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Heavy metals in river and coast sediments of the Jakarta Bay region (Indonesia) — Geogenic versus anthropogenic sources

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ABSTRACT

Sediment geochemistry of the Jakarta region, a densely populated tropical coast, is studied — with particular focus on rivers discharging to Jakarta Bay. Weathering volcanics in the river catchment area control the composition of major elements, As, Cr and in part Cu. In contrast, Zn, Ni, Pb and partly Cu are affected by anthropogenic sources, mainly in central Jakarta City. The data reflect a high variability of local emission sources, among which metal processing industries, fertilizers or untreated animal waste may be important. In particular, the role of street dusts is emphasized. Locally, heavy metals reach levels considered to have adverse biological effects. River discharge leads to anthropogenic enrichment of heavy metals in the coastal sediments. Element data also show geogenic effects on the composition of the coastal sediments, such as mixing of detrital silicates with biogenic carbonates as well as suspended particulate matter from the ocean.

1. Introduction

The chemical composition of sediments is on the one hand controlled by geogenic components, such as detrital minerals or precipitates formed in the water, biogenic minerals or organic matter. On the other hand, the chemical composition of sediments is affected by anthropogenic emissions. The latter may be present as particulate matter or organic and inorganic contaminants adsorbed to geogenic components.

This can well be observed in sediments of densely populated coasts, such as Jakarta Bay, the area which is addressed in this study. Sources of sedimentary components in coastal areas are local river discharges, suspended particulate matter in the oceanic water column, particles derived from Aeolian transport or volcanic fallouts as well as biogenic matter or chemical precipitates formed in the coastal water column.

The chemical composition of Jakarta Bay sediments and the anthropogenic input of heavy metals were in detailed studied by Williams et al. (1997, 2000). According to these studies, the trace metals V, Cr, Co and Ni are mainly controlled by the abundance of geogenic argillaceous terrestrial material whereas Cu, Zn, Pb and Sn derive from anthropogenic municipal and industrial sources. This is confirmed by results of Takarina (2010) and Zuraida et al. (2012), who also reported on heavy metal contamination of the Jakarta Bay sediments.

On the basis of ^{210}Pb geochronology, analysis of heavy metals and Pb isotopes, Hosono et al. (2011) showed the onset of the anthropogenic input of heavy metals in the 1920s and a significant increase of Zn and Pb accumulation between the 1970s and the end of the 1990s. Despite of stricter environmental regulations in Indonesia, which are in line with decreasing Pb and Zn concentrations in younger sediments (Hosono et al., 2011), anthropogenic metal discharge to the Jakarta Bay ecosystem still is significant. This is corroborated by other studies, which point to increasing metal contamination in the Jakarta Bay (Takarina, 2010). Enhanced metal contamination in combination with other human-induced stressors is also considered to have caused adverse effects on marine communities in the Jakarta Bay (van der Meij et al., 2009, 2010, Cleary et al., 2014, Dsikowitzky et al., 2016a–this issue). Discharge of untreated municipal wastewaters was shown to be most relevant for water quality (Dsikowitzky et al., 2016b–this issue).

Most rivers debouching into the Jakarta Bay pass densely populated and industrially affected areas, their sediments certainly act as a first

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important sink to anthropogenic input of heavy metals. These rivers flowing through the megacity Jakarta are characterized by significant sediment discharge, which is mainly due to the high seasonality in rainfall at the dry subhumid conditions in the region (Cecil et al., 2003). Rivers therefore certainly represent the most important source of sedimentary components, and consequently also of geogenic and anthropogenic heavy metals in the Jakarta Bay. While most studies have focussed on the bay sediments, the Jakarta river sediments have not been intensively studied (Williams et al., 1997, 2000, Takarina, 2010, Zuraida et al., 2012).

Thus, it is the aim of this study to characterize the mineralogical and chemical composition and in particular the heavy metal signatures (Cr, Ni, Cu, Zn, As, Pb) of sediment samples from rivers debouching into the Jakarta Bay. Another goal is to distinguish anthropogenic and geogenic input of heavy metals to these sediments. The role of river sediments for the composition of coastal sediments is discussed. Finally, a risk assessment is carried out to show if negative biological effects have to be expected due to enhanced heavy metal concentrations.

2. Study area

The study area, situated in the NW of Java, Indonesia, is characterized by a dry subhumid monsoon-type climate, leading to strong precipitation mainly in the months between December and March. In contrast, the months from May to September represent the dry season with hardly any rainfall (Cecil et al., 2003, Hoekstra and Tiktanata, 1988).

The catchment area of rivers discharging to the Jakarta Bay comprises the low coastal Plain of Jakarta, the mountainous Bogor zone as well as the Quaternary volcanic centres of central Java. The Plain of Jakarta mainly consists of Miocene to Holocene shallow marine sediments as well as of fluvial deposits derived from erosion of volcanic rocks (Bronto, 1989). The Bogor zone following to the south of the coastal plain is formed by strongly folded tuffaceous siliciclastic sediments and intrusive rocks, also mainly of Miocene and younger age. At its southern margin this zone is intruded and overlain by the Quaternary subvolcanic and volcanic rocks (Bronto, 1989).

The predominance of easily erodible volcanic rocks and soils in combination with the strongly seasonal rainfall lead to high soil erosion and denudation rates (Cecil et al., 2003, Hoekstra and Tiktanata, 1988).

In addition to the two larger fluvial systems of Cisadane and Citarum rivers situated to the west and east of the Jakarta Bay, respectively, several rivers, among which the Pesanggrahan, Ciliwung, Sunter and Bekasi rivers are the largest, discharge into the central part of the bay (Fig. 1). Central Jakarta and also the surrounding densely populated areas – which form Greater Jakarta – are characterized by the existence of numerous canals, which may also be connected to rivers. In particular the lower reaches of many rivers are canalized.

Greater Jakarta belongs to the largest cities in the world (Zuraida et al., 2012). The population of Jakarta City was estimated to 10 million in 2009 (Hudalah and Firman, 2012). It is a major economic center in Indonesia and hosts many industrial sectors, including metal processing, pharmaceutical manufacturing units, pulp and paper production facilities, tanneries as well as chemical and petrochemical industries (BPLDH 2013, Williams et al., 1997). Consequently, the Jakarta Bay may be considered as a focal point in which industrial as well as agricultural emissions can be observed in addition to animal or human excretions as well as municipal wastes (Zuraida et al., 2012). Intensive industrial emissions including heavy metals are reported for the harbour area (Tanjung Priok) in the center of the bay. The south-western shore-line is characterized by intensive industrial activity, e.g. Muara Baru, Sunda Kelapa, as well as the eastern part of the bay close to the Sunter and Cakung river mouths (Takarina, 2010, Williams et al., 1997). Highest industrial pollutant loads of a single river are reported for Bekasi river, which discharges to the eastern part of the bay (Williams et al., 1997).

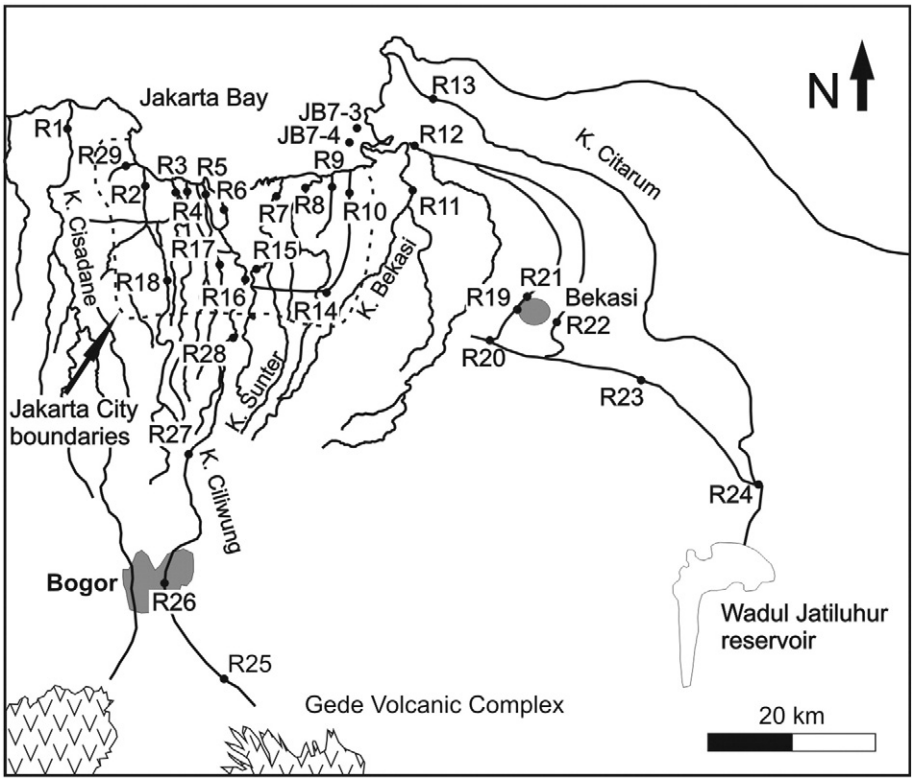

Fig. 1. Sketch map showing the fluvial system debouching to the Jakarta Bay and sites for sampling of river sediments in the City of Jakarta as well as near to the towns of Bogor and Bekasi. At sites JB7-3 and JB7-4 samples were dredged in the bay.