Cutoff switch may limit spread, duration of oxygen minimum zones

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Credit: Tiago Fioreze / Wikipedia

A new study examining the impact of iron released from continental margin sediments has documented a natural limiting switch that may keep these ocean systems from developing a runaway feedback loop that could lead to unchecked hypoxic areas, or persistent "dead zones."

The findings are particularly important, scientists say, because as the climate warms oxygen minimum zones are expected to expand in coming decades and could affect coastal fisheries as well as the global carbon cycle. But the study, which was led by researchers at Oregon State University, suggests that there may be a limit to the expansion of these OMZs.

The results are being published this week in the journal *Nature Geoscience*.

It is well-documented that iron is a crucial catalyst for fueling biological productivity in the oceans. When there is an insufficient amount of iron in the water column, microscopic plants called phytoplankton cannot fully consume nitrates and phosphates, limiting their growth. There are several potential sources of iron – including river sediments, windblown dust and continental margin sediments – but to be useful to plankton, the iron must be dissolved rather than locked up in sediments.

Oxygen may be a key that unlocks the storehouse of iron.

In high-oxygen environments, most of the iron that is dissolved in the water precipitates – turning into iron oxide coatings (similar to rust) on particles, which sink to the seafloor. Organic remains of plants and animals also sink to the seafloor and their rotting remains consume the oxygen dissolved in seawater. As oxygen lowers, a hypoxic dead zone may form. When it does the iron oxides dissolve and may diffuse back into the water column where the iron again becomes available to fertilize plankton growth, as long as other major nutrients such as nitrate and phosphate are available.

"When this moderate hypoxic state occurs, the iron release fuels more biological productivity and the organic particles fall to the sea floor where they decay and consume more oxygen, making hypoxia worse," said Florian Scholz, a postdoctoral researcher in OSU's College of Earth, Ocean, and Atmospheric Sciences and lead author on the *Nature Geoscience* study. "That leads to this feedback loop of more iron release triggering more productivity, triggering more iron release.

"But we found that when the oxygen approaches zero a new group of minerals, iron sulfides, are formed," Scholz added. "This is the key to the limit switch because when the iron gets locked up in sulfides, it is no longer dissolved and thus not available to the plankton. The runaway hypoxia stops and the hypoxic region is limited."

An important part of the study was the development of indicators for sedimentary iron release during past periods of ocean deoxygenation, the researchers said. Scholz and his colleagues investigated a sediment core from the upwelling area of Peru, where the subsurface water column has one of the lowest ongoing oxygen levels on Earth.

In their study, the researchers looked at concentrations of iron, uranium and molybdenum in ocean sediments dating back 140,000 years.

The key to the discovery, they say, was determining whether sediments buried during a past period of ocean deoxygenation had an iron deficit. Sediment with an iron deficit suggests that the iron was removed and potentially transported offshore into iron-limited ocean regions. Conversely, when the sediments held a lot of iron, it likely was retained and thus not available for fertilization.

"Florian found that there are two states in which iron is locked up and unavailable to fuel plant growth," said Alan Mix, an Oregon State geochemist and co-author on the study. "When there is a lot of iron in the sediment, but no molybdenum, the iron is stored in oxide minerals.

"This happens when oxygen is abundant," Mix added. "But if there is iron and molybdenum, then the iron is stored in sulfide minerals like pyrite, meaning the system has little or no oxygen available.

What the researchers discovered in the Peru system "is a window for iron release, which could be a key to the biological productivity in this iron-limited ocean region," Scholz said.

The near-anoxic Peru system differs from the Pacific Northwest coast of the United States, which has experienced several hypoxic events over the past decade. The Northwest waters are not yet as low in oxygen or iron as Peru.

"These basic reactions have been known for a while," Mix said, "but documenting them in the real world on a large scale – and associating them with climate change – is quite significant and especially important given projections of growing hypoxia in a warming climate."

More information: The impact of ocean deoxygenation on iron release from continental margin sediments, DOI: 10.1038/ngeo2162

Provided by Oregon State University

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