

IOW press release - July 15, 2021

Major Baltic Inflows can cause just minor and only temporary improvements of the Baltic Sea's state of eutrophication

With detailed analyses of water and sediment samples from the Gotland Basin, geoscientists from the Leibniz Institute for Baltic Sea Research succeeded in tracing the geochemical processes following the Major Baltic Inflow in 2014/2015. Their conclusion: even very large amounts of oxygenated waters cause only small and temporary improvements of the nutrient situation in the central Baltic Sea. Already 1.5 years after the event, the oxygen reserves in the Gotland Basin were depleted again and phosphate deposited by then escaped back into solution. However, certain trace metal accumulations remained in the sediment, which were unknown in connection with saltwater intrusions so far.

Sporadic intrusions of large quantities of saline North Sea water are seen as an opponent to spreading "dead zones" in the bottom waters of the central Baltic Sea. These so-called Major Baltic Inflows (MBI) carry oxygenated North Sea waters into the Baltic Sea, where it sinks due to its - compared to the brackish Baltic waters - higher density and flows towards the central Baltic Sea basins. This is the only process that allows fast oxygenation of the deep water thereby impeding the spreading of "dead zones". Accordingly, hopes were high when, in December 2014, the third largest saltwater intrusion since 1880 brought very large quantities of salt and oxygen into the Baltic Sea.

Oxygenation not only enables the sea floor to become resettled with higher organisms, it also triggers a chain of oxidation processes during which phosphate compounds precipitate. Phosphorus, a crucial nutrient that, along with nitrogen, is responsible for eutrophication and the associated summer cyanobacterial blooms ("blue-green algae") in the Baltic Sea, is thus removed from the water

The Warnemünde geoscientists Olaf Dellwig, Antje Wegwerth and Helge Arz took this dual positive effect of saltwater intrusions as an opportunity to study the geochemical processes of this domino effect in the deep water and sediments of the Gotland Basin, starting from the event in December 2014 until autumn 2019. Pre-ventilation data were also available for comparison purposes.

They were primarily driven by three questions: (1) How effective is phosphate precipitation, and thus the decrease of this nutrient in the deep water after a saltwater intrusion? (2) Which minerals form during deep-water oxygenation and how stable are they when oxygen-deficiency re-establishes? (3) Can such minerals serve as tracers of earlier saltwater intrusions in older sediments?

- Within the entire observation period of more than 4.5 years, the phosphate inventory in the water column below a water depth of 80 m decreased only by a maximum of 30% compared to the values before the saltwater intrusion. Already 1.5 years after the major ventilation event in 2014/2015, conditions were again similar to the original situation.
- In contrast to the saltwater intrusions in the 1960s and 1970s, which occurred in a high frequency, nearly annually, the MBI from 2014/2015 did not result in any

significant formation of manganese carbonate (rhodochrosite), a mineral that was used as a witness for saltwater intrusions in older deposits.

- While trace metals such as molybdenum and uranium were briefly released into the water by oxygenation, significant amounts of cobalt entered the seafloor deposits.

“We specifically searched for this pattern of cobalt enrichment with simultaneous depletion of molybdenum and uranium in dated sediments from the last 70 years and found confirmation that it has always appeared in parallel with saltwater intrusions since the 1980s,” explains Olaf Dellwig, geochemist at the IOW. He and his colleagues are pleased to be able to use this combination of trace metals to identify past saltwater intrusions that were not recorded by the uncertain indicator of manganese carbonate layers. For the Baltic Sea ecosystem, the result is less pleasing: Single saltwater intrusions are not expected to lead to any sustainable reduction of the “dead zones” and reduction of the nutrient inventory in the future.

For further details: Dellwig, O., Wegwerth, A. and Arz, H.W., 2021. *Anatomy of the Major Baltic Inflow in 2014: Impact of manganese and iron shuttling on phosphorus and trace metals in the Gotland Basin, Baltic Sea*. Continental Shelf Research, 223: 104449. <https://doi.org/10.1016/j.csr.2021.104449>

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