Chemosphere 179 (2017) 367–378

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Spatial variation and risk assessment of trace metals in water and sediment of the Mekong Delta

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HIGHLIGHTS

- Trace metal transportation are controlled by SPM concentrations.
- Dissolved trace metal distribution vary in the salinity gradient.
- Ecotoxicological indexes in surface sediments show low to medium contamination.

ARTICLE INFO

Article history:
Received 29 November 2016
Received in revised form
23 March 2017
Accepted 26 March 2017
Available online 27 March 2017

Handling Editor: Martine Leermakers

Keywords:
Mekong Delta
Trace metals
Ecotoxicological index
Tropical river
Estuary

ABSTRACT

The Mekong Delta, is home to 17 million inhabitants and faces numerous challenges relating to climate change, environmental degradation and water issues. In this study, we assess trace metals concentrations (Al, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Mo, Cd, Hg, Pb) in the water, suspended particulate matter and surface sediments of the Tien River, the Northern branch of the Mekong Delta, during both dry and rainy seasons. Metal concentrations in the dissolved and suspended particle phases remain in the low concentration range of the main Asian Tropical River. During transportation in the riverine part, we evidenced that V, Cr, Co, As and Pb are dominant in the particulate phase while Mo, Ni and Cu dominate in the dissolved fraction. In the salinity gradient, dissolved U, V, Mo exhibit conservative behaviour while Ni, Cu, As, Co and Cd showed additive behaviour suggesting desorption processes. In the surface sediment, metal concentrations are controlled by the particle-size, POC contents and Fe, Al and Mn – oxy(hydr)oxides. Calculated Enrichment Factor and Geoaccumulation Index evidenced As enrichment while the calculated mean effect range median quotients evidenced a low to medium ecotoxicological potential effects range in the surface sediments.

1. Introduction

Deltas and estuaries play a major role in material and element transport from river to ocean and on biogeochemical cycles. The various physical and chemical gradients that occur in this mixing environment affect the partitioning, mobility and reactivity of elements such as nutrients and trace metals (e.g. Du Laing et al., 2008; de Souza Machado et al., 2016; Garnier et al., 2010). Because of their persistence, toxicity and ability to accumulate in organisms, trace metals are major pollutants and are considered a high priority (i.e. European Water Framework Directive (Anonymous, 2000), US-EPA (40 CFR Part 423, Appendix A). Trace metals in aquatic environments originate mostly from natural erosion and soil leaching. They are also released by human activity such as industrial, domestic, urban and agricultural practices. Suspended particles are a key factor in contaminant transport from the continent to the ocean, making their quality assessment a major scientific concern (e.g. Apitz and Power, 2002). Understanding the processes controlling elemental transport and reactivity between

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http://dx.doi.org/10.1016/j.chemosphere.2017.03.105
0045-6535/

the dissolved and particulate (both suspended and deposited sediments) phases in rivers and more particularly in estuaries is thus crucial to assess their impact in terms of contamination and ecotoxicological risks.

The Mekong River is the longest River in Southeast Asia with a total length of 4800 km and a drainage basin of 795,000 km^2. It originates in the Tibetan Plateau of western China and flows southward through China, Myanmar, Laos, Thailand, and Cambodia, before entering Vietnam through the Delta and then discharging into the South China Sea. The Mekong Delta is one of the world's largest deltas (39 000 km^2) and has a population of around 17 million people (GSO, 2016). It is the principal area of rice production in Vietnam and its economy is largely reliant on agriculture (namely rice and fruit) and aquaculture (mainly shrimp and catfish). Despite recent intensification of agricultural and aquaculture activity as well as rapid urban growth, the Mekong Delta remains one of the poorest regions in Vietnam (Renaud and Künzer, 2012). The delta's natural and social systems face numerous challenges related to climate change, environmental degradation and water issues such as flooding, water pollution and access to water (Xue et al., 2011; Renaud and Künzer, 2012). Hydroelectric dams on the Mekong River and its tributaries have severely impacted the aquatic ecosystem's biodiversity (Campbell, 2012). Sediment supply to the delta and the ocean is also impacted, and estimates suggest that it retains about 32–41 million tons of sediment per year (Kummu et al., 2010). Indeed, before dam construction, the Mekong was one of the 10 largest sediment suppliers to the world's oceans with an annual sediment flux estimated at around 160 million tons (Milliman and Meade, 1983; Milliman and Ren, 1995). Numerous dams are currently under construction or in the planning stages on the main stream and in the tributaries, increasing the vulnerability of the Mekong River. The Mekong Delta river quality is also threatened by the development of intensive agricultural and aquaculture activity and the release of pesticides (Toan et al., 2013), antibiotics (Giang et al., 2015), nutrients and trace metals (Wilbers et al., 2014).

Information on trace metal risk assessment in the Mekong Delta's waters and surface sediments is not readily available (e.g. Cenci and Martin, 2004; Noh et al., 2013; Wilbers et al., 2014) and studies that are available have mainly focused on arsenic groundwater contamination issues and consequences to population health (Berg et al., 2007; Buschmann et al., 2008; Hoang et al., 2010). Thus, considering the environmental challenges that are facing the Mekong Delta, the purpose of this study is to evaluate trace element contamination (Al, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Mo, Cd, Hg, Pb, U) of the Tien River, Mekong Delta, Vietnam. Two snapshot campaigns were performed along the Tien River during the contrasted seasons (dry and rainy seasons). The objectives were (i) to get an inventory of dissolved and particulate polymetallic concentrations which affect the quality of the river, (ii) to identify the fate of metal distribution in the water column and sediment and the factors controlling their partitioning, and (iii) to provide a risk assessment of surface sediments based on geochemical and ecotoxicological indexes.

2. Material and methods

2.1. The Tien River, Mekong Delta, Vietnam

The Mekong Delta begins in Phnom Penh, Cambodia, where the river divides into its two main branches, the Mekong and the Bassac, which are respectively subdivided into six and three branches, the Tien River being the northern branch of the Delta (Fig. 1, 150 km long, 450–2250 m width, up to 10 m depth). The Mekong Delta is composed of Holocene alluvial sediments of marine and fluvial origin that were rapidly deposited beginning 8000 year BP (Nguyen et al., 2000; Xue et al., 2011). The climate is monsoonal humid and tropical, with average temperatures of 27–30 °C. The rainy season (approximately 80% of the annual rainfall) lasts from May to October. Accordingly, the Mekong River discharge reaches a minimum in April–May and a maximum in September–October in the lower Mekong (Xue et al., 2012) and the same is true for the Bassac River where the river discharge fluctuates from 200 m^3 s^{-1} to 7000 m^3 s^{-1} respectively (Loisel et al., 2014).

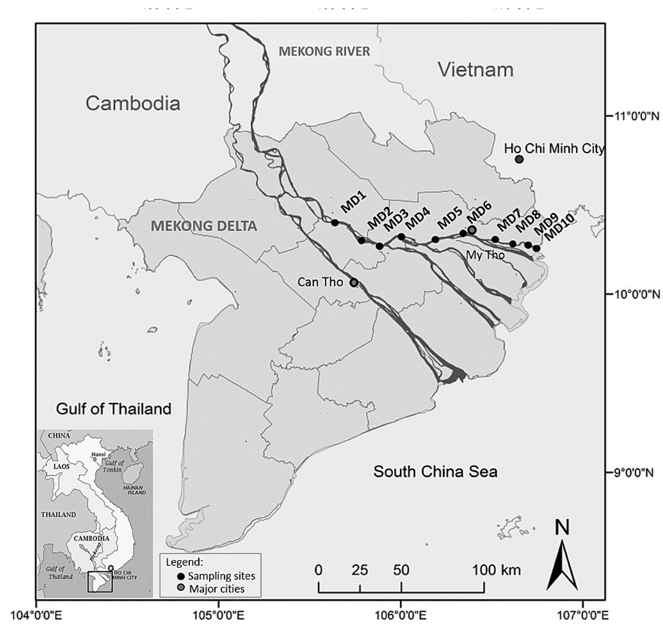

Fig. 1. Sampling location map.

2.2. Sampling and handling

Two snapshot campaigns were conducted along the Tien River during dry and wet seasons, in March and October 2013, respectively. At each site (Table 1a), temperature, pH, dissolved oxygen, conductivity and salinity were immediately measured in situ using a multi parameter probe (WTW 3420®). Then, water was sampled at 10–50 cm below surface using a Niskin non-metallic water sampling bottle (General Oceanic®) and stored in 5L PE bottle. All filtered and unfiltered samples were stored in a cooler (~4 °C) until being brought back to the laboratory. A first filtration was performed on glass microfiber filter (0.7 μm GF/F Whatman®, pre-weighed and preheated at 500 °C). The filtrate was stored in a 60 ml bottle and kept at −18 °C for analyses of dissolved nutrient while filters, used for determination of suspended particulate matter (SPM) and particulate organic carbon (POC) concentrations, were dried at 50 °C, then weighed and stored at room temperature. A second filtration was realized on pre-weighed PTFE filters (0.20 μm Omnipore®) for analysis of particulate and dissolved trace metals. After filtration, the filtrate was acidified (Normapur HNO_3 2% v/v) and stored in a 30 ml acid pre-cleaned PP bottle (Normapur HNO_3 10% v/v) at 4 °C while the filters were kept in sterile plastic petri dishes at −18 °C, then freeze-dried, weighed and stored in the plastic petri dishes. To prevent contamination during collection and handling, all equipment was cleaned and we wrapped each subsample individually in two polyethylene bags. Surface sediments were collected at each site using a Shipek sediment grab sampler, immediately stored in PE bags at −18 °C and, freeze-dried.