IMPACTS OF POSSIBLE SEEPAGE FROM CO_2 SUB-SEABOTTOM STORAGE

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Introduction

CCS – Carbon dioxide (CO_2) Capture and Storage is one of a portfolio of CO_2 mitigation methods to avoid anthropogenic climate change. Under certain assumptions it can contribute globally up to 20% of necessary emission reductions by 2050. One of the most promising places to store the resulting large volumes of CO_2 for a long time is in sedimentary rocks below the continental margins. Since 2007 the conventions protecting the oceans against pollution, OSPAR and London Protocol, permits the CO_2 storage deep below the sea bottom. Both set up criteria to secure the oceans against CO_2 seeping back into the ocean or atmosphere, before national authorities are allowed to give permits for such storage. Important criteria are to be able to detect and stop any seepage and to present an EIA - Environmental Impact Assessment. To make an EIA, operators and authorities need to have scientific knowledge about what the consequences could be for the living creatures in and on the sea bottom, if an improbable seepage should happen.

Primary & Secondary effects of CO_2 *seepage*

In the case of CO_2 seepage from a sub-seabottom reservoir, the released CO_2 may change pH and pCO_2 in the sediment pore water and the seawater, which represents a risk to local biota in itself. Most of the research so far has focused on the impact of acidification on calcifying organisms and effects of increased pCO_2 or decreased pH on marine invertebrates. However, the actual impacts of acidification, including secondary mechanisms, may range across a broad spectrum of chemical, ecological and physiological processes. CO_2 acidification may cause cascade effects in ecosystem if it affect a process which has a key-function in the complex ecosystem. Therefore not only the primary effects (CO_2 increase and pH decreases) but also secondary effects (change in the mobility, solubility and bioavailability of trace and heavy metals, nutrients and inorganic – organic toxins) should be studied. All of these impacts are still poorly understood and should also be a priority area for CO_2 acidification research.

Effects on sediment-water chemistry

The CO_2 leakage may cause either rapid extraction of some easily soluble fractions of some trace metals like Cu, Cd, Ni and Zn from the sediment and suspended particles or slow but continuous enhancement of easily soluble fractions of other elements like Pb, Al (Ardelan et al., 2009; Ardelan and Steinnes 2010). Truly soluble fractions of some rare-earth elements such as Y, Ce, Pr, Sm, Tr, and La and Uranium (unpublished results) in the seawater also increased significantly due to CO_2 leakage. The enhancement of easily soluble fractions of various heavy metals may create toxic cascade effects in marine ecology, from the benthic systems to the pelagic systems. Among heavy metals, Pb is particularly interesting. The reduced use of leaded gasoline in developed countries since 1970 and 80s has effectively decreased the flux of anthropogenic Pb into the ocean. This trend of decrease in industrial Pb emission has been traced in marine systems (Inoue and Tanimizu, 2008). However, the previously released anthropogenic

Pb has already accumulated in marine sediments and in case of CO_2 leakage (or increased Ocean Acidification due to increasing CO_2 concentration in atmosphere) and associated pH decrease this accumulated anthropogenic Pb will be mobilized back into seawater.

Cold-water Coral Desmophyllum -associated cyanobacteria. Photo: C. Jantzen, AWI, Germany

Possible effects on benthic microbial ecosystem: Bacteria have generation times in the order of hours to days and any changes in the environment caused by CO_2 acidification, such as changes in the water and sediment chemistry, dissolution of metals etc., are likely to cause changes in the bacterial community, transient or permanent during CO_2 leakage. Unfortunately, data on the direct and indirect impact of high CO_2 and low pH on prokaryotes (bacteria and archaea) are very limited. Prokaryotes maintain their intracellular system slightly alkaline pH by spending energy in ATP (Egil Sakshaug, personal communication), therefore, they may have serious problem when water becomes acidified by CO_2. Moreover, Fe-Mn shuttle in surface sediment and sediment-water interface has been disturbed due to CO_2 acidification (Ardelan and Steinnes, 2010). Natural bacterial stratification may have also been affected due to disturbed Fe-Mn shuttles.

Experimental setups:

The most of the experiments to study the impact of CO_2 leakage on biogeochemistry and ecosystem were done at atmospheric pressure. The prospective CO_2 injection in the North Sea and Barents Sea however is planned at 100-300 m water depth, at a pressure of 10-30 atmospheres. Further work on the impact of CO_2 on trace and heavy metals mobility and bacterial community at the sediment-water interface is now in progress using a titanium pressure tank (Karl Erik TiTank, Fig. 1) where conditions may be chosen to mimic real situation if CO_2 leakage occurs. The experimental studies on the marine ecosystem are missing, in various degrees, regarding the environmental factors at the depth where the possible seepage may occur from CO_2 storage zones. The current studies have been skipping basic chemical steps in the sense that they don't account for realistic parameters and this makes the majority of the research questionable. Many basic data simply do not exist in the studies and the knowledge about the potential chemical impacts of CO_2 seepage at sediment-water interface is limited. This is, therefore an area where further research is urgently needed. Experiments in the Karl Erik TiTank can mimic real situation of possible seepage of CO_2 from storage site i.e. low temperature and high pressure. By focusing on biogeochemical parameters and variables that might be influenced by CO_2 seepage in realistic conditions, this research is moving beyond the earlier studies.

The current concern of CO_2 leakage is diffuse seepage that is difficult to detect. Moreover, the type of impact, if any, caused by this leakage is most likely chronic. The majority of the studies performed so far are primarily concentrated on the acute effects by focusing on mortality as a function of time exposure with different fixed pH values. The biological research has focused largely on acid-base regulation and cardio-respiration control, other aspects are little investigated. The Karl Erik TiTank makes it possible to perform experiments with low level of CO_2 seepage in long-term and thereby predicts realistic effects of CO_2 on aquatic communities. The outcome of the experiment may be used further for improvement of monitoring techniques to detect low level CO_2 seepage and investigating chronic impact of CO_2 seepage in marine ecosystem.

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Figure 1: Picture and Transect of pressurized Titanium tank (Karl Erik TiTank).
Illustrations: Statoil