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Role of tidal pumping on nutrient cycling in a temperate lagoon (Arcachon Bay, France)

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Abstract

The hypothesis of nutrient-rich pore-waters seeping at low tide through sediments to channel waters, which drain tidal flats during ebb, was evaluated in the Arcachon lagoon. The back of the bay is affected by freshwater inputs and underground freshwater discharges. The upper part of tidal flat consists of permeable sandy sediments, which are covered by a muddy sediment layer on the lower part. Permeable sediments outcrop in the bed of channel web. Surface water chemistry and early diagenesis processes in sediment were estimated by collecting channel web waters and cores on a tidal flat and in channels at different seasons and time scales. Waters from tidal creeks are under-oxygenated, and enriched in reduced solutes. Muddy sediments showed evidences of strong organic matter mineralization and bioturbation. Underlying permeable sandy sediments revealed as well evidences of an enrichment of inorganic nutrients, and dilution with fresh continental groundwater. During ebb, tidal creek waters stem from mudflats by seeping of anoxic pore-waters, and from permeable sediments by advection of reduced waters. A rough estimation shows that the yearly contribution of this tidal pump of pore-waters for dissolved inorganic phosphorus (DIP) and ammonia inputs is of the same order of magnitude than river inputs for the studied part of the bay. Extrapolated to the whole Arcachon lagoon, pore-water discharge at low tide supplies to water column at least 556 kmol yr^{-1} and 18300 kmol yr^{-1} of DIP and NH_4^+, respectively. Tidal drainage at low tide represents therefore a minimal contribution of recycled nutrient of 55% for DIP and 15% for dissolved inorganic nitrogen to the lagoon.

Keywords: Tidal pump; Tidal creek water; Organic matter mineralization; Phosphorus; Nitrogen; Pore-waters seeping; Arcachon Bay

1. Introduction

Lagoon environments are highly dynamic systems controlled by physical processes and subjected to marine and continental influences. They play a key role as spawning grounds for fish and shellfish, and have been extensively exploited for aquaculture, fishing, tourism … Eutrophication is a naturally occurring process in most lagoons because of their function as a sink for nutrient inputs from land and sea (De Wit et al., 2001). Thus, processes controlling nutrient levels and distributions in lagoon environments must be understood to assess the impact of human activities and global natural change on the chemical cycling and ecology of these coastal ecosystems.

In lagoon ecosystems, where depth is low and intertidal zone is extended, the sediment becomes the central unit of biogeochemical nutrient cycles and

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intense biological productivity. During immersion, numerous studies demonstrated complex interactions and high exchanges between sediment and overlying water occurring in tidal environments (Falcao and Vale, 1995; Rocha et al., 1995; Rocha, 1998; Morin and Morse, 1999; Mortimer et al., 1999; Welsh et al., 2000; Sakamaki et al., 2006). The coupling between benthic processes and exchanges with water is linked to benthic production and deposition of organic matter, subsequent remineralization of organic matter with release of inorganic nutrients to pore-waters, and transport of dissolved nutrients back into overlying water column (Jahnke et al., 2003; Sakamaki et al., 2006). Thus, sediments are either sinks or sources of nutrients derived from external inputs and internal recycling processes. Early diagenesis products are transported to the water column through several processes. In addition to spontaneous molecular diffusion at the sediment water interface, transport of solute by bioturbation (irrigation from burrows and biodiffusion) and discharge of advective groundwater or seawater from bottom permeable sediment layers take place (Simmons, 1992; Huettel et al., 1998; Moore, 1999; Koretsky et al., 2002; Charette et al., 2005; Grigg et al., 2005; Meysman et al., 2006). During ebb, a large channel web drains intertidal flats. Sediment-channel water exchanges can be an important pathway for nutrient cycles and budget for lagoons (Agosta, 1985).

The present study focuses on the chemical composition of tidal creek waters that drain intertidal mudflats during ebb in a mesotidal coastal lagoon. We observed first that most of these creeks were not connected to surface flowing continental waters. Second, at low tide, and before flood tide reached the creeks, the runoff of flowing waters could not be explained by surface water eluviation. These observations suggested that waters flowing in tidal creeks originated partly from nutrient-rich pore-waters. Our objective was to verify this hypothesis, and to estimate the impact of these waters on the global nutrient cycle of the lagoon. Tidal creek

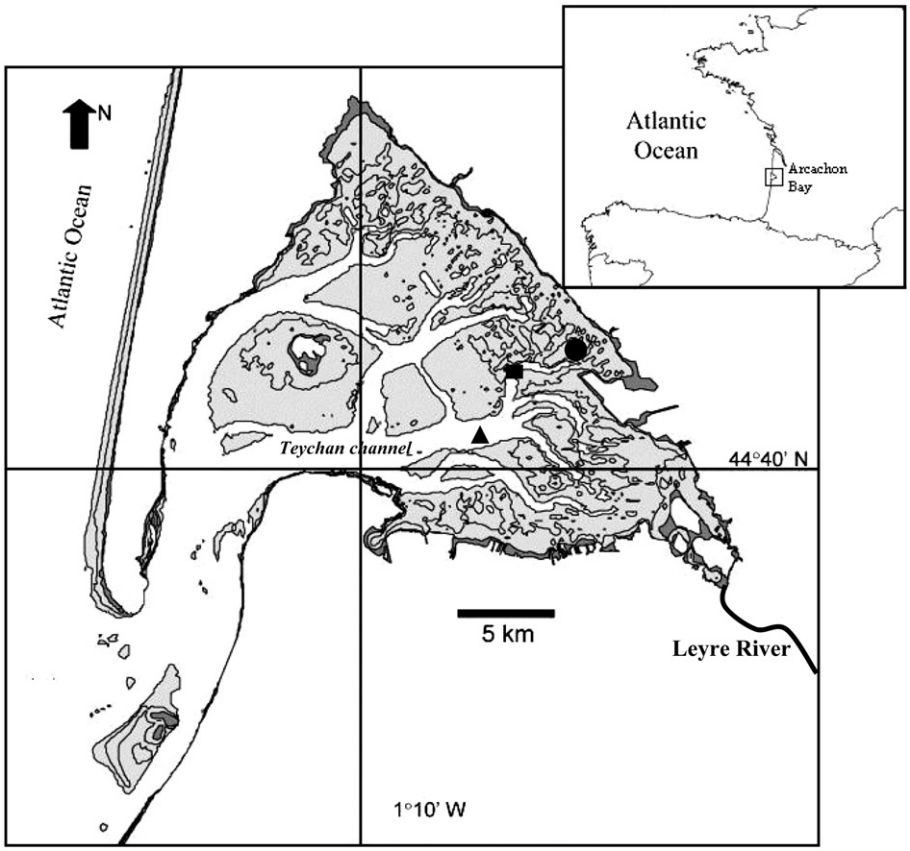

Fig. 1. Map of Arcachon Bay (France). Location of the study site (black circle), biweekly monitoring (black triangle), and tidal cycle sampling (black square). Grey areas indicate intertidal flats.