than fresh water at the same temperature.

Testing for dissolved oxygen in a flooded farm field with spoiling sugar beets.

Causes of Low Dissolved Oxygen

Low dissolved oxygen (DO) primarily results from excessive algae growth caused by phosphorus. Nitrogen is another nutrient that can contribute to algae growth. As the algae die and decompose, the process consumes dissolved oxygen. This can result in insufficient amounts of dissolved oxygen available for fish and other aquatic life. Die-off and decomposition of submerged plants also contributes to low dissolved oxygen. The process of decomposition is called Carbonaceous Biochemical Oxygen Demand (CBOD).

Sources of phosphorus include discharges from municipal and private wastewater treatment, cropland and urban storm water runoff, and natural decay of vegetation. Direct discharge of pollutants from point source and nonpoint sources into a river segment add to its CBOD loadings, creating an oxygen demand that may

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depress DO below acceptable concentrations. Nutrient levels can in certain rivers occasionally cause sufficient eutrophication to generate CBOD loads from decaying algae. This may not occur locally, but instead farther downstream in pools where the current slows and algae collect.

Ground Water

Ground water, a primary source of river flow during dry weather and base flow conditions, is naturally low in DO. During winter months when ice cover inhibits aeration from the air, ground water inflows will contribute to occurrences of low DO in a river. During summer, the cooler ground water inflow may at first lower the DO concentration, but it also tends to reduce the river temperature which improves the ability of the water to hold oxygen.

Temperature

Water temperature is important because it not only establishes the maximum oxygen-holding capacity of water, but also has direct influence on rates of biochemical reactions and transformation processes occurring within the water column and in the sediment bed. Warmer temperatures decrease oxygen solubility in water while at the same time increasing metabolic rates that affect BOD decay, sediment oxygen demand, nitrification, photosynthesis, and respiration. In Minnesota, the critical conditions for stream DO usually occur during the late summer season when water temperatures are high and stream flow rates are normally low.

For example, an impaired trout water on the North Shore of Lake Superior will have contributing factors much different from an impaired headwater creek in southern Minnesota. The northern trout stream may suffer from watershed disturbances due to urbanization and the loss of riparian vegetation that once provided shade to cool the stream. The southern creek may be impacted by agricultural nonpoint loadings as well as hydrological changes from artificial drainage in the watershed.

Stream Flow, Geography

The natural setting, stream morphology, and flow regime also play large roles in the re-aeration and oxygen capacity of a stream. For example, a stream reach directly downstream from a wetland may reflect the naturally low DO concentrations found in wetlands. A shallow, high gradient turbulent stream has better inherent re-aeration potential than does a low gradient, sluggish stream with deep pools. Under conditions of low stream flow, a normally well-aerated stream with alternating riffles and pools may be reduced to mostly stagnant pools having low oxygen levels. Therefore, any analysis of DO impairment must recognize and acknowledge these types of physical constraints that are imposed by the natural characteristics of a watershed on its river system.

Water Classifications

Surface waters are classified according to their best use and the need for water quality protection (Mn Rules 7050.0140). Lakes and most streams are in Class 2, suitable for aquatic recreation, including bathing. Class 2A sets a standard of 7-milligrams-per-liter level of dissolved oxygen to support a healthy community of cold water fish such as trout. Class 2B sets a 5-milligrams-per-liter standard of dissolved oxygen, for cool or warm water fish.

Hypoxia in Gulf of Mexico

Also known as hypoxia, low dissolved oxygen occurs in a large area of northern Gulf of Mexico. Extending from the mouth of the Mississippi River along the Louisiana coast, a zone of less than 2 ppm of DO covers an area about the size of New Jersey for much of the year, where aquatic life can't survive. The condition is primarily caused by excessive nutrients, primarily nitrogen and phosphorus. There are many sources, but the largest is agriculture in the Upper Mississippi and Ohio River Basins. Nutrients from these basins fuel algae growth followed by oxygen-depleting bacterial action.

More Information

General information about the TMDL program:
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651-757-2670, 800-657-3864.
MPCA Total Maximum Daily Load Web page:
http://www.pca.state.mn.us/water/tmdl/index.html
Dissolved Oxygen TMDL protocol:
http://www.pca.state.mn.us/publications/wq-iw1-09.pdf
(1.83 MB)