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Impact of water column hypoxia on sulfate reduction and Fe-S-P cycles in sediments and benthic P release

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Phosphorus (P) is a key nutrient, not only regulating primary production as a limiting nutrient but also inducing eutrophication that can stimulate (harmful) algal blooms in coastal ecosystems. Sediment serves either as a source or a sink of P in the coastal ocean. Oxygen concentrations in the open ocean and coastal waters have been declining over the past few decades, and there are around 400 hypoxic sites worldwide. The Jinhae Bay located on the southern coast of Korea is characterized by severe eutrophication and seasonally recurring hypoxia for the last 4 decades. The development of stratification in the summer has resulted in hypoxic conditions in the bottom water, Long-term monitoring revealed that the concentration of dissolved inorganic phosphorus (DIP) in bottom water increased under hypoxic conditions, which indicated that the sediments act as an internal source of P in the bottom water. Although hypoxia in the water column can be a major factor regulating the behavior of P in sediments, the impact of water-column hypoxia on sulfate reduction and resultant P behaviors (i.e., adsorption/desorption and precipitation/release) in sediments are relatively less understood.

We investigated changes in sulfate reduction rates (SRRs) and resulting P dynamics in sediments with the variations of the hypoxic condition (i.e., pre-hypoxia, earlier-hypoxia, later-hypoxia, and post-hypoxia) in the water column in 2019. SRRs (28.1-46.8 mmol m^{-2} d^{-1}) and P concentrations (2.85-6.35 mmol m^{-2}) during the hypoxia increased 5-6 times and 2-6 times, respectively, higher than those measured at pre-hypoxia conditions. Accordingly, the content of Fe-bound P in sediments decreased as the P is desorbed from Fe during the H_2S oxidation coupled to FeOOH reduction. Benthic P release was greatly stimulated when the bottom water was in anoxic condition. Interestingly, high SRR accompanied by the accumulation of P and S in pore water were observed even after the hypoxia condition (i.e., post-hypoxia period), indicating that there is a time-lag between water column and sediment in generation/extinction of the hypoxia. Our results demonstrate that expansion of hypoxia in the water column has a great impact on biogeochemical S-Fe-P cycles and benthic P, which ultimately deepens eutrophication in coastal waters.