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Nutrient dynamics at the sediment–water interface in a Mediterranean lagoon (Thau, France): Influence of biodeposition by shellfish farming activities

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Abstract

The Thau Lagoon, a French Mediterranean shallow lagoon, is a site where extensive shellfish farming occurs. The aim of the present work is to evaluate the role of this activity on nutrient exchange at the sediment–water interface in relation to organic matter (OM) sedimentation and degradation. Two stations inside (C5) and outside (C4) of the shellfish farming areas were sampled at three seasons. Porewater chemistry surveys and calculated diffusive fluxes were used to evaluate the trophic status of the Thau lagoon. Quantitative (Particulate Organic Carbon) as well as qualitative OM (Hydrogen Index, Carbohydrates) analyses were performed on sediments to assess OM characteristics. Results emphasized that surficial sediments at C5 are always more enriched in OM. Porewater nutrient concentrations are 10–20 times higher at C5 than at C4. In June 2003, the porewater profiles exhibit a sharp gradient at the bottom waters, indicating a hypereutrophic status, leading to an anoxic crisis.

Keywords: Nutrients; Dissolved organic matter; Nutrient fluxes; Neutral carbohydrate; Sediment–water interface; Coastal waters; Eutrophication

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1. Introduction

The French Mediterranean coast is bordered by several shallow lagoons formed during the later stages of the Holocence transgression. These lagoons, located in a densely populated transition zone between the continent and the sea, are very fragile ecosystems, and have been heavily impacted by human activity. These lagoons, and especially Thau, suffer from eutrophication as a result of (i) excessive nutrients inputs from the catchment, (ii) very low water renewal (water residence time of about three months) and (iii) specific climate conditions (high temperature, limited rainfull periods, low tidal currents, Bacher et al., 1996).

Thau, the biggest of the lagoons, is the site of shellfish farming. The shellfish production zones cover 1/5 of the lagoon area and its annual production represents about 15,000 t. This production is made according to an original technique of binding oysters (or mussels) on ropes, themselves fixed on metallic structures (tables). Then, the continual immersion of oysters-mussels ropes involves an abundant epibiose development. The presence of these heterotrophic organisms (epibiose) in the water column modifies the transfer and the transformation of the organic matter within the lagoon ecosystem (Mazouni et al., 1996, 1998). For example, sedimentation fluxes have been estimated from 100 to 400 mg C m^{-2} h^{-1} in shellfish areas. These fluxes, 2–4 times higher than in the areas without shellfish, can significantly increase the sedimentation rate (Grenz et al., 1992). In addition, the combination of high organic matter (OM) productivity, high summer temperature (25 °C water surface temperature) and low wind speed induces the rapid depletion of dissolved oxygen and subsequent anoxia (Harzallah and Chapelle, 2002). Anoxic conditions develop in summer both at the sediment–water interface and at the bottom of the water column. These anoxic episodes, locally named ''malaigues'', induce a high turbidity and H_2S smell during the summer months with a large shellfish mortality.

Previous studies have established that the sediment compartment is a sink for particulate phosphate (Boström et al., 1982, 1988; Caraco et al., 1990). This compartment could also become a source through the release of dissolved species under well defined pH and Redox conditions (Boers, 1991; Song and Müller, 1999). Numerous parameters influence the exchange of nutrients at the sediment–water interface and accentuate the influence of multi-environmental parameters such as bacterial activity (Gächter and Meyer, 1993), iron-hydroxide chemistry or oxygen conditions (Maine et al., 1992; De Montigny et al., 1993). Moreover, OM buried in sediments may impact the nutrient release by forming refractory organo-metallic complexes with iron and phosphorus (Paludan and Jensen, 1995; De Groot and Golterman, 1993; Hirata, 1985). Even if these complexes are subjected to microbiological mineralisation as a carbon and an energy source, their low availability may delay the nutrient release. If this low bioavailable OM quantity exceeds the bacterial mineralisation capacity of the sediment, these complexes will accumulate in the sediment compartment as a 'residual organic phosphate' fraction (De Groot and Golterman, 1993) that will only be remobilised with difficulty. The determination of bulk sedimentary OM content alone is therefore not sufficient to characterize nutrient release at the sediment–water interface: measurements of OM quality and degradation rate are needed to fully assess the extent of degradation of (and potential nutrient release from) sediment organic components.

The aim of the present work is to discuss the role of shellfish farming on the nutrient exchange dynamic at the sediment–water interface in two contrasting sites of the Thau Lagoon: inside and outside of the shellfish farming areas. A seasonal porewater survey