Benthic nutrient fluxes in the intertidal flat within the Changjiang (Yangtze River) Estuary

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Abstract In an annual cycle from March 2005 to February 2006, benthic nutrient fluxes were measured monthly in the Dongtan intertidal flat within the Changjiang (Yangtze River) Estuary. Except for NH4+, there always showed high fluxes from overlying water into sediment for other four nutrients. Sediments in the high and middle marshes, covered with halophyte and consisting of macrofauna, demonstrated more capabilities of assimilating nutrients from overlying water than the low marsh. Sampling seasons and nutrient concentrations in the overlying water could both exert significant effects on these fluxes. Additionally, according to the model provided by previous study, denitrification rates, that utilizing NO3- transported from overlying water (D_w) in Dongtan sediments, were estimated to be from -16 to 193 μmol·h⁻¹·m⁻² with an average value of 63 μmol·h⁻¹·m⁻² (n=18). These estimated values are still underestimates of the in-situ rates owing to the lack of consideration of D_N, i.e., denitrification supported by the local NO3- production via nitrification.

Key words benthic flux; nutrient; denitrification; Changjiang (Yangtze River) Estuary

1 Introduction

Couplings between benthic and pelagic systems play a critical role in nutrient cycling in estuarine and coastal areas (Nixon, 1981; Graf, 1992). Benthic fluxes of nutrients and other chemical compounds are indicators of the rates at which organic matter recycles within sediments (Berelson et al., 1990). In some estuarine areas, sediment-water exchanges can be important sources or sinks of nutrients and other metals to the above water column, and this mechanism not only modifies the distributions of these chemical constituents, but also results in their non-conservative behaviors. And benthic fluxes may provide chemical compounds at such a magnitude as comparable or even higher than those contributed by local river inputs (Conley et al., 1997; Friedl et al., 1998; Hammond et al., 1999; Warnken et al., 2001; Friedrich et al., 2002; Liu Sumei et al., 2003a; Jahnke et al., 2003; Wang Fenghai et al., 2003; Choe et al., 2004; Zhang Jing et al., 2004).

The Changjiang (Yangtze River) is the largest river on the Eurasian continent, and it globally ranks the third in length (6300 km), the fifth in freshwater runoff (924.8 × 10⁹ m³·a⁻¹) and the fourth in sediment discharge (0.5 × 10⁹ t·a⁻¹) (Tian Rucheng et al., 1993). More than 50% of the Changjiang particulates deposit in the estuarine areas (Chen Jiyu et al., 1985). The huge sediment delivery and unique hydrodynamic features have given birth to a series of lands as well as marshes. Dongtan, with an area of 222 km² and located on the eastern side of the Chongming Island, is considered to be the largest and most developed intertidal flat in this region (Chen Jiyu et al., 1985; Yang Shilun and Xu Haigen, 1994).

Over the last few decades, increasing eutrophication in the Changjiang Estuary and its adjacent coastal regions has been induced by increasing terrestrial delivery of nutrients, particularly NO3- (Shen Zhiliang, 2001; Liu Sumei et al., 2003b; Yan Weijin et al., 2003; Lin Chuanlan et al., 2005; Chai Chao et al., 2006; Li Chongming et al., 2006). In the mean time, hypoxia and even anoxia events are frequently observed (Li Daoji et al., 2002). The Changjiang Estuary is influenced by semidiurnal tides with tidal magnitude of 2–4 m. And Dongtan is inundated by the flood tidal currents with high nutrients twice a day, except for some landward area with high elevation that is flooded only in spring tide period.

In the present paper, monthly investigations were carried out to study the benthic nutrient fluxes at three
representative stations in Dongtan, over an annual cycle. The present study is aimed to elucidate how these benthic fluxes change with seasonal variation and how they respond to the influence of factors such as halophyte uptake and bioirrigation. Finally, a model previously established by Christensen et al. (1990) was applied to estimate the denitrification rates in Dongtan.

2 Materials and methods

2.1 Sampling sites

A dozen of investigations were carried out in Dongtan intertidal flat once a month from March 2005 to February 2006, and three representative stations on a transect perpendicular to the shore line were occupied (Fig. 1). The most landward station in the High Marsh (referred to HM hereafter; 31º28.4' N, 121º56.2' E) was located about 1 km away from the bank constructed in 1998 and flooded twice a day only in spring tide days. The most seaward station in the Low Marsh (referred to LM hereafter; 31º28.1' N, 121º56.6' E) was located about 3 km offshore and flooded twice every day. The remaining station in the Middle Marsh (referred to MM hereafter; 31º28.3' N, 121º56.4' E) was located in the transition zone. The three stations were chosen to represent different sediment properties and environmental conditions. HM and MM had extensive coverage of halophyte coverage that were dominated by *Scripus mariqueter* and *Carex scabritolis* with height of 20–30 cm. Infauna such as clamworms (*Nephthys polybranchia* and *Tyllorrhynchus heterochaetus*) and other gasteropod species (generally 1–3 mm in diameter) were easily found at HM and MM. According to our measurements, the amounts of gasteropod (mainly *Rissoina* sp., *Stenothyra* glabra, and *Assiminea violacea*) in the sediments (0–30 cm) at HM and MM could reach such a density as up to 5×10³ m⁻². In contrast, plant and presence of meio- and macro- fauna were only occasionally observed at LM, which is also called as bare flat.

Yang Shilun and Xu Haigen (1994) pointed out that, due to the decreasing velocity of incoming tidal currents, grain sizes of sediment in intertidal flats of Changjiang Estuary generally increase with the increasing distance to land, which is also confirmed by our results (Fig. 2). Additionally, capture and protection processes induced by halophyte coverage lead to even finer sediments at HM and MM; whereas at LM, owing to rare halophyte coverage and more erosion, much larger grain sizes are generally displayed (Yang Shilun, 1998). Also, nitrogen contents (%) in sediment increase successively from LM to HM (Fig. 3), presumably implying that organic matter is more ready to bound with smaller particulates.

2.2 Incubation experiments

During each sampling process, sediment core (about 30 cm in length) was collected using a 14-cm-diameter (surface area of 0.015 m²) Plexiglass tube, and then was transferred to the land laboratory in a distance of approximately 5 km from Dongtan. Care was taken to avoid disturbing the cores. In the laboratory, incubation experiments were started immediately to minimize artifacts. To mimic the *in-situ* conditions, for LM sediments, overlying water used in the incubations were from the Changjiang discharge collected at the seaward edge of Dongtan; and for HM and MM sediments, from the nearby tidal creeks. Before incubations, 2 L of overlying water were gently and slowly flushed onto the sediment surface so that disturbance and resuspension of the sediment were believed to be minimized. It should be noted that the samples at t=0 were collected independently before incubations, from the overlying waters that had not been flushed onto