Artificial Ocean Alkalinisation in the Baltic Sea

CDRmare - RETAKE

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In Short

- climate change
- ocean acidification
- carbon dioxid removal
- artificial ocean alkalinisation
- Baltic Sea
- potential and feasibility
- risks and co-benefits

Since the beginning of the industrial age, carbon dioxide concentrations in the atmosphere have almost doubled [**??**]. In order to curb the detrimental effects of the resulting climate change on the environment, economy and livelihoods, the temperature increase needs to be kept well below 2 ℃ with a preferable maximum increase of 1.5 ℃ by 2100 [**??**]. As a response, the EU set the goal to become carbon neutral by 2050 to keep the increase in global temperature by 2100 under 2 ℃. If the 1.5 ℃ goal is to be achieved, global CO_2 emissions need to be decreased further by 1 -2 Gt per year. Simply becoming carbon neutral will not suffice to achieve the set goal [**??**]). To counter the current excess in emissions it is necessary to become carbon negative which demands methods of active carbon dioxide removal (CDR). Many potential approaches for CDR are linked to the marine environment. Indeed, the oceans play a vital role in climate change as they absorb 25 % of the atmospheric carbon dioxide while photosynthesis greatly contributes to the long term export of carbon to the deep ocean [**??**].

The CDR method of artificial ocean alkalinisation aims to accelerate natural weathering of rocks. Alkaline minerals like calcite ($CaCO_3$) or olivine are introduced to the ocean for the purpose of raising its buffering ability. This is the ability to absorb additional CO_2 causing a flux of atmospheric carbon to the ocean [**??**]. Due to this buffering effect, ocean alkalinisation may not only counter rising carbon dioxide concentrations in the atmosphere, but also ocean acidification, which is becoming an increasing threat to marine life (Fig. [**??**]).

The Baltic Sea is a potential candidate for this approach as there are large areas that are undersaturated in calcite [**??**] and thus have a capacity to dissolve added calcite. Furthermore, the bottom water in many regions becomes either seasonally or is even permanently low in oxygen [**??**]. During prolonged periods of low oxygen, the resulting oxidation of organic matter produces acidic sediments, which are also beneficial for calcite dissolution. The bottom water in the Gotland Deep frequently becomes stagnant and depleted in oxygen for several years, making it a potenitally promising location for the addition of calcite.

As a semi-enclosed system, the Baltic Sea is suitable for budget calculations of alkalinity and other tracers where internal and external fluxes can be tracked more easily than in areas with fewer boundaries [**??**]. This project is aimed to assess the potential, beneficial side effects and risks of artifical alkalinisation in the Baltic Sea.

Previous simulations of OAE in the Baltic Sea within the scope of this project have shown that the overall potential and efficiency of OAE with calcite highly depend on the release site. The immediacy with which the carbon capture begins after the release of the calcite differed greatly between the shallow coastal location and the deep basin. The local net changes in pH and alkalinity were higher in the shallow location than in the deep basin suggesting different environmental implications related to the release site. As the simulations were run for the past 40 years, the potential of the calcite release in the future with ever more increasing CO_2 emission is an open question. Furthermore, the role of calcifying organisms such as mussels during OAE endeavours with calcite in the Baltic Sea needs to be explored. Added calcite may drive calcite formation in bivalves and thereby remove the dissolved calcite from the water column. This form of biogenic calcite repre-

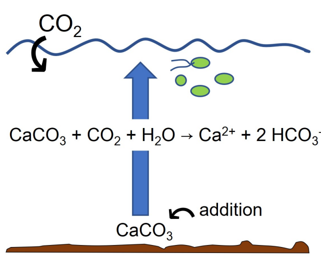

Figure 1: *CO_2 that dissolves in water releases H^+ from H_20, which increases the concentration of free reactive H^+ and therefore lowers the pH (-lg[H^+]): a process known as ocean acidification. When $CaCO_3$ dissolves in water it disociatiates into Ca^{2+} and CO_3^{2-}. The carbonate (CO_3^{2-}) can take on H^+ thus buffering both the low pH and raising the waters capacity to take up more CO_2.*

ciptation could lower the efficiency of OAE as the added caclite is no longer available to drive carbon capture through alkalinity enhancement.

The Baltic Sea is a comparatively small sea with many neighbouring countries and a unique ecosystem that is facing a lot of stress from overfishing, pollutants and climate change. Sound knowledge of both release sites and potential surfacing sites of artificial alkalinity are therefore paramount for both political and environmental reasons.

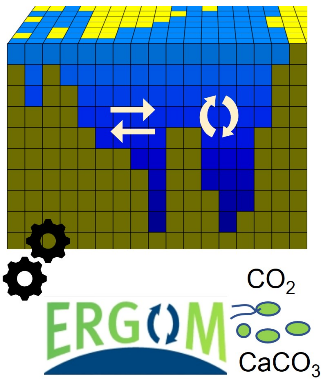

Figure 2: *Artificial ocean alkalinisation in the Baltic Sea will be simulated with a hydrodynamic-biogeochemical model. The hydrodynamic model MOM describes physical processes including mixing and layering of water masses while the biogeochemical model ERGOM resolves the chemical processes of alkalinisation and its effects on the ecosystem.*

A hierarchy of numerical models is used to simulate deployment in the Baltic Sea, and to extrapolate experimental results from local to regional and global scales. A hydrodynamic model (Modular Ocean Model) is used to describe the physical processes and in particular the vertical mixing processes (Fig. [**??**]). This model is coupled with a biogeochemical model (ERGOM) that describes the carbon chemistry, processes of alkalinisation and the ecosystem. The key questions are:

1. How will OAE in the Baltic Sea perform under a pessimistic future climate scenario?
2. How will bivalves respond to added calcite in the Baltic Sea?
3. Will bivalves impact the efficiency of calcite addition as an OAE method in the Baltic Sea?
4. What are the predictions for CO_2 capture, storage potential and storage period?

The results shall inform on the feasibility of artificial alkalinisation in different regions of the Baltic Sea and possible side benefits (e.g. countering ocean acidification), guide monitoring of the method regarding potential risks for the environment and enlighten which aspects of this method require further research.

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https://www.io-warnemuende.de/

More Information

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Project Partners

CDRmare Consortium

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DFG Subject Area

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