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Accumulation of toxic metals and organic micro-pollutants in sediments from tropical urban rivers, Kinshasa, Democratic Republic of the Congo

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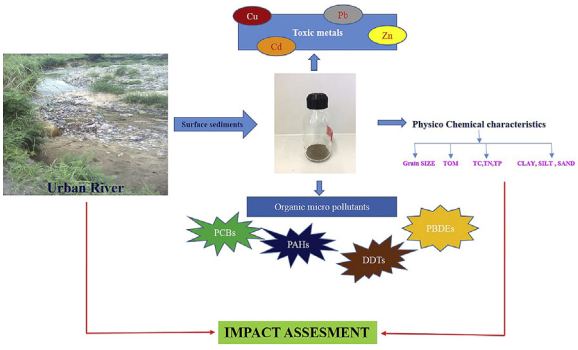
HIGHLIGHTS

- First investigation of metals, OCPs, PCBs, PBDEs and PAHs in urban rivers of Kinshasa.
- High level of metals, OCPs, PCBs, PBDEs and PAHs was detected in sediment samples.
- PBDE congeners are relatively higher compared to many similar environment in Africa.
- High level of DDTs, deltamethrin and chlorpyrifos was detected in sediment samples.
- Correlation among the parameters states that the contaminants may have the same origin.

GRAPHICAL ABSTRACT



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ABSTRACT

The increasing contamination of fresh water resource by toxic metals and Persistence Organic Pollutants (POPs) is a major environmental concern globally. In the present investigation, surface sediments collected from three main rivers named, Makelele, Kalamu and Nsanga, draining through the city of Kinshasa, Democratic Republic of the Congo, were characterized for grain size, organic matter, toxic metals, POPs (including organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs)), and polycyclic aromatic hydrocarbons (PAHs). Furthermore, enrichment factor (EF) and geoaccumulation index (*Igeo*) were performed to determine metal source and pollution status. The results highlighted high concentration of toxic metals in all sediment samples, reaching the values (mg kg^{-1}) of 325 (Cu), 549 (Zn), 165 (Pb) and 1.5 (Cd). High values of PCBs and OCPs were detected in sediment samples, e.g. in Makelele river, PCB values ranged from 0.9 to 10.9 with total PCBs ($\sum$7 PCBs × 4.3): 169.3 μg kg^{-1}; OCPs from 21.6 to 146.8 with $\sum$OCPs: 270.6 μg kg^{-1}. The PBDEs concentrations were higher in investigated rivers comparatively with values detected in many rivers

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PAHs
Tropical conditions

from Sub-Saharan Africa. The ΣPAHs value ranged from 22.6 to 1011.9 μg kg^{-1}. River contamination may be explained by local intense domestic activities, urban and agricultural runoff, industrial and hospital wastewaters discharge into the rivers without prior treatment. This research provides not only a first baseline information on the extent of contamination in this tropical ecosystem but also represents useful tools incorporated to evaluate sediment quality in the river receiving systems which can be applied to similar aquatic environments.

1. Introduction

The water resource contamination by toxic metals and POPs is a worldwide problem because these chemicals are not degradable in the environment and can persist in sediments for decades or even centuries. Most of them are characterized by long-term stability and can have high toxic effects on aquatic living organisms (Wildi et al., 2004; Ghrefat and Yusuf, 2006; Thevenon et al., 2012; Mwanamoki et al., 2014b). Previous studies have highlighted that sediment as recipients and reservoirs of toxic heavy metals (Poté et al., 2008; Varol, 2011). In addition, accumulated toxic elements and POPs in sediments over the period of time serve as important indicators to assess and revaluate the pollution history (Mwanamoki et al., 2014a; Devarajan et al., 2015b; Doong et al., 2008). On the other hand, polluted sediments represent a significant source of contamination in freshwater organisms and have long-term implications for human health (Thevenon et al., 2013; Raghunath et al., 1999). The discharge of untreated urban effluents into river environments is a major concern in developing countries. Given this fact, in recent years accumulation of heavy metals in river sediments from developing countries have been reported with more attention (Mubedi et al., 2013; Devarajan et al., 2015b; Tamim et al., 2016; Laffite et al., 2016). Hydrophobic organic compounds (HOCs), such as PAHs, PCBs, and OCPs have been identified as environmental pollutants in all environmental compartments (Wu et al., 1999; Poté et al., 2008). Due to their high persistence and low solubility in water, HOCs can accumulate in sediments (Poté et al., 2008). European Union (EU) and the US Environmental Protection Agency (USEPA) highlighted that PAHs are of significant concern with regard to human health as having carcinogenic properties and bioavailability with water, soil, and sediments (Sindermann, 2006; Zhang et al., 2012). PCBs, PAHs, OCPs, and PBDEs are known to have extraordinary stability, high toxicity, extremely high long-range atmospheric transportability, and potential threats to human health and environmental ecosystems (Cui et al., 2016; Pozo et al., 2012). Heavy metals, POPs and PAHs could be accumulated in aquatic organisms and eventually may transfer to higher order organisms including humans (Pardos et al., 2004; Huang et al., 2006; Díez et al., 2009). Therefore, it is important to assess the accumulation of toxic heavy metals and POPs in the environmental compartments to evaluate the ecological risk.

Kinshasa is the capital and largest city of the Democratic Republic of the Congo (DRC) and has an estimated population of more than 13 million. In Congo DR urban rivers are specially considered as several sources of pollution including sanitary landfills, mining activities, discharge of effluents from industries, hospitals, and urban activities. The Makelele, Kalamu, and Nsanga Rivers are the main rivers and tributaries of Congo River that drain the capital city of Kinshasa (Tshibanda et al., 2014; Mwanamoki et al., 2015). These rivers serve as sources of recreational use, bathing, drinking water supply and irrigation for urban agriculture. A very few comprehensive studies of heavy metals, pesticides and POPs in Congo River Basin have been conducted (Verhaert et al., 2013; Mwanamoki et al., 2014b, 2015; Laffite et al., 2016). These studies recommended further researches in the urban river receiving systems in studied area to evaluate the quality of the aquatic ecosystem. The levels of toxic metals, persistent organic pollutants (POPs: including organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs) and polybrominated biphenyl ethers (PBDEs), and polycyclic aromatic hydrocarbons (PAHs) in sediments are good indicators to evaluate the environmental quality of aquatic systems. Therefore, the objective of the present study was to discuss the occurrence and spatial distribution of toxic metals, POPs and PAHs in sediments from three of main rivers draining the capital city of Kinshasa. Sediment analyses were performed for the physico-chemical characterization including sediment grain-size, total organic matter (loss on ignition), total carbon (TC), total phosphorus (TP), metals including Cr, Mn, Fe, Co, Ni, Cu, Zn, Mo, Ag, Cd, Sn, Sb, and Pb, and persistent organic pollutants (including OCPs, PCBs, PBDEs) and PAHs. In addition, the degree of sediment pollution by heavy metals was evaluated using geo-accumulation index (*Igeo*) and enrichment factor (EF) calculation.

2. Material and methods

2.1. Study sites and sampling procedure

Three rivers named Makelele, Kalamu and Nsanga draining the capital city of Kinshasa (Fig. 1), DRC were selected in this study according to the recommendations of our previous studies (Mubedi et al., 2013; Tshibanda et al., 2014; Mwanamoki et al., 2014a,b, 2015). Sampling took place in January 2016. The surface sediments (0–4 cm layer) were collected from (i) Makelele River (R1, n = 3, labelled: R1A, R1B, R1C), (ii) Kalamu River (R2, n = 4, labelled: R2A, R2B, R2C, R2D) and Nsanga River (R3, n = 2, labelled:

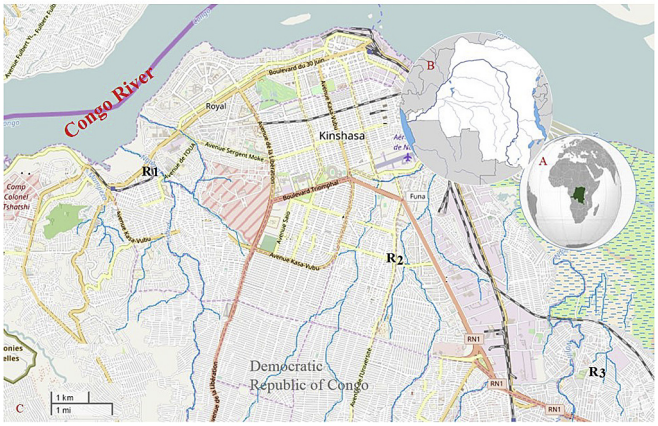

Fig. 1. Location map of the study area. A: Location Map of Congo DR in Africa. B: Map of Congo DR. C: Location map of studied Rivers, R1: Makelele, R2: Kalamu, R3: Nsanga at Kinshasa, Congo DR.