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# Spatial distribution and seasonal variation of the trace hazardous element contamination in Jakarta Bay, Indonesia

Tuti Hartati Siregar [a,*], Nandang Priyanto [a], Ajeng Kurniasari Putri [a], Novalia Rachmawati [a], Radestya Triwibowo [a], Larissa Dsikowitzky [b], Jan Schwarzbauer [b]

[a] Research Centre for Marine and Fisheries Product Processing and Biotechnology, Ministry of Marine and Fisheries, KS Tubun Petamburan VI Slipi, Jakarta, Indonesia
[b] Institute of Geology and Geochemistry of Petroleum and Coal, RWTH Aachen University, Lochnerstr. 4-20, 52056 Aachen, Germany

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ABSTRACT

The Jakarta Bay Ecosystem is located in the vicinity of the megacity Jakarta, the capital city of Indonesia. Surrounding rivers and canals, carrying solid and fluid waste from households and several industrial areas, flow into the bay. Therefore, the levels of selected trace hazardous elements in water, surface sediments and animal tissues were determined. Samples were collected from two different seasons. The spatial distribution pattern of trace elements in sediment and water as well as the seasonal variation of the contamination were assessed. Quality assessment of sediment using the effects range median (ERM) showed that the concentrations of Hg, Cu and Cr at some stations exceeded the recommended values. Moreover, the concentrations of several trace hazardous elements in the sediments exceeded previously reported toxicity thresholds for benthic species.
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## 1. Introduction

Trace elements such as Cd, Hg, Cu, Pb and As are known as harmful pollutants in marine environments. These metals enter coastal ecosystems through riverine transport of trace element loads originating from the natural weathering of rocks in the catchment areas or from anthropogenic sources, such as industrial or municipal wastewater discharges. A further source is atmospheric deposition.

Trace hazardous elements that have adverse effect on human health including lead (Pb), cadmium (Cd), copper (Cu), zinc (Zn) and nickel (Ni) have been detected in water and sediment from Jakarta Bay during the last 15 years (Arifin et al., 2012; Rochyatun and Rozak, 2007; Williams et al., 2000). Because the Jakarta Bay Ecosystem is located in the vicinity of the megacity Jakarta, and surrounded by industrial zones, trace hazardous elements reach the bay from several sources such as industrial discharges, municipal wastewater discharges, surface run-off and dust precipitation (Arifin et al., 2012; Idris, 2008; Tajam and Kamal, 2013; Williams et al., 2000). In addition, agricultural activities and aquaculture practices have also influenced the pollution in the Jakarta Bay. An example of aquaculture practices in Jakarta Bay is the massive culture of green mussels (*Perna viridis*) since 1979 (Haryati et al., 2013) where the production reached 1270 tons in 2013 (BPS, 2015). The mussel is the most popular and economically affordable seafood product for the coastal communities in Jakarta, and has also been marketed to the surrounding cities such as Tangerang, Bandung and Cirebon. Therefore, despite the severe pollution in this area, the Jakarta Bay provides economic and social benefit for the local fishermen. Seafood production from Jakarta Bay supplies cheap protein source for consumers in Jakarta and its surrounding. However, the consumption of seafood from this area increases the risk for local communities to be exposed to the trace hazardous elements from Jakarta Bay (Putri et al., 2012).

The contamination of Jakarta Bay with trace hazardous elements was reported to be comparable to some other big cities in Indonesia, such as Semarang and Surabaya. The trend of this contamination was reported to decrease during the last 10 years due to more strict regulations (Arifin et al., 2012; BPLDH, 2014; Hosono et al., 2011; Williams et al., 2000). Unfortunately, up to today huge amounts of poorly treated wastewaters are discharged into the 13 canals/rivers which flow into the Jakarta Bay (e.g. Dsikowitzky et al., 2016).

An extensive research on the dynamical distribution of hazardous metals such as Hg, Pb, Cd, Cu, Cr, Co and As in Jakarta Bay is so far missing and was therefore conducted within the present study. This research aims to draw a complete picture of the spatial distribution of trace hazardous elements in Jakarta Bay considering also the origin of the

* Corresponding author.
*E-mail address:* tuti.hs@gmail.com (T.H. Siregar).

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contamination, seasonal variations and possible accumulation of the studied elements by economic important bivalve and fish species in Jakarta Bay.

## 2. Materials and methods

### 2.1. Study site

Jakarta Bay is located in the North of Jakarta, the capital city of Indonesia (latitude 106°21′ to 107°03′E and longitude 5°10′ to 6°10′S). Jakarta Bay is constrained by two capes, Tanjung Pasir to the West and Tanjung Karawang to the East. There are four major rivers discharging freshwater as well as wastewater from Jakarta and its surroundings settlements into the bay, namely Sungai Cisadane in the most westward and just outside of the bay, Sungai Angke and Sungai Ciliwung in the middle of the bay and Sungai Citarum with the largest river delta at the easternmost cape. The total area of Jakarta Bay is about 514 $km^2$, with a shoreline length of 76 km (BPLDH, 2014). The depth of Jakarta Bay is 18 m on average (BPLDH, 2014; Hosono et al., 2011; Williams et al., 2000). Besides the four major rivers, there are smaller rivers and canals discharging around 1400 $m^3$ solid and liquid waste into the center of the bay (BPLDH, 2014). The industrial areas which are located close to the Jakarta Bay such as Cilincing - North Jakarta, Pulogadung - East Jakarta, Bekasi and Bogor may also contribute to the increasing pollution of the Jakarta Bay (at stations R1, R2, R3, R6, R14, R15, see Fig. 1). According to the Statistical Bureau of DKI Jakarta (BPS, 2014) the population of Jakarta City was 10.1 million in 2014, and the total area of Jakarta City was 662.33 $km^2$.

### 2.2. Sample collection

A sampling network of 26 sampling stations in Jakarta Bay and of 16 estuary stations were sampled in April (wet transitional to dry season, sampling campaign I) and November 2014 (dry transitional to wet season, sampling campaign II) (Fig. 1). Sites were positioned along transects using a Garmin 585 global positioning system (GPS) with a resolution of about 3.5 m. Sample collection was done following the method described by Hutagalung et al. (1997). Surface sediment samples were collected using a Van Veen grab. They were stored in polypropylene tubes and kept on ice until being transported to the laboratory. Water samples were recovered from 1 to 2 m depth below the water surface using a Nansen bottle. The samples were filtered using a 0.45 μm PPDF filter, filled in polypropylene bottles, acidified with 1% $HNO_3$ for preservation and kept on ice until being transported to the laboratory. For mercury analysis, samples were stored in brown glass bottles, preserved with $HNO_3$ and $K_2Cr_2O_7$ and kept on ice until being transported to the laboratory. Mussel samples were bought from the owners of aquaculture facilities in the Jakarta Bay, while fish samples were purchased from the local fisherman who at the time of sampling caught fish in the bay. Background information about the sampled fish and mussel species are presented in Table 1. In situ measurements such as pH, salinity, temperature and turbidity were also performed. All samples were stored at 4 °C prior to analysis.

### 2.3. Sample preparation and analysis

Before analysis, all laboratory equipment was cleaned with 2% nitric acid pro analysis (Merck, USA). Sample preparation and analysis was performed following the method provided by the instrument manual (Berghoff, Germany for microwave destruction and Agilent 7700X, USA for ICPMS analysis).

Sediment samples were dried in an oven at a temperature of 105 °C for 8 h. 100 mg sample aliquots were placed in a digestion vessel. Then 8 ml of $HNO_3$ (65%, suprapur) and 2 ml of HF (40%, pro analysis) were added. After 2 min, the vessel was closed and heated in a microwave oven (Berghof speedwave two, Germany) with the program stated in

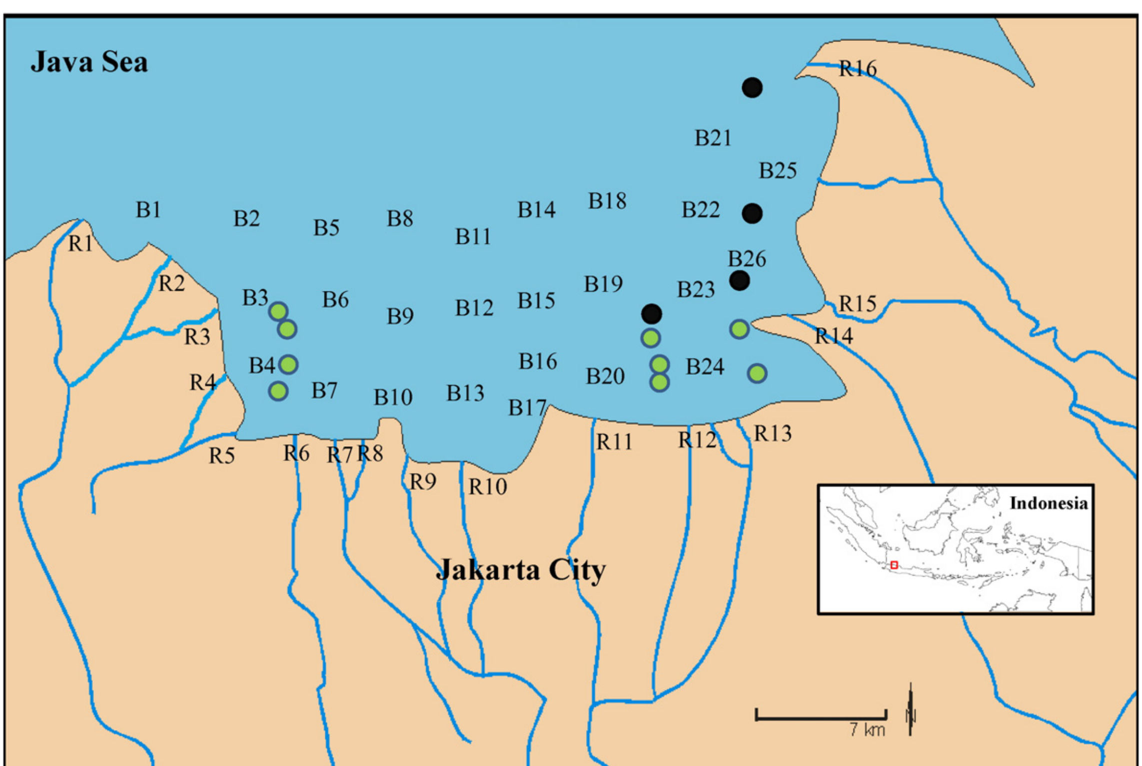


**Fig. 1.** Schematic map of the study area. Water and sediment samples were taken in Jakarta Bay and at the mouths of the rivers/canals which discharge into Jakarta Bay. The sampled rivers/canals flow through the Greater Jakarta City area. Green dots indicate the aquaculture facilities where green mussel samples (*Perna viridis*) were taken. The black dots indicate the locations where fish samples were bought from the local fishermen.

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