Available online at www.sciencedirect.com
ScienceDirect
Journal of Marine Systems 73 (2008) 223–235
JOURNAL OF MARINE SYSTEMS
www.elsevier.com/locate/jmarsys

Changes in dissolved silicate loads to the Baltic Sea — The effects of lakes and reservoirs

Christoph Humborg [a,*], Erik Smedberg [a], Miguel Rodriguez Medina [b], Carl-Magnus Mörth [c]

[a] Department of Applied Environmental Research, Stockholm University, SE-106 91 Stockholm, Sweden
[b] Department of Systems Ecology, Stockholm University, SE-106 91 Stockholm, Sweden
[c] Department of Geology and Geochemistry, Stockholm University, SE-106 91 Stockholm, Sweden

Received 22 August 2006; accepted 12 October 2007
Available online 23 December 2007

Abstract

We tested the hypothesis that dissolved silicate (DSi) yields [kg km^{-2} yr^{-1}] of 82 major watersheds of the Baltic Sea can be expressed as a function of the hydraulic load (HL) as a measure of water residence time and the total organic carbon (TOC) concentration, both variables potentially increasing the DSi yield. Most boreal rivers fitted a linear regression model using HL as an independent variable to explain the DSi yield. Rivers with high HL, *i.e.*, shortest residence times, showed highest DSi yields up to 2300 kg km^{-2} yr^{-1}. This is most likely caused by an excess supply of DSi, *i.e.*, the geochemical sources prevail over biological sinks in these boreal watersheds. The DSi yield for regulated and unregulated larger rivers of the boreal watersheds constituting about 40% of the total water discharge and of the total DSi load to the Baltic Sea, respectively, can be expressed as: DSi yield = 190 + 49.5 HL[m yr^{-1}] + 0.346 TOC [µM] (R^2 = 0.80). Since both HL and TOC concentrations have decreased after damming, the DSi yields have decreased significantly in the regulated boreal watersheds, for the River Luleälven we estimated more than 30%. The larger eutrophic watersheds draining cultivated landscape of the southern catchment of the Baltic Sea and representing about 50% of the annual water discharge to the Baltic Sea, deviated from this pattern and showed lower DSi yields between 60–580 kg km^{-2} yr^{-1}. DSi yields showed saturation curve like relationship to HL and it appears that DSi is retained in the watersheds efficiently through biogenic silica (BSi) production and subsequent sedimentation along the entire river network. The relationship between HL and DSi yields for all larger cultivated watersheds was best fitted by a Freundlich isotherm (DSi = 115.7HL^{109}; R^2 = 0.73), because once lake and reservoir area exceeds 10% of the watershed area, minimum DSi yields were reached. To estimate an uperturbed DSi yield for the larger eutrophic southeastern watersheds is still difficult, since no unperturbed watersheds for comparison were available. However, a rough estimate indicate that the DSi flux from the cultivated watersheds to the Baltic Sea is nowadays only half the uperturbed flux. Overall, the riverine DSi loads to the Baltic Sea might have dropped with 30–40% during the last century.
© 2007 Elsevier B.V. All rights reserved.

Keywords: Dissolved silicate; Biogenic silica; Retention; River loads; Damming; Eutrophication; Baltic Sea

1. Introduction

On a global scale, dissolved silicate (DSi) river concentrations and loads have been described as a function of runoff temperature and bedrock type (Meybeck, 1979) or runoff-temperature and physical denudation (Gaillardet et al., 1999). These factors are also believed to be the major environmental variables controlling chemical weathering rates of silicate minerals. DSi yields range between roughly 500–5000 kg km^{-2} yr^{-1} globally and are highest in areas with high weathering

* Corresponding author.
E-mail address: christoph.humborg@itm.su.se (C. Humborg).

0924-7963/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.jmarsys.2007.10.014

rates, *i.e.*, in the Himalayans and watersheds on volcanic bedrocks (Jennerjahn et al., 2006). These authors stress also the significance of specific discharge that correlate significantly with DSi yields. On a regional scale, the global patterns between DSi yield and the above mentioned environmental variables are more difficult to observe, since the heterogeneity in landscape and hydrological variables between watersheds become clearly discernable in small to mid sized watersheds (10^2 to 10^5 km^2) compared to major global watersheds integrating various landcover types (Smith et al., 2005). For the same reasons, human impacts vary more between smaller watershed systems making it difficult to disentangle natural from anthropogenic effects on DSi land sea fluxes.

The effects of lakes in lowering DSi concentrations of aquatic systems and DSi loads to the sea has been first described by Schelske and Stoermer (1971) for the eutrophic Lower Great Lakes and by Van Bennekom and Salomons (1979) for the Aswan Dam and has been called the “artificial lake effect”. Dams convert a river into a lake, increasing water residence times and often improving light conditions in the water column giving the preconditions for algal growth, including diatoms. Diatoms frustules consists of biogenic silica (BSi) that is sequestered in the sediments; this effect is later on referred to as “particle trapping”. BSi trapping can be very efficient even in natural lakes. Hofmann et al. (2002) observed some 85% of the main Si export from Lake Lugano occurred via deposition and burial of diatom frustules in the sediments, and only les than 20% of the sediment loss was re-supplied to the water column by diffusion. Conley et al. (2000) have shown that lake area of a watershed and DSi concentrations are negatively correlated for Scandinavian rivers including eutrophic, but also ultraoligothrophic river systems. Thus, diatom blooms behind dams and subsequent sequestration of BSi in the reservoirs sediments (Conley et al., 1993) cannot be the only reason for the observed decrease in DSi concentrations. Later, it has been suggested that perturbed surface water–groundwater interactions through hydrological alterations leading to less contact of river and stream waters with vegetated soils along the riparian zone are additional causes for the reduced DSi concentrations observed in many ultraoligothrophic regulated rivers in Northern Sweden (Humborg et al., 2002; Humborg et al., 2006a); this effect is later on referred to as “weathering reductions induced by hydrological alterations”. Generally, there is accumulating evidence that plants play a significant role in the global Si cycle (Conley, 2002) and control even the riverine DSi export fluxes (Derry et al., 2005). DSi concentrations in the boreal rivers of Northern Sweden can best be described as a function of vegetation and peatland cover (Humborg et al., 2004) as well as a function of the degree of damming (Humborg et al., 2002). For the eutrophic watersheds of the Baltic Sea the effect of BSi particle trapping has been demonstrated by comparing the moderately dammed Vistula with the undammed Odra and it has been concluded that a full trapping of diatom derived BSi might be responsible for some 25% reduction in DSi loads of these types of rivers (Humborg et al., 2006a). In heavily dammed eutrophic rivers possibly the co-occurrence of both effects, *i.e.*, weathering reductions induced by hydrological alterations and particle trapping, may lead to even lower DSi land–sea fluxes.

The aim of this paper is to investigate the effect of lentic waters (lakes and reservoirs) in different biomes of the Baltic Sea catchment and discuss probable past DSi inputs into the Baltic Sea; even effects of vegetation will be tested. The data set on DSi land–sea fluxes generated by the SIBER project covers the entire Baltic Sea catchments ($1.73*10^6$ km^2), which include subarctic watersheds in the North, boreal watersheds along the major parts of Sweden, Finland and Russia and temperate watersheds in the southeastern part (Baltic States, Poland, Germany) and thus provides for the first time a full data set of DSi fluxes from all major rivers to the Baltic Sea. Previous data compilations can be found in the GLORI database that cover only a few rivers and is based on much less observations (Meybeck and Ragu, 1995). This new data base allows us for a first time to compare DSi fluxes in various biomes on this regional scale and to come up with a rough estimate on the possible reductions in DSi land–sea fluxes to the Baltic Sea due to anthropogenic impacts. This task is not straight forward, because a complete set of monitoring data on DSi river laods to the Baltic Sea exist since the 1980ies and show no significant trends (Papush and Danielsson, 2006), i.e., the existing time series reflect the situation after major anthropogenic impacts as eutrophication and damming of rivers have already occurred. However there are other ways to estimate long-term trends in DSi. We will use the concept of water residence time that has been widely used to describe the riverine exports of nitrogen (N) and phosphorus (P), but to our knowledge not for DSi, to the coastal water bodies (Howarth, 1996; Nixon et al., 1996; Behrendt and Opitz, 1999), since lakes and reservoirs change the residence times significantly. We will test the hypothesis that effects of reservoirs and lakes will manifest differently in the different biomes of the Baltic Sea catchment, since the underlying processes, *i.e.*, weathering reductions induced by hydrological alterations and particle trapping, do play different roles in the various biomes.

Download English Version:

https://daneshyari.com/en/article/4549057

Download Persian Version:

https://daneshyari.com/article/4549057

Daneshyari.com