Could submarine groundwater discharge be a significant carbon source to the southern Baltic Sea?*

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Abstract

Submarine Groundwater Discharge (SGD) is an important yet poorly recognised pathway of material transport to the marine environment. This work reports on the results of dissolved inorganic carbon (DIC) and dissolved organic carbon (DOC) concentrations and loads in the groundwater seeping into the southern Baltic Sea. Most of the research was carried out in the Bay of Puck (2009–2010), while in 2013

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the study was extended to include several other groundwater seepage impacted areas situated along the Polish coastline. The annual average concentrations of DIC and DOC in the groundwater were equal to 64.5 ± 10.0 mg C L^{-1} and 5.8 ± 0.9 mg C L^{-1} respectively. The carbon specific flux into the Bay of Puck was estimated at 850 mg m^{-2} yr^{-1}. The loads of carbon via SGD were scaled up for the Baltic Sea sub-basins and the entire Baltic Sea. The DIC and DOC fluxes via SGD to the Baltic Sea were estimated at 283.6 ± 66.7 kt yr^{-1} and 25.5 ± 4.2 kt yr^{-1}. The SGD derived carbon load to the Baltic Sea is an important component of the carbon budget, which gives the sea a firmly heterotrophic status.

1. Introduction

The carbon cycle is one of the most significant biogeochemical cycles as regards the flow of matter and energy in the environment. A major constituent of the carbon cycle is carbon dioxide (CO_2). In recent decades the amount of CO_2 in the atmosphere has increased significantly as a consequence of fossil fuel combustion, which has resulted in global warming and seawater acidification (IPCC 2007, Chen & Borges 2009). Takahashi et al. (2009) estimated that almost 35% of anthropogenic CO_2 emissions are absorbed by seas and oceans, while almost 1/3 of this load is absorbed by shelf seas. It has been estimated that shelf seas, including the Baltic Sea, are responsible for approximately 20% of marine organic matter production and about 80% of the total organic matter load deposited to marine sediments (Borges 2005). However, recent findings question earlier estimates regarding CO_2 sequestration, at least in selected coastal seas (Kuliński & Pempkowiak 2012, Omstedt et al. 2014). One of the possible reasons is that the important pathway of material exchange between land and ocean– Submarine Groundwater Discharge (SGD) is neglected. Although data concerning carbon concentrations and fluxes via SGD are limited (Cai et al. 2003, Santos et al. 2009, Moore 2010, Liu et al. 2012), it is clear that SGD must be considered an important carbon source for the marine environment. It is especially important for shelf seas, which play a significant role in the global transfer of matter and energy between land, ocean and atmosphere (Thomas et al. 2009). The Baltic is an example of such a sea.

The Baltic used to be characterised as an autotrophic semi-enclosed brackish sea (Thomas et al. 2004). Substantial amounts of nutrients, mostly from agriculture and industry, enter this sea from rivers, making the Baltic one of the most productive marine ecosystems in the world (Emelyanov 1995, Thomas et al. 2004). Primary production, river run-off and import from the North Sea are major sources of organic matter in the Baltic Sea (Thomas et al. 2003, Wasmund et al. 2003, Kuliński & Pempkowiak 2012). At the same time the Baltic is a net source of organic matter for the North Sea (Kuliński & Pempkowiak 2011). A recent study by Kuliński