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Anoxic waters

Anoxic waters are areas of sea water, fresh water, or groundwater that are depleted of dissolved oxygen and are a more severe condition of hypoxia. The US Geological Survey defines anoxic groundwater as those with dissolved oxygen concentration of less than 0.5 milligrams per litre.[1] This condition is generally found in areas that have restricted water exchange.

In most cases, oxygen is prevented from reaching the deeper levels by a physical barrier[2] as well as by a pronounced density stratification, in which, for instance, heavier hypersaline waters rest at the bottom of a basin. Anoxic conditions will occur if the rate of oxidation of organic matter by bacteria is greater than the supply of dissolved oxygen.

Anoxic waters are a natural phenomenon,[3] and have occurred throughout geological history. In fact, some postulate that the Permian–Triassic extinction event, a mass extinction of species from world's oceans, resulted from widespread anoxic conditions. At present anoxic basins exist, for example, in the Baltic Sea,[4] and elsewhere (see below). Recently, there have been some indications that eutrophication has increased the extent of the anoxic zones in areas including the Baltic Sea, the Gulf of Mexico,[5] and Hood Canal in Washington State.[6]

Contents

Causes and effects

Anoxic conditions result from several factors; for example, stagnation conditions, density stratification,[7] inputs of organic material, and strong thermoclines. Examples of which are fjords (where shallow sills at their entrance prevent circulation) and deep ocean western boundaries where circulation is especially low while production at upper levels is exceptionally high. In wastewater treatment, the absence of oxygen alone is indicated *anoxic* while the term anaerobic is used to indicate the absence of any common electron acceptor such as nitrate, sulfate or oxygen.

When oxygen is depleted in a basin, bacteria first turn to the second-best electron acceptor, which in sea water, is nitrate. Denitrification occurs, and the nitrate will be consumed rather rapidly. After reducing some other minor elements, the bacteria will turn to reducing sulfate. This results in the byproduct of hydrogen sulfide (H_2S), a chemical toxic to most biota and responsible for the characteristic "rotten egg" smell and dark black sediment color.[8]

$SO_4^{-2} + H^{+1} \rightarrow H_2S + H_2O$ + chemical energy

If anoxic sea water becomes reoxygenized, sulfides will be oxidized to sulfate according to the chemical equation:

$HS^- + 2\ O_2 \rightarrow HSO_4^-$

or, more precisely:

$(CH_2O)_{106}(NH_3)_{16}H_3PO_4 + 53\ SO_4^{2-} \rightarrow 53\ CO_2 + 53\ HCO_3^- + 53\ HS^- + 16\ NH_3 + 53\ H_2O + H_3PO_4$

Anoxia is quite common in muddy ocean bottoms where there are both high amounts of organic matter and low levels of inflow of oxygenated water through the sediment. Below a few centimeters from the surface the interstitial water (water between sediment) is oxygen free.

Anoxia is further influenced by biochemical oxygen demand (BOD), which is the amount of oxygen used by marine organisms in the process of breaking down organic matter. BOD is influenced by the type of organisms present, the pH of the water, temperature, and the type of organic matter present in the area. BOD is directly related to the amount of dissolved oxygen available, especially in smaller bodies of water such as rivers and streams. As BOD increases, available oxygen decreases. This causes stress on larger organisms. BOD comes from natural and anthropogenic sources, including: dead organisms, manure, wastewater, and urban runoff.[9]

In the Baltic Sea, the slowed rate of decomposition under anoxic conditions has left remarkably preserved fossils retaining impressions of soft body parts, in Lagerstätten.[10]

Human caused anoxic conditions

Eutrophication, an influx of nutrients (phosphate/nitrate), often a byproduct of agricultural run-off and sewage discharge, can result in large but short-lived algae blooms. Upon a bloom’s conclusion, the dead algae sink to the bottom and are broken down until all oxygen is expended. Such a case is the Gulf of Mexico where a seasonal dead zone occurs, which can be disturbed by weather patterns such as hurricanes and tropical convection. Sewage discharge, specifically that of nutrient concentrated “sludge”, can be especially damaging to ecosystem diversity. Species sensitive to anoxic conditions are replaced by fewer hardier species, reducing the overall variability of the affected area.[8]

Gradual environmental changes through eutrophication or global warming can cause major oxic-anoxic regime shifts. Based on model studies this can occur abruptly, with a transition between an oxic state dominated by cyanobacteria, and an anoxic state with sulfate-reducing bacteria and phototrophic sulfur bacteria.[11]

Daily and seasonal cycles

The temperature of a body of water directly affects the amount of dissolved oxygen it can hold. Following Henry's law, as water becomes warmer, oxygen becomes less soluble in it. This property leads to daily anoxic cycles on small geographic scales and seasonal cycles of anoxia on larger scales. Thus, bodies of water are more vulnerable to anoxic conditions during the warmest period of the day and during summer months. This problem can be further exacerbated in the vicinity of industrial discharge where warm water used to cool machinery is less able to hold oxygen than the basin to which it is released.

Daily cycles are also influenced by the activity of photosynthetic organisms. The lack of photosynthesis during nighttime hours in the absence of light can result in anoxic conditions intensifying throughout the night with a maximum shortly after sunrise.[12]

Biological adaptation

Organisms have adapted a variety of mechanisms to live within anoxic sediment. While some are able to pump oxygen from higher water levels down into the sediment, other adaptations include specific hemoglobins for low oxygen environments, slow movement to reduce rate of metabolism, and symbiotic relationships with anaerobic bacteria. In all cases, the prevalence of toxic H_2S results in low levels of biologic activity and a lower level of species diversity if the area is not normally anoxic.[8]

Anoxic basins

- Bannock Basin in Levantine Sea, eastern Mediterranean Sea;
- Black Sea Basin, off eastern Europe, below 50 metres (150 feet);
- Caspian Sea Basin, below 100 metres (300 feet);
- Cariaco Basin, off north central Venezuela;
- Gotland Deep, in the Baltic off Sweden;
- L'Atalante basin, eastern Mediterranean Sea
- Mariager Fjord, off Denmark;
- Orca Basin, northeast Gulf of Mexico;
- Saanich Inlet, off Vancouver Island, Canada;

See also

- Anoxic event
- Dead zone (ecology)
- Hypoxia (environmental)
- Meromictic
- Mortichnia
- Ocean deoxygenation
- Oxygen minimum zones

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