European Commission

Science for Environment Policy

Aerosol pollutants can have long-range effects on ocean oxygen levels

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Oxygen decline is occurring in many of the world's oceans and has important consequences for marine ecosystems, but the causes are not fully understood. Aerosol pollutants may be partly responsible, according to a new study which modelled the effects of atmospheric pollution over the Pacific Ocean. The findings suggest that air pollution can exacerbate climate impacts on the ocean, even when the source is far away.

At least half of the world's oxygen comes from the ocean[1]. The reduction in the amount of oxygen in the oceans is therefore of high concern, both for marine ecosystems and humans. Areas of extremely low oxygen are known as 'dead zones'. Often unable to support marine life due to severely depleted oxygen levels, these areas result mostly from human activities and are growing in number. Less severe areas of low oxygen are called 'oxygen minimum zones', and organisms that live within them require special adaptations in order to survive. Some of the world's biggest oxygen minimum zones are found in the Pacific Ocean, where oxygen concentrations have decreased considerably in recent years. These are mostly formed naturally, although can be affected by human activities.

One known human cause of oxygen decline is climate change, as increased temperatures reduce the ability of oxygen to dissolve in water. However, in the case of Pacific Ocean oxygen minimum zones, the decline is not associated with a temperature increase — suggesting that there must be another cause.

Another possible cause is aerosols — tiny particles found in the air, such as dust, air pollutants, smoke, and chemicals such as iron and nitrogen. Soluble iron (a form of iron able to dissolve in the ocean) can come from burning fuels. Atmospheric pollutants such as dust can also make iron soluble. Atmospheric pollution has also increased the amount of nitrogen that enters the ocean. Both nutrients can affect the function of phytoplankton — the organisms that *release* oxygen into the water during photosynthesis; they increase the production of organic matter by phytoplankton in the ocean and in doing so increase respiration (a process that *uses* oxygen, the opposite of photosynthesis).

In a new study, researchers investigated whether an increase in these nutrients (due to atmospheric pollution) has caused the decline of oxygen in the Pacific Ocean. To test the hypothesis, the researchers combined models of atmospheric chemistry, ocean circulation and biogeochemical cycling. They simulated the effect of pollution on iron and nitrogen deposition — using a 3D atmospheric chemical transport model, and a dust-iron dissolution scheme, which modelled the dust and iron deposited in the ocean — as well as its impacts on ocean productivity and biogeochemical cycling for the late 20th century. The models were fed with climatological circulation and pre-industrial aerosol deposition data (estimating the increase of human pollution from 1750 to 2002 based on global coal production). Although the researchers say their work is robust, they do note the uncertainty of some inputs and the lack of potentially important feedbacks — such as processes involving nutrient cycling — in the simulations.

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1. http://news.nationalgeographic.com/news/2004/06/0607_040607_phytoplankton.html

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According to the simulations, the largest increase in the amount of iron deposited occurred in the North Pacific Ocean (where the fraction of soluble aerosol iron increased from 0.61% to 1.8% from pre-industrial to contemporary states). Nitrogen showed similar patterns; annual average deposition increased in the central North Pacific Ocean by around 70%. However, the biggest decrease in oxygen concentration occurred in the eastern tropical part of the Pacific.

So, although aerosol deposition increased the most in mid-latitudes, the biggest changes in productivity and oxygen levels were seen in the tropics. To explain this, the researchers say the ocean circulation likely transports iron that is added to the water in mid-latitudes to the tropics, leading to increased productivity, respiration and consequently loss of oxygen in those regions.

Finally, the researchers estimated the importance of the three individual mechanisms: variability in ocean circulation (which can affect the transport of dissolved oxygen), pollution-driven iron deposition, and pollution-driven nitrogen deposition (both of which promote respiration). This showed that the effects of circulation and iron deposition are significantly greater than those of nitrogen deposition. The researchers therefore suggest that these two factors are likely responsible for the increase in the tropical Pacific oxygen minimum zone.

Overall, these results suggest that anthropogenic pollution can exacerbate the impact of climate on declining ocean oxygen levels, and can have long-ranging effects. Changes to oxygen concentration in the ocean could have long-term implications in terms of nutrient cycling and marine ecosystems. It is therefore important that policies consider the long-distance pollution impacts of aerosol deposition highlighted by this study.

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