Occurrence of endocrine-disrupting chemicals (EDCs) in river water and sediment of the Mahakam River

Tony Hadibarata, Risky Ayu Kristanti and Ahmed Hossam Mahmoud

ABSTRACT

The study was performed to examine the occurrence of endocrine disrupting chemicals (EDCs), including four steroid estrogens, one plasticizer, and three preservatives in the Mahakam River, Indonesia. The physicochemical analysis of river water and sediment quality parameters were determined as well as the concentration of EDCs. The range of values for pH, total dissolved solids (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD), total suspended solids (TSS), nitrate, ammonium, phosphate, and oil/grease in river water and sediment were higher than recommended limits prescribed by the World Health Organization's Guidelines for Drinking-water Quality (GDWQ). Bisphenol A (BPA) was the most widely found EDC with the highest concentration level at 652 ng/L (mean 134 ng/L) in the river water and ranged from ND (not detected) to 952 ng/L (mean 275 ng/L) in the sediment. Correlation analysis to investigate the relationship between the EDCs' concentrations in water and sediment also revealed a significant correlation ($R^2 = 0.93$) between the EDCs' concentrations. High concentrations of EDCs are found in urban and residential areas because these compounds are commonly found in both human and animal bodies, resulting in the disposal of EDCs into canals and rivers in urban and suburban areas, as well as livestock manure and waste that is generated from intensive livestock farming around the suburban area.

Key words | EDCs, Mahakam River, physicochemical analysis, spatial distribution

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INTRODUCTION

Water quality is one of the important issues in the aquatic environment area. Most concerned studies focus on human health and the ecological impact caused by waste disposal of various elements in many sectors, such as agriculture, industry, medical treatment, and even common residential conveniences. The occurrence of natural and synthetic endocrine disrupting chemicals (EDCs) has become a worldwide environmental concern (Welshons *et al.* 2003; Brion *et al.* 2004; Hibberd *et al.* 2009; Weiss *et al.* 2015; Solecki *et al.* 2017). These compounds are a serious pollutant due to their harmful impact on the human system/organs such as breast tissue, the reproductive system, pancreas, and adipose tissue. Examples of natural and synthetic EDCs are hormones, pharmaceuticals, pesticides, alkylphenols (APs), bisphenol A (BPA), polyhalogenated compounds, and phthalates, that enter the environment from diverse sources. From the EDCs' classification, preservatives, estrogens, and plasticizers have received huge consideration because of their impact on the sexual functions of humans and animals, effecting decreased fecundity, shift in gender role, unwanted bioactivity effects, and developmental of abnormalities (Jobling *et al.* 2004; Madsen *et al.* 2004; vom Saal & Welshons 2006).

EDCs have been widely detected frequently at very low concentrations (ng/L to μg/L) in many countries, and their possible hazards and impacts on living organisms in the

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aquatic environment have also been investigated in America (Brun *et al.* 2006; Zhang *et al.* 2007), Europe (Labadie & Budzinski 2005; Lindqvist *et al.* 2005), and Japan (Furuichi *et al.* 2004; Madsen *et al.* 2004). The main contributor of river water contamination in Indonesia is commonly from the wastewater discharge of municipalities due to the increasing residents in urban and suburban areas with a lack of wastewater treatment facilities. On the contrary, the investigations of EDCs' occurrence and distribution in river water are very limited (Richardson *et al.* 2005; Xu *et al.* 2007).

The Mahakam River is one of the longest rivers in Indonesia with a catchment area of approximately 77,100 km^2 and is an important river in East Kalimantan Province for the daily economic needs of people living in the surrounding area, such as providing drinking water supply, water transportation, irrigation, aquatic farming, sand mining, and river crossings. Previous studies reported that, nowadays, the Mahakam River is highly contaminated by various organic and inorganic pollutants, and many people still think that rivers are dumping sites (Suyatna 2007; Supinganto & Budiana 2015). However, no comprehensive study is available on EDC contamination in river water and sediment on the Mahakam River. The aim of the study was to investigate the occurrence and distribution of EDCs in surface water and sediment from Mahakam River, East Kalimantan, Indonesia.

MATERIALS AND METHODS

Chemicals

Estriol (>99%), 1,2,4 triazole (>99%), methyl paraben (>99%), 17α-ethinylestradiol (>99%), estrone (>99%), 17β-estradiol (>99%), 3,4,4 trichlorocarbanilide (TCC) (>99%), and bisphenol A (>99%) were purchased from Sigma-Aldrich (St Louis, MO, USA). All chemicals were >98% purity and used as standard for analytical purposes. Standard solutions (1 g/L) were made by using toluene as the solvent and placed at low temperature (4 °C) prior to use. All organic solvents (hexane, ethyl acetate, dichloromethane, methanol) used throughout the experiment were analytical grade and purchased from Sigma-Aldrich.

Study area and sample collection

The Mahakam River has a length of ±980 km, and it is estimated that the river catchment area is located between 113 °E to 118 °E longitude and 2 °N to 1 °S latitude and is approximately 77,100 km^2. It originates from the Cemaru highland (1,681 m) in the center of Kalimantan island and river water travels southeast and finally enters into the Makassar Strait. According to the regional climate of the equator area, Mahakam river catchment has two peaks of rainfall, which usually occur in May and December. The sampling was conducted by collecting water and sediment from three urban areas on the Mahakam River (Samarinda City area, Tenggarong City area, and Kota Bangun City area) in East Kalimantan (Figure 1). The sampling location is a densely populated area consisting of housing, industries, and commerce that occasionally receives municipal wastewater. Thirty-six samples of surficial river water and sediment from 12 sampling points were collected from the Mahakam River in December 2017. Details of the sampling locations and characteristics of sites are shown in Table 1 and Figure 1. The river water samples were taken from a depth of ±1 m and the river bank. Water samples were collected in three times pre-rinsed amber glass bottles and then sodium azide was added to each sample to block the possibility of biodegradation.

Physicochemical analysis

The classification, physicochemical properties, and potential origin of EDCs in water environment are shown in Table 2. All the EDCs are commonly used in Indonesia to produce

Figure 1 | Map showing the sampling locations of river water and sediment of the Mahakam River, East Kalimantan, Indonesia.

Table 1 | Description of the sampling sites

Sampling point	Location		Description of sampling point
S1	0°36′24.0″S	117°17′.7″E	Mahakam Delta, tributary of Sanga-Sanga River mouth, petroleum industry, residence
S2	0°34′34.9″S	117°16′36.4″E	Mahakam Delta, residence
S3	0°34′28.8″S	117°12′56.5″E	Samarinda Port, wood industry, shipbuilding industry, residence, agriculture
S4	0°31′18.9″S	117°09′07.6″E	Samarinda City, tributary of Karang Mumus River mouth, residence, livestock, commercial
S5	0°35′06.6″S	117°04′.4″E	Wood industry, commercial, residence, livestock, agriculture
S6	0°35′14.9″S	117°03′20.8″E	Wood industry, coal mining, residence, livestock, agriculture
S7	0°27′17.2″S	117°00′09.2″E	Tenggarong City, tributary of Tenggarong River mouth, residence
S8	0°22′.5″S	116°59′18.3″E	Wood industry, coal mining, residence
S9	0°09′35.4″S	116°43′05.3″E	Tributary of Muara Kaman River mouth, wood industry, residence
S10	0°08′.3″S	116°40′55.9″E	Tributary of Muara Kaman River mouth, wood industry, residence
S11	0°13′39.1″S	116°36′23.8″E	Tributary of Belayan River mouth, wood industry, residence
S12	0°14′14.6″S	116°34′15.0″E	Mouth of Lake Melintang, residence

some product, such as estrogen, plasticizer, and preservative. The physicochemical analysis of river water and the sediment quality parameters were performed according to standard methods (APHA 1998). pH, total dissolved solids (TDS), dissolved oxygen (DO) and total suspended solids (TSS) were analyzed *in situ* by using portable equipment. Other physicochemical variables (biochemical oxygen demand (BOD), ammonium, nitrate, phosphate, and oil and grease) were analyzed according to the previous methods (APHA 1998).

Sample preparation and analytical methods

Filtration of collected water samples was performed using glass fiber filters (0.7 μm) to eliminate impurities. Then, the samples were extracted using C18 solid-phase extraction (SPE) (Zeng *et al.* 2009). The extract was concentrated by evaporator and nitrogen gas to the final concentration of 0.5 mL. The assay control was run alongside the samples by preparing purified water. All the target compounds

Table 2 | Classification, physicochemical properties, and sources of some endocrine disrupting compounds in aquatic ecosystems

Compound	Molecular formula	Molecular weight	Solubility	Classification	Sources
Estrone (E1)	$C_{18}H_{22}O_2$	270.4	Acetone, dioxane, water	Estrogen	Feces and urine by livestock and humans (Sami & Fatma 2019)
17β-estradiol (E2)	$C_{18}H_{24}O_2$	272.4	Acetone, ethanol, water	Estrogen	
17α-ethinyl estradiol (EE2)	$C_{20}H_{24}O_2$	296.4	Ethanol, acetone, water	Estrogen	
Estriol	$C_{18}H_{24}O_3$	288.4	Ethanol, dimethylformamide	Estrogen	
Bisphenol A (BPA)	$C_{15}H_{16}O_2$	228.3	Acetone, acetic acid, water	Plasticizer	Household cleaners, metals, leather, textiles, food, beverages, rubber, plastics, pesticides, and personal care products (Abreu-Cavalheiro & Monteiro 2014)
Trichlorocarbanilide	$C_{13}H_9Cl_3N_3O$	315.58	Methanol	Preservative	Cosmetics, personal care products, and pesticides (Andersen *et al.* 2008)
1,2,4-Triazole	$C_2H_3N_3$	69.1	Water	Preservative	
Methyl paraben	$C_8H_8O_3$	152.15	Ethanol, methanol	Preservative	Fungicide and bacteriostatic (Coogan *et al.* 2007)

were prepared as 1,000 mg/L stock solution by dissolving the pre-weighted amount of particular pollutant in high-performance liquid chromatography (HPLC) grade toluene. For the required concentration, the stock solution was diluted. To inhibit degradation, the stock solution was preserved at 18 °C. All the glass wares used in the study were rinsed with tap water followed by distilled water and then dried at 80 °C for a few hours. A four-point calibration curve was prepared from the stock upon dilution for a certain concentration level using a gas chromatography flame ion detector (GC-FID Agilent 7820A, column type HP5, He (helium) flow rate is 3.0 mL/min). Oven temperature for EDCs (except 3,4,4 trichlorocarbanilide) was started at 100 °C initial temperature, held for 1 min, then increased to a temperature of 200 °C at a rate of 7 °C/min and held for 3 min. Finally, a temperature of 280 °C at the rate of 10 °C was reached. For 3,4,4, trichlorocarbanilide, the oven was set to 70 °C for 1 min and then increased to 300 °C at the rate of 20 °C and held for 3 min. Some good R^2 values in the range of 0.89–0.99 were obtained for all target compounds. Samples were prepared taking 100 mL of river water and liquid–liquid extraction by 100 mL hexane and 100 mL ethyl acetate (twice). The extracts (400 mL) were dried using a rotary evaporator. Afterwards, a round bottom flask was washed with 5 mL toluene and loaded on a silica column for column chromatography. For this purpose, the loaded column was eluted by 150 mL of hexane, 150 mL of dichloromethane, and 150 mL of methanol. Each 150 mL of chemical was evaporated and washed with 5 mL of the respective solvent. Finally, 1 mL was injected into GC-FID and the presence of the target compound determined by matching retention time with an authentic standard.

Quality assurance and quality control

Preparation of EDCs' standard was conducted at six levels by using suitable volumes of the working standard solution. The external standard was added for the quantification procedure. The calibration curve was prepared to measure the concentration of the resulting peak area of the GC chromatogram. The SPE-GCMS procedure was used to analyze EDCs' concentration and provide good correlation coefficients ($R^2 > 0.9$). The results of this study were not justified by substitute recoveries. The use of pharmaceuticals and personal care items such as disinfectants and detergents that contain surfactants were avoided during the sample collection and analysis to minimize the contamination of samples. The reagent blanks were arranged to evaluate the possible impurity of the samples and to confirm the analytical system and glassware were free of contamination. All samples were analyzed in triplicate.

RESULTS AND DISCUSSION

Physiochemical parameters of the river

The physicochemical parameter results for the samples from the 12 sampling points in the Mahakam River are presented in Table 3. Mean pH, TDS, DO, BOD, TSS, nitrate, ammonium, phosphate, and oil and grease in the river water were 6.85, 162.47 mg/L, 4.87 mg/L, 13.58 mg/L, 63.28 mg/L, 1.28 mg/kg, 0.85 mg/kg, 0.19 mg/kg, and 4.16 ppm while for the sediments, nitrate, ammonium, phosphate, and oil/grease were 1.38 mg/kg, 1.13 mg/kg, 0.21 mg/kg, and 6.25 mg/kg. The pH of the river water and sediment varied from 6 to 7 with the range of values for other parameters higher than safe limits recommended by the World Health Organization's Guidelines for Drinking-water Quality (GDWQ) (WHO 1993). All physicochemical parameters from sediment were higher than the river water, indicating that accumulation of pollutant occurred in the sediment.

Table 3 | Physiochemical parameters (mean ± SD, n = 3) of river water and sediment collected from Mahakam River

	Parameters								
Sample	pH	TDS (mg/L)	DO (mg/L)	BOD (mg/L)	TSS (%)	Nitrate (mg/kg)	Ammonium-N (mg/kg)	Phosphate (mg/kg)	Oil and grease (ppm)
Water	6.85 ± 0.5	162.47 ± 19.2	4.87 ± 0.9	13.58 ± 0.97	63.28 ± 1.21	1.28 ± 0.32	0.85 ± 0.21	0.19 ± 0.02	4.16 ± 0.28
Sediment	6.82 ± 0.6	NA	NA	NA	NA	1.35 ± 0.81	1.13 ± 0.62	0.21 ± 0.02	6.25 ± 0.72

Occurrence and concentration level of EDCs

This study showed that all EDCs were found at all sampling sites. The concentration levels of EDCs in river and sediment samples are shown in Table 4. All concentrations of the targeted compounds were detected at ng/L level. BPA was the most commonly found compound in the sample with the highest concentration level at 652 ng/L (mean 134 ng/L) in river water and 952 ng/L (mean 275 ng/L) in the sediment. BPA was not only detected in river water but also sediment that was collected from S11 and S12. On the contrary, estriol was the least commonly found EDC and was recorded in concentrations ranging from ND to 2.65 ng/L (mean 0.38 bg/L) in river water and from ND to 5.02 ng/L (mean 0.97 ng/L) in sediment. Estriol was not detected in river water or sediment collected from S1, S4, S7, S8, S10, and S12. E1 was the most highly abundant EDC in all sampling sites among the four estrogens, except S8 and S10. E1 also showed a high concentration in the sediment sample (82 ng/L). E2 was found in concentrations varying from ND to 25 ng/L in all the sampled sites. The concentration levels of EDCs in this study were relatively higher than other Asian countries (Table 5). In this study, we assumed that the high concentration levels of non-estrogen EDCs such as BPA, TCC, TA, and MP was because of the wide use and discharge of fertilizers, pesticides and plastic into the Mahakam River. Previous studies showed that the water environment has received relatively large amounts of waste disposal, thereby reducing the groundwater and surface water quality (Jobling *et al.* 2003; Tankiewicz *et al.* 2010). BPA was commonly found in the samples because it is the common material used for epoxy resin, plastic, and plastic-based product industries (Hibberd *et al.* 2009; Geens *et al.* 2012; Esteve *et al.* 2016). Currently, BPA is used worldwide due to its elasticity and heat resistance characteristics (Giulivo *et al.* 2016) while in

Table 4 | Occurrence of EDCs (ng/L) in river water and sediment collected from Mahakam River, East Kalimantan, Indonesia

Sampling site	Sample type	E1	E2	EE2	Estriol	BPA	Trichlocarban	Triazole	Methylparaben
S1	Water	21.27	5.52	8.85	ND	782.5	81.4	91.1	ND
	Sediment	82.12	12.51	ND	ND	952.6	125.4	144.8	21.2
S2	Water	15.21	ND	ND	ND	211.3	215.2	221.6	22.3
	Sediment	52.29	10.55	2.21	1.21	228.1	285.3	521.5	35.2
S3	Water	18.62	3.21	ND	ND	85.3	15.3	321.5	ND
	Sediment	42.21	25.12	5.21	1.33	108.2	412.3	551.6	85.2
S4	Water	2.11	5.21	ND	ND	211.2	335.2	11.2	ND
	Sediment	5.41	6.85	1.10	ND	331.2	532.9	653.2	65.3
S5	Water	3.52	7.45	2.04	ND	ND	ND	12.2	ND
	Sediment	10.25	7.85	2.41	1.07	ND	105.2	252.3	ND
S6	Water	ND	ND	ND	2.65	22.1	155.3	12.3	ND
	Sediment	5.21	ND	ND	5.02	285.2	285.9	63.2	ND
S7	Water	ND	ND	ND	ND	310.2	ND	ND	1.3
	Sediment	23.29	ND	ND	ND	625.2	ND	ND	225.2
S8	Water	ND	1.23	ND	ND	ND	ND	1.2	ND
	Sediment	ND	2.29	ND	ND	85.4	21.2	95.5	ND
S9	Water	12.22	ND	1.21	ND	12.8	ND	32.8	ND
	Sediment	41.22	5.33	1.98	1.02	304.5	241.2	109.6	ND
S10	Water	ND	1.42	ND	ND	106.3	21.85	100.3	221.2
	Sediment	ND	2.12	ND	ND	254.3	36.85	321.3	338.2
S11	Water	3.22	1.22	ND	1.92	ND	ND		ND
	Sediment	8.25	2.09	1.21	2.01	103.6	ND	ND	ND
S12	Water	11.08	ND	3.15	ND	ND	ND	ND	ND
	Sediment	18.55	ND	3.19	ND	21.2	ND	12.3	ND

Table 5 | Concentrations of EDCs in natural waters presented in the literature (unit: ng/L)

EDCs	Concentration	Location	Reference
E1	ND–9.900 ng/L	China	
	ND–5.000 ng/L	South Korea	
	1.000–304.0 ng/L	Marina Bay, Singapore	Wee & Aris (2017)
	ND–1.080 ng/L	North China	
	6.500–16.300 ng/L	Mumbai, India	
	ND–5.74 ng/L	Turkey	Aydin & Talinli (2013)
	ND–26.5 ng/L	Mahakam, Indonesia	This study
E2	ND–1.100 ng/L	North China	
	ND	South Korea	Wee & Aris (2017)
	ND	Singapore	
	ND–10.2 ng/L	Turkey	Aydin & Talinli (2013)
	ND–26.5 ng/L	Mahakam, Indonesia	This study
EE2	ND	China	Wee & Aris (2017)
	ND	South Korea	
	ND–11.7 ng/L	Turkey	Aydin & Talinli (2013)
	ND–68.8 ng/L	Mahakam, Indonesia	This study
Estriol (E3)	ND–18.100 ng/L	North China	
	ND–18.100 ng/L	North China	Wee & Aris (2017)
	ND	South Korea	
	3.000–51.000 ng/L	Marina Bay, Singapore	
	ND–11.3 ng/L	Turkey	Aydin & Talinli (2013)
	ND–3.6 μg/L	Mahakam, Indonesia	This study
BPA	512.000 ng/L	China	
	6.630–136.000 ng/L	Kaveri River, India	
	9.820–36.000 ng/L	Vellar River, India	Wee & Aris (2017)
	5.000–324.00 ng/L	Singapore	
	30.000–625.000 ng/L	Marina Bay, Singapore	
	5.000–1,918.00 ng/L	Singapore mangrove	
	ND–37 μg/L	Mahakam, Indonesia	
Trichlocarban	3.56×10^{-7} M	Taiwan	Liu *et al.* (2018)
	ND–392.4 ng/L	Malaysia	This study
Triazole	1,080–2,855.61 ng/L	Spain	Serra-Roig *et al.* (2016)
		Mahakam, Indonesia	This study
Methyl paraben	<1,062 ng/L	South China	
	<0.3–400 ng/L	South Wales, UK	
	ND–22.8 ng/L	Southern India	Błędzka *et al.* (2014)
	25–676 ng/L	Okushima and Osaka, Japan	
	ND–5.75 ng/L	Mahakam, Indonesia	This study

ND, not detected.

agriculture and livestock, this compound is unmetabolized, undegradable, and remains active in animal bodies and causes harmful impacts for aquatic organisms.

Spatial distribution of EDCs

Figure 2 shows the average concentration of EDCs (ng/L) in river water and sediment. It was found that the concentration of non-estrogenic compounds in sediment samples was more than 100 ng/L at sites S1, S2, S3, S4, S7, and S10 while in river water samples, only site S1 was recorded higher than 100 ng/L. S1 was recorded as the highest contaminated sampling site, with a high concentration of BPA in sediment at 952 ng/L and river water at 652 ng/L, followed by S7, with a high concentration of BPA in sediment (625 ng/L) and river water (310 ng/L). Sites S3 and

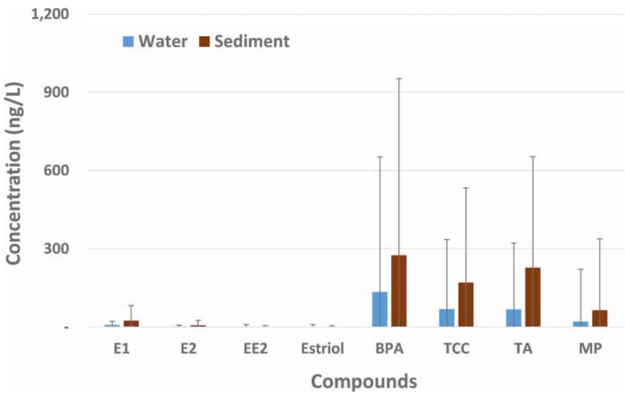

Figure 2 | Average concentration of EDCs (ng/L) in river water and sediment (the whiskers indicate the maximum and minimum value).

S4 were also considered as the most contaminated sample sites due to very high concentrations of TA in river water (321 ng/L) and sediment (551 ng/L), and very high concentrations of TCC in river water (335 ng/L) and sediment (532 ng/L). Sites S1, S2, S3, and S4 are located in highly populated urban and suburban areas comprising commercial, residential, and heavy-weight industry such as wood industry, shipbuilding, and inter-island port. These locations are at the mouth of the Karang Mumus River, a tributary of the Mahakam River, and the most polluted river in East Kalimantan. High concentrations of these target compounds were found in urban and residential areas because E1, E2, EE2, and estriol are commonly found in both human and animal bodies, resulting in the disposal of EDCs into the canal and river in urban and suburban areas. The other contributor of EDCs was livestock manure and waste generated from the intensive livestock farming around the suburban area of the Mahakam River, including the release of urine into the environment without treatment. Preservatives used in plantations and agricultural areas for pesticides might also be considered major causes of EDCs in the river water and sediment. Our results were similar to a previous study which found that E2 is the main estrogenic chemical discharged from animals especially mammals, chicken, and fish, and this compound is related to the sexual and reproductive systems of animals. E2 is also produced naturally by pregnant and menstruating women and this compound is excreted from the body through feces and urine (Welshons *et al.* 2003; Barreiros *et al.* 2016).

On the other hand, EE2 is generally found in pharmaceuticals, birth control pills, hormone therapies for menopausal symptoms, and treatment of gynecological disorders, prostate cancer, and breast cancer. EE2 also increases the productivity of livestock and prevents reproductive disorders. A characteristic of EE2 is low solubility in water and causing chronic impacts to humans and animals due to the fact the compound is easily deposited in a living organism (Chen *et al.* 2010; De Wit *et al.* 2010; Bartelt-Hunt *et al.* 2011). Releasing chemicals into aquatic environments such as lakes, rivers, and seas might be causing heavy pollution due to biogeochemical processes of pollutants which are easily adsorbed by suspended substrates in water bodies (Olujimi *et al.* 2010). The movement of EDCs in a water body is very high, and the accumulation of those compounds and their transformation in sediment depends on the acidity of the sediment. It is known that acidic sediment (lower pH) may contribute to high accumulation and decreasing degradation rate. EDCs might be undergoing some process such as biodegradation by microorganisms, photochemical degradation, and sorption that contributes to their transformation. These processes precipitate EDCs into sediments in the river flow so that the concentration of EDCs in the aquatic ecosystem reduces (Petrovic *et al.* 2002; Huang *et al.* 2008). According to EDCs' classification, the composition of plasticizer and preservative was of considerable predominance in all samples (Figure 3). The results showed that preservative EDCs mostly dominated in river water and sediment samples (51% and 60%). The plasticizer BPA was significantly found in river water (44%) while the concentration was less in sediment. Natural and synthetic estrogens such as E1, E2, EE2, and estriol were detected at less than 5% in river water samples and sediment. Correlation analysis between EDCs' concentration in river water and sediment is shown in Figure 4. It is shown that EDCs' concentration in water has a strong correlation with EDCs' concentration in sediment as calculated from the analysis of significant correlation at $R^2 = 0.93$ because these compounds may have a common pollutant source. Identical configurations and significant correlations were discovered by a previous study which showed that the organic pollutants might come from the same sources and environmental behavior (Zhang *et al.* 2004).

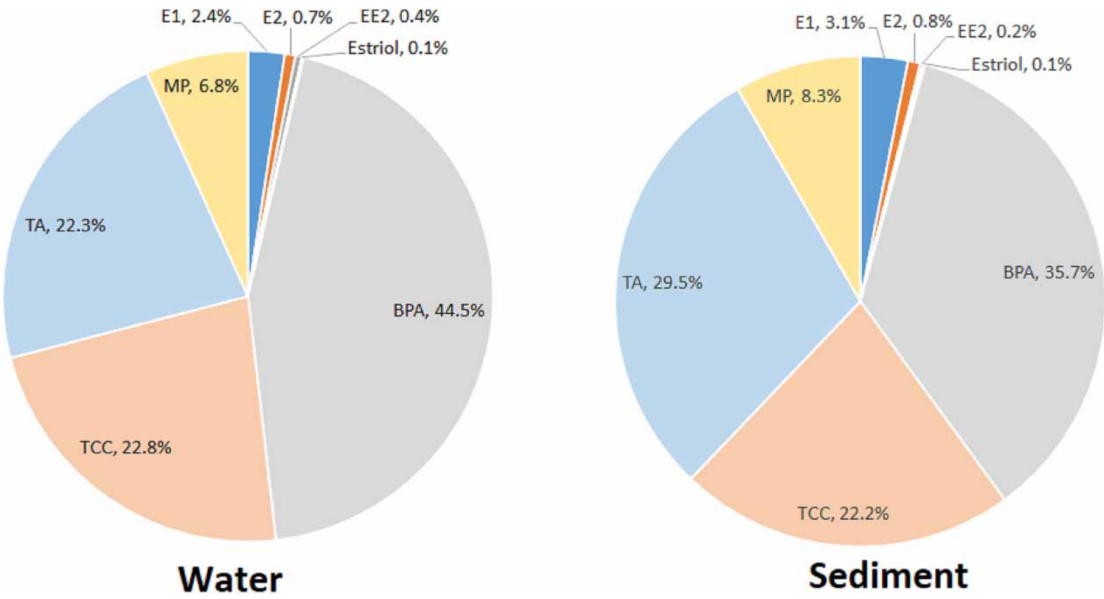

Figure 3 | Relative percentage (%) of EDCs in river water and sediment samples from Mahakam River, East Kalimantan, Indonesia.

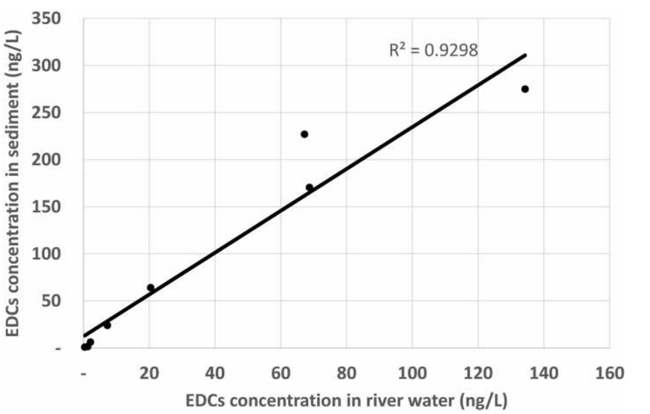

Figure 4 | Correlation analysis between EDCs' concentration in river water and sediment.

CONCLUSIONS

All EDCs including estrogen, plasticizer, and preservative were detected at ng/L level in all sampling sites of the Mahakam River. E1 and E2 concentrations in all areas of the Mahakam River were higher compared to those of EE2 and estriol. These results indicate that aquatic organisms might be exposed to concentrations of E1 and E2. However, the preservatives TCC, TA, and MP were the dominant EDCs among all target compounds. The high concentrations of these target compounds are found in urban and residential areas because the compounds are commonly found in both human and animals bodies, resulting in the disposal of EDCs into the canal and river in urban and suburban areas, as well as livestock manure and waste generated from the intensive livestock farming around the suburban area of the Mahakam River. The results exhibited that special attention must be given to controlling organic pollution, especially EDCs, in the catchment of the Mahakam River.

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