Oxygen-deficiency in Oceanic Waters

Syed Wajih A. NAQVI
Kuwait Institute for Scientific Research, Salmiya, Kuwait

An efficient circulation ensures adequate supply of oxygen to subsurface waters, preventing them from turning anoxic in most oceanic areas. However, in a few regions oxygen demand for respiration exceeds its supply, resulting in complete oxygen removal within a thick layer at intermediate depths. Such oxygen-deficient zones (ODZs) are found in the eastern boundary upwelling regions of the Pacific Ocean (off Peru-Chile and Mexico) and the Atlantic Ocean (off Namibia), and in the northern Indian Ocean (Arabian Sea and Bay of Bengal). Although containing <7% of the oceanic volume, the ODZs make significant contribution to biogeochemical cycles, especially the global nitrogen balance. This is because in the absence of oxygen degradation of organic matter sinking from the surface layer is carried out by microbes using other oxidants of which nitrate, fairly abundant in seawater, is energetically most economical. Resultant production of molecular nitrogen (N_2) by this process (denitrification) and by anaerobic ammonium oxidation (anammox) in oceanic ODZs and sediments is the major nitrogen sink and a key component of the nitrogen cycle. The ODZs are also important for cycling of nitrous oxide (N_2O), an intermediate of the redox chemistry of nitrogen and a potent greenhouse gas, providing conditions suitable for both its production and consumption of, but serving as a strong net source. Consequently, emissions from low-oxygen zones account for up to one-third of the global oceanic N_2O efflux. The open ocean ODZs can extend to continental margins through upwelling of surface waters as, for example, happens seasonally over the western Indian continental shelf. Conditions in such shallow systems are often more severe, sometimes resulting in sulphate reduction and very high accumulation of N_2O.

Oceanic ODZs have varied in size and intensity in the geological past associated with and possibly contributing to climatic changes. Presently they appear to be experiencing changes driven by human activities. Available data show that ODZs of the Pacific have expanded significantly over the past few decades. Evidence for such an expansion is lacking from the Indian Ocean where (in the Bay of Bengal) the world’s largest ODZ that does not experience large scale nitrogen loss is located. Given the near zero (nanomolar) oxygen concentrations, any intensification of this and other similar systems is expected to greatly impact the nitrogen budget.

Human activities are having an even larger impact in coastal areas where hundreds of oxygen-depleted (hypoxic) zone have developed in the past few decades, largely due to nutrient over-enrichment (eutrophication) caused by huge increase in terrestrial nutrient loading arising from sources such as agriculture, human waste, fossil fuel and industries. These “dead zones”, so called because of the adverse impact they have on marine ecosystems and fisheries, are not only detrimental for ocean health but also for human wellbeing. Global concerted efforts are urgently needed to take remedial measures for checking ocean deoxygenation by cutting down greenhouse gas emissions to the atmosphere and nutrient inputs to the oceans.