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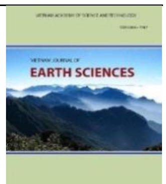

Presence of trace elements in sediments of Can Gio mangrove forest, Ho Chi Minh city, Vietnam

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ABSTRACT

Can Gio mangrove forest (CGM) is located in the South-East of Ho Chi Minh City (HCMC), situated between an estuarine system of Dong Nai-Sai Gon river and a part of Vam Co river. The CGM is the largest restored mangrove forest in Vietnam and the UNESCO's Mangrove Biosphere Reserve. The CGM has been gradually facing to numeric challenges of global climate change, environmental degradation and socio-economic development for the last decades. To evaluate sediment quality in the CGM, we collected 13 cores to analyze for sediment grain size, organic matter content, and trace element concentration of Cd, Cr, Cu, Ni, Pb, Zn. Results showed that trace element concentrations ranged from uncontaminated (Cd, Cu, and Zn) to very minor contaminated (Cr, Ni, and Pb). The concentrations were gradually influenced by suspended particle size and the mangrove plants.

Keywords: Can Gio mangrove biosphere reserve; sediment quality; mangrove sediment; trace elements; heavy metals.

1. Introduction

Mangrove forests are a spectacular ecosystem, occupying the boundary between land and sea, and globally distribution of 181,077 km^2 in area and centered in the tropics (Spalding, Blasco, & Field, 2010; Thomas et al., 2017). In most areas, mangroves forests are important filters of pollutants from atmospheric deposition, continental run-off and tidal currents. Trace elements are considered to be key issues due to their long-lasting effect on ecosystems. Trace elements reach the mangrove forests by incorporating in suspended particles, transporting by tides and river discharges (Lacerda, 1998). As much 80% of suspended sediments were trapped in the mangrove forests from coastal currents during period of spring tides (Furukawaa, Wolanski, & Mueller, 1997).

Mangrove sediments are relatively homogeneous in texture and rich in organic matter. Thus, they act as an effective sink of contaminants, particularly in the case of trace elements, for example, earlier study in mangrove forests from Ba Lat estuary revealed that the trace elements in mangrove

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sediments mainly originated from the discharges of untreated effluents by industry, domestic sewage and non-point sources (Tue, Quy, & Amono, 2012).

Dong Nai-Sai Gon river basin is the third largest river system in Viet Nam with 43,681.78 km^2 (Truong, 2007), originating from the highland mountains (Gia Lai, Kon Tum and a small part in Cambodia). The river flows through 11 provinces, including the megacities of Ho Chi Minh (HCMC), Bien Hoa and Binh Duong. In HCMC urban, canal water was highly polluted with nutrients and trace elements, and increased impressively (e.g., Cr and Hg rose up to 10-fold higher) in comparison to the upstream side of the Sai Gon river (Strady et al., 2016).

For the last decades, socio-economic development of the megacities in upstream of the CGM has been impressively grown up, and concurrently it may create and transport effluent pollution into water discharge flowed seaward to reach the CGM. Therefore, the study aims to assess presence of trace elements in sediment of the CGM.

2. Materials and methods

2.1. Study area

The Can Gio mangrove forest (CGM) is the largest restored mangrove forest in Viet Nam, being well known as an UNECOS's mangrove biosphere reserve (UNECOS's, 2000). The CGM covers approximately an area of 35,000 ha (HCMC, 2017) with high biodiversity of fauna and flora, being dominated by three families of mangrove trees such as *Avicenniaceae*, *Rhizophoraceae* and *Sonneratiaceae*. Figure 1 shows location of the study area (Hong & San, 1993; Tri, Hong, Cuc, 2000; Tuan, Oanh, Thanh, Quy, 2002; Nam, 2007). The CGM plays numerically important roles for HCMC and its surrounding areas, including livelihood for local communities, supporting as "green lung" for regulating local climate, providing habitat for wild animals, serving like a perfect natural environment for studying, maintaining genes, and contributing to reduce the impacts from climate change and sea level rise.

The CGM is located within a tropical monsoon climate zone. Temperature and humidity is high with respective average value of 28.7°C and 72%. Average annual precipitation is 1,760.6 mm (HCM SO, 2015). The study area is characterized by a quite flat terrain and filled with Holocene sediments. Tide is semi-diurnal tide (Tuan, Oanh, Thanh, & Quy, 2002; Kitazawa, Nakagawa, Hashimoto, Tateishi, 2006; HCM SO, 2015).

2.2. Sampling and handling

Thirteen sediment cores were handy drilled by using a sediment hand-auger in the mangrove forest from 20th to 23rd August, 2016. The sampling locations are shown in Fig. 1. Sediment cores were approximately one meter in length (Table 1). The lithology of cores were immediately described after the collection, then placed in a PVC tube and kept at 4°C. Log descriptions in Fig. 2 showed that the sediment cores divided into two layers, were basically homogeneous in structure. The upper layer was brown-grey, soupy condensed sediment from 20 cm to 35 cm length, meaning its oxidation. The lower one was blueish-grey, soft clayey sediment mixed with a few charcoal debris scattering from 60 up to 100 cm. The methods of collection and preparation of sediment samples are strictly followed the guidelines of United Nations Environment Program and IAEA (IAEA, 2003; UN Environment Program, 2006).

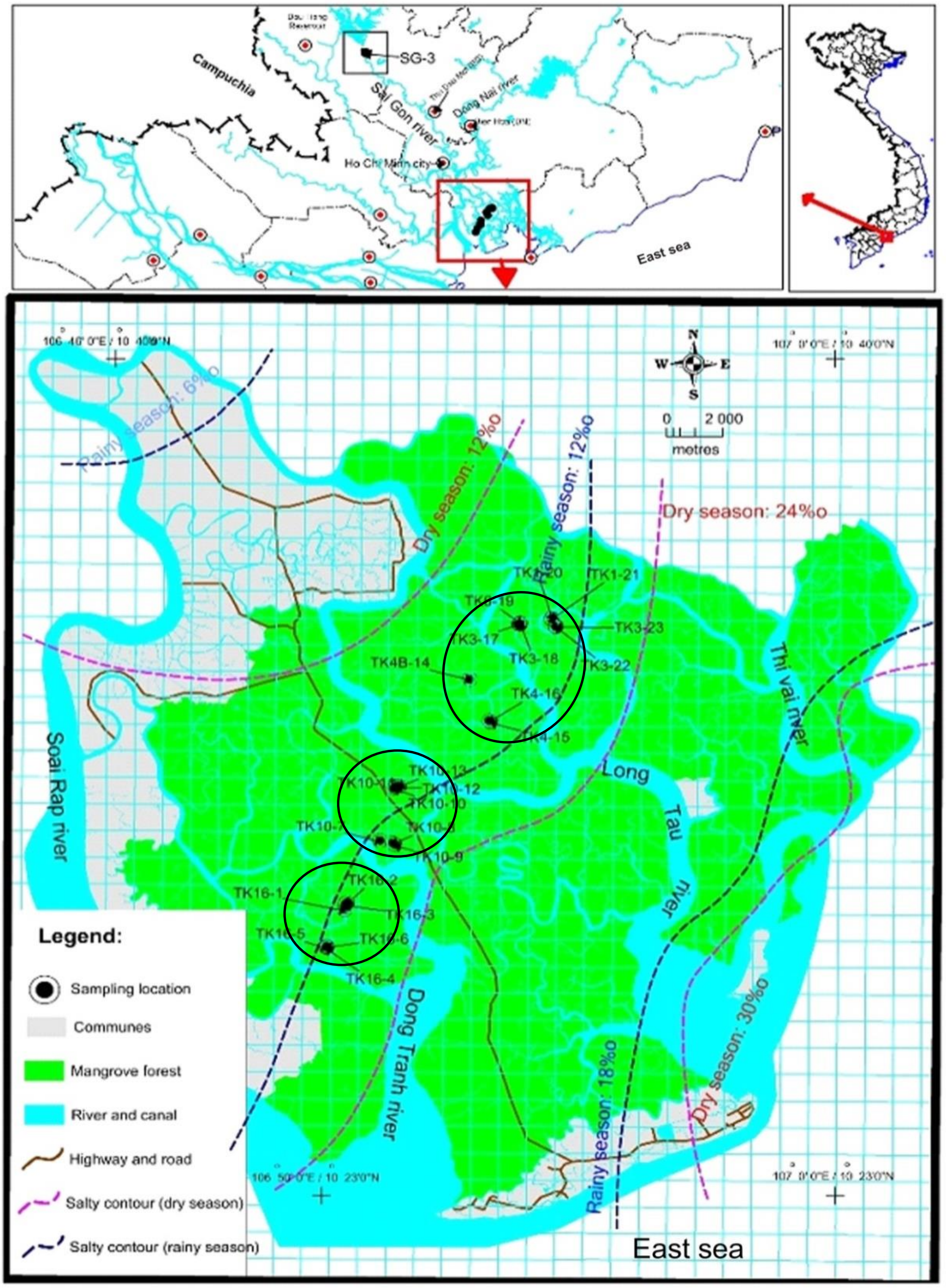

Figure 1. The study area and sampling locations in the CGM

Table 1. Sampling locations of sediment cores in the CGM

Coring site names (*)	Coordinates		Core length (cm)
TK16-01	10°28'56.65"N	106°50'29.73"E	92
TK16-02	10°28'55.10"N	106°50'28.04"E	93
TK16-03	10°28'47.98"N	106°50'27.02"E	101
TK16-04	10°28'1.96"N	106°50'5.83"E	62
TK16-05	10°28'2.54"N	106°50'5.97"E	79
TK16-06	10°28'3.35"N	106°50'6.20"E	100
TK10-07	10°30'12.22"N	106°51'8.42"E	98
TK10-10	10°31'16.30"N	106°51'24.72"E	91
TK10-11	10°31'18.02"N	106°51'26.54"E	84
TK10-12	10°31'18.60"N	106°51'27.43"E	97
TK04-16	10°32'38.27"N	106°53'15.88"E	99
TK01-18	10°34'36.28"N	106°53'51.92"E	100
TK03-22	10°34'32.84"N	106°54'33.48"E	74

*TK16 denotes for the mangrove forest zone number in the Can Gio Biosphere Reserve and the followed digit denotes for sampling site

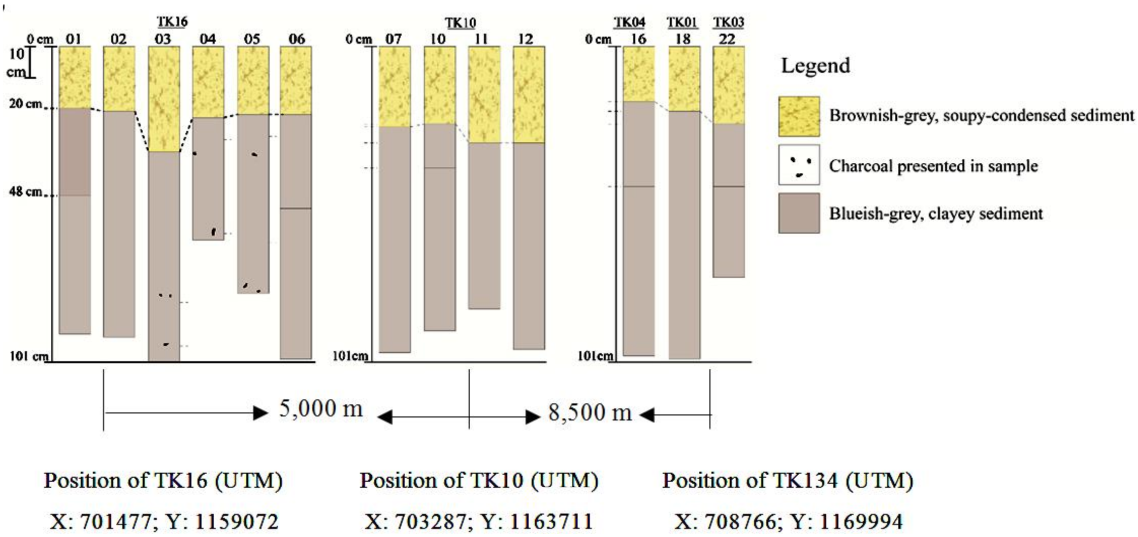

Figure 2. Log description of the sediment cores in the CGM

2.3. Analytical methods

2.3.1. Sediment grain size analysis

For each sample, 15 grams of wet sediments were used for grain size. Prior analysis, the wet sediment samples were sieved for coarse organic matter, then, treated with hydrogen peroxide 30% at 50°C for digestion all the remained organic matter. The particle grain sizes were measured with a sequence of 3 times during 3 minutes of ultra-sonic agitation using Malvern Mastersizer 3000 laser diffraction micro-granulometer. The grain size analysis was conducted in GéHCO laboratory, Francois Rabelais - Tours University, France. Results of grain size analysis were plotted and presented by Passega's CM pattern (Passega R., 1957; Passega R., 1964). The CM pattern represented well to characterize depositional environments by linking the particle size and the process of their deposition. A combination on a bi-logarithmic diagram of two parameters of an accumulative grain size distribution, the coarsest one percentile value C and the median M. Where, C and M respectively represented 90th percentile (D90) and 50th percentile (D50). The pattern has been widely used in the literature to reconstruct depositional environments (Vandenberghe, 1975; Bravard, Goichot, & Tronchere, 2014).

2.3.2. Geochemical composition and LOI analysis

For each sample, 50 grams of wet sediments were dried at 40°C until to gain a constant weight, then ground into fine powder (particle size 2µm) by using a mortar and pestle. Each aliquot of 3 g of dry sediments were taken to analyze major elements and trace elements by using with an inductively coupled plasma mass spectrometer (ICapQ, Thermos). Organic matter content via LOI was calculated by the weight difference between before and after burning at 980°C in the automatic tunnel oven over a period of about 60 minutes (Carignan, Hild, Mevelle, Morel, & Yeghicheyan, 2001), during the first step of the process of trace element analysis. The analysis process was performed at Nancy Laboratory (France). Preparation, analysis and data processing were performed followed the methods outlined by Carignan, Hild, Mevelle, Morel, & Yeghicheyan (2001).

2.4. Calculation of enrichment factors, geo-accumulation indexes and assessment of sediment quality

2.4.1. Enrichment Factors

Evaluation of trace element enrichment factors (EFs) in sediments was widely applied to differentiate the natural geochemical background to anthropogenic inputs (Rollinson, 1993; Zhang & Liu, 2002) and was a relative indicator of geochemical elements compared with the bedrock (Laura, Probsta, Probsta, Ulrich, 2003). The *EFs* were calculated using the Eq. (Herut & Sandler, 2006).

$$EF_i \quad \frac{Celement_{i.sample}/CAl_2O}{Celement_{i.background}/CAl_2O_{3.i.ba}} \qquad (1)$$

Where EF_i is enrichment factor of element i, $Celement_{i.sample}$ and $CAl_2O_{3.i.sample}$ are concentrations of element i and Al_2O_{3i} in the sample, respectively; $Celement_{i.background}$ and $CAl_2O_{3.i.background}$ are average concentrations of element i and Al_2O_{3i} in upper continental crust (UCC), respectively (Table 03) (Wedepohl, 1995). Al_2O_3 concentration represents well for normalization.

The EFs has been globally used for examining anthropogenic impacts on elemental distribution in the geological environment and evaluating the ecological risk of the mangrove sediments (Lacerda, 1998; Ong Che, 1999; Maiti & Chowdhury, 2013; Li, et al., 2015; Wang, et al., 2016). In 2002, Zhang and Liu (Zhang & Liu, 2002) defined the EF values ranged between 0.5 and 1.5, indicating for physical weathering processes, while other values indicated sources of trace elements from anthropogenic sources. In detail, 1.5 < EF < 3 indicates for minor enrichment, 3 < EF < 5 indicates for moderate enrichment, 5 < EF < 10 indicates for moderately severe enrichment, 10 < EF < 25 indicates for severe enrichment, 25 < EF < 50 indicates for very severe enrichment, and EF > 50 indicates for extremely severe enrichment.

2.4.2. Geo-accumulation indexes (Igeo)

Assessment of trace element enrichment's levels was employed by the geo-accumulation indexes (Muller G., 1979), who originally defined trace element concentrations in the < 2µm fraction with respect to the background value Bn as a pristine value for the study area. The *Igeo* calculation is based on the Eq. (2) below:

$$Igeo = Log_2 \frac{C_n}{1.5 * B_n} \qquad (2)$$

Where C_n is the measured concentration in the sediment sample for trace element n, B_n taken in SG3 site in Emilie's study (SG3 site is shown in Fig. 1 upstream Sai Gon river) (Strady, et al., 2016) is as the background value for the trace element n, and factor 1.5 is a possible variation in background data due to lithological variations. The background value is employed, in case, there is no consent value of geological background in the CGM and it could make a large scale for assessing sediment quality in the CGM when both background geological values of upper continental crust and upstream sites are together used. The geo-accumulation indexes are classified into seven classes: *Igeo≤ 0*, class 0, uncontaminated; *0≤Igeo≤1*, class 1, uncontaminated to moderately contaminated; *1≤Igeo≤2*, class 2, moderately contaminated; *2≤Igeo≤3*, class 3, moderately contaminated to strongly contaminated; *3≤Igeo≤4*, class 4, strongly contaminated; *4≤Igeo≤5*, class 5, strongly contaminated to extremely contaminated; *Igeo≥5*, class 6, extremely contaminated.

2.4.3. Sediment quality guidelines (SQGs)

Sediment quality guidelines have been widely applied for evaluating the environmental quality to protect the organism ecosystems. In marine ecosystems, the most significant outcomes for the development of SQGs are the Effects Range Low (ERL) and the Effects Range-Median (ERM) (Long & Morgan, 1990. Another, the mean Effects Range-Median quotients (m-ERM-q) is a specific index of pollutant from the SQGs obtained in lab experiments using amphipod organism (Long, Field, & MacDonald, 1998; Hubner, Astin, & Herbert., 2009), it is used to count for the contaminant mixtures, including trace elements to assess sediment quality in terms of adverse biological effects, calculated follows Eq. (3) below:

$$\text{m–ERM –q} = \sum_{i=1}^{n}(\mathrm{C}i/\mathrm{ERM}i)/\mathrm{n} \qquad (3)$$

Where C_i is the concentration of the pollutant i in the sample. ERM_i is the experimentally defined effective concentration for the pollutant i; n is the number of studied pollutant i. Long et al (1998) defined four grades of toxic probability for biota such as low (m-ERM-q < 0.1), low – medium (m-ERM-q from 0.11 to 0.5), medium-high (m-ERM-q from 0.51 to 1.5) and high priority grades (m-ERM-q > 1.5). Them-ERM-q index is derived from the concept of effect range low (ERL, i.e 10 percentile of the effect dataset) and effect range median (ERM, i.e. 50 percentile of the effect dataset) defined by (Long, MacDonald, Smith, & Calder, 1995).

2.5. Statistical methods

The data is statistically analyzed by using XLSTAT software, version 2016. Pearson correlation coefficient matrixes and one-way ANOVA at probability level ($p < 0.05$) are used to determine whether the particle size and LOI percentages have an effect on the concentration of trace elements in the mangrove sediment.

3. Results and discussions

3.1. Factors influencing distribution and deposition of trace elements in sediments of the CGM

3.1.1. Sediment grain size distribution

Sediments in the CGM were originated from suspended material sources, transported by Sai Gon and Dong Nai river and apart from Vam Co river at the western, with total water discharge of 47.065 billion cubic meters (Claudia & Huy, 2004). The respective concentration of suspended materials measured at Ganh Rai and Soai Rap rivers were 1398.1 $mg.l^{-1}$, 1226.4 $mg.l^{-1}$ during high tides and 997.6 $mg.l^{-1}$, 2265 $mg.l^{-1}$ during low tide (Toan & Bay, 2006).

The sediments in the CGM mostly composed of very fine silt (67.6%–86.7%), clay (average value of 14.7%). The median grain sizes (D50) was less than 10 µm in triple units (Table 2, Fig. 4). The particle size and the proportion of silt and clay were quite similar in triple sites (TK16, TK10 and TK1-3-4). However, a little variation in depth of the particle sizes is observed.

Based on Passega's CM diagram (Passega R., 1957; Passega R., 1964) and Folk's grain size parameters (Folk & Ward, 1957), the linkage between the grain size and their depositional processes is quite clear and suitable with suspended domain (domain T) in all sampling zones of TK16, TK10 and TK1-3-4. Results demonstrated that the sediment deposition processes had occurred in suspension (Fig. 3). In TK16 zone, there were only few samples with their sediment grain sizes scattered parallel to domain RS (sedimentation of particle in uniform suspension). While few others in the TK1-3-4 zone were parallel to CM line, but both the particle sizes represented in domain that were tightly close to domain T, below and very far to domain RS, so that they show to be at suspended transportational regimes. Moreover, the flow velocity in sampling sites being solely inundated during the high tide, was often a low value due to low energy flows (Cang & Thanh, 2008; Phuoc, An, Cang, Chung, Tien, 2010). Therefore, the sediments in the sampling sites of the CGM have been continuously accreted during the last decades.

Results of trace element analysis showed that Pb and Zn concentration in sediment cores of the CGM were twice higher than those in the upper continental crust (Wedepohl, 1995). Correspondingly, concentrations of Cr, Ni, and Pb were twice higher than those in the SG3 site of Emilie's study (Strady, et al., 2016). However, all these trace element concentrations were still very low in comparison to the sediment quality regulation of Vietnam in 2012 (QCVN43:2012/BTNMT, 2012). The higher variations that may be explained the trace elements have originated from the urban area of HCMC.

The correlation matrix of trace element concentrations with particle sizes indicated that all concentrations of Cr, Cu, Ni, Pb and Zn dispersed spatially against increasing particle sizes (Table 4). With D50 was less than 10 µm (see Fig. 3 and Table 3) and no much changing concentrations of trace elements between upper and lower layers, we suggest that trace elements seem not to move deeply.

Table 2. Sediment grain sizes in µM, the percentage of particle size in the ranges of (0 - 2 µM) and (2-63 µM)

Parameter	Min	Max	Mean	SD
Dx (10)	1.0	2.6	1.5	0.4
Dx (50)	4.9	25.9	8.3	4.7
Dx (90)	21.7	99.2	40.3	18.7
Particle size in the range (0-2 µM)	7.2	20.1	14.7	3.5
Particle size in the range (2-63 µM)	67.6	86.9	79.7	4.2

Table 3. Concentrations of trace elements in ppm, LOI in percentage, D(50) - mean grain size in µM; Average value of upper continental crust (Wedepohl, 1995); geochemical value of SG3 site of Emilie's study upstream from HCM city

Variable	Min	Max	Mean	SD	Average of UCC	Emilie's SG3 site
Cd	0.04	0.16	0.07	0.03	0.10	0.07
Cr	76.36	115.69	102.45	9.63	126.00	51.2
Cu	19.42	29.20	26.46	2.20	25.00	18.1
Ni	42.56	62.59	50.59	4.62	56.00	17.8
Pb	18.13	30.05	26.62	2.64	14.80	14.6
Zn	75.44	135.64	107.22	15.44	65.00	101
LOI	13.90	37.02	19.28	5.40		
D(50)	**4.9**	**25.9**	**8.3**	**4.7**		

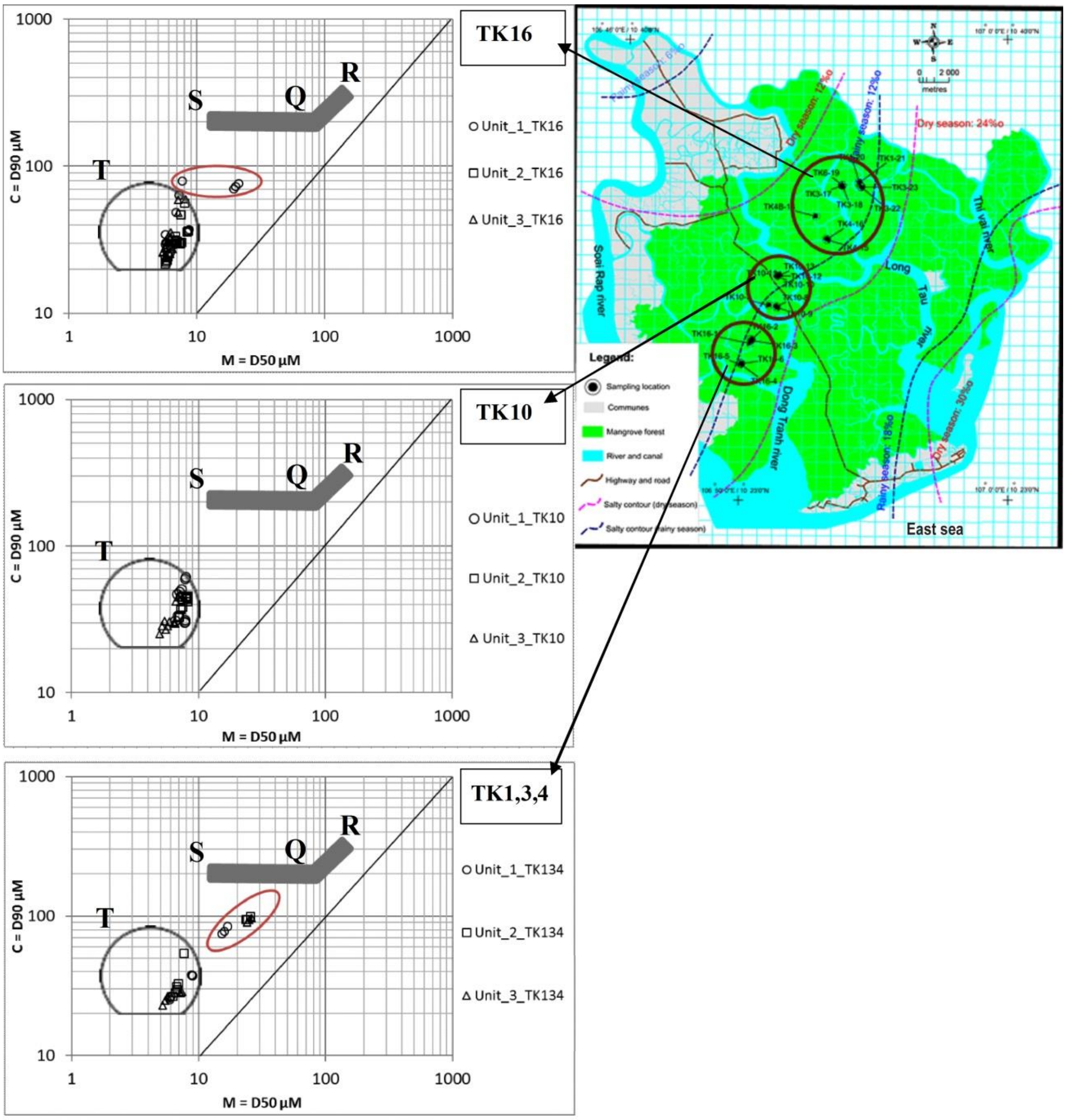

Figure 3. C-M pattern of particle grain sizes in sediment cores of Unit-1, Unit-2 and unit-3 of TK16, TK10 and TK1-3-4

Table 4. Correlation matrix among trace element concentrations (ppm), D(50) (µM) and LOI (%)

Variables	Cr	Pb	Cu	Zn	Ni	Cd	D(50)	LOI
Cr	**1**							
Pb	**0.91**	**1**						
Cu	**0.81**	**0.76**	**1**					
Zn	**0.70**	**0.67**	**0.74**	**1**				
Ni	**0.52**	0.39	**0.54**	**0.74**	**1**			
Cd	**-0.73**	**-0.74**	-0.33	-0.42	-0.15	**1**		
D(50)	0.16	0.11	0.07	-0.02	-0.03	0.03	**1**	
LOI	**-0.83**	**-0.86**	-0.47	-0.44	-0.27	**0.77**	-0.18	**1**

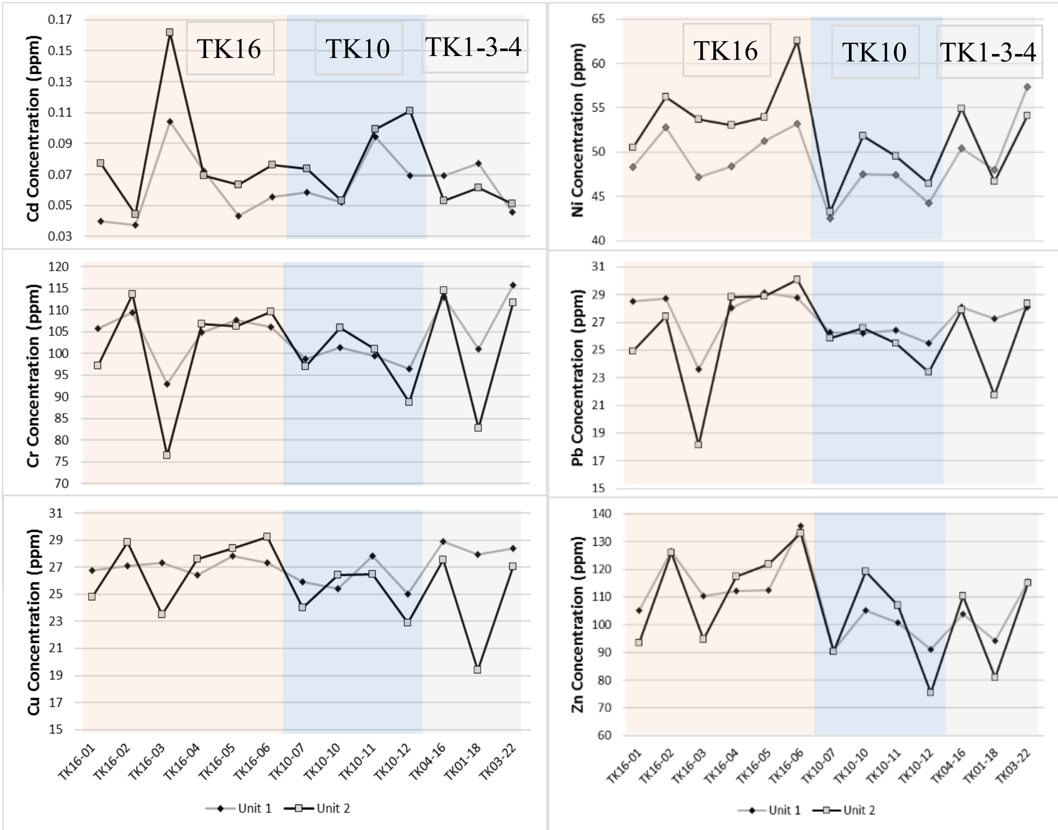

Figure 4. Top-bottom pattern of trace element concentrations in ppm, light grey line with black dots is top layer (unit 1), black line with light grey dots is bottom layer (unit 2); pink area is TK16 area, light blue area is TK10 area, light grey area is TK1-3-4 area

3.1.2. Mangrove forest cover

The organic matter content via LOI value ranged from 13.90% to 37.02% with an overall mean of 19.28% (Table 3). The LOI had a strongly negative correlation with Cr and Pb concentration, negative correlation with Cu and Zn concentration, weakly negative correlation with Ni concentration (Table 4). The trace element concentrations retained in the mangrove sediments would depend on the type of trace elements and the mangrove soil characteristics (Tam & Wong, 1996; Zheng, Xiao-yong, & Peng, 1997) and mangrove species (Mohd & Nor, 2010; Marchand, Allenbach, Lallier-Verges, 2011; Kathiresan, Saravanakumar, & Mullai, 2014; Pumijumnong & Danpradit, 2016). For instance, *Rh. mucronata* trees could restrict uptake of Cr and Pb with its bioaccumulation factor (BAF) < 1 and translocation factor (TF) from root to leaf > 1 (Baruddin, Shazili, Pradit, 2017). These evidences demonstrated for the decrease in concentration of trace elements (except Cd) with the increase in LOI values in the sediment core from TK16-01, TK16-03 and TK134-18, where the degraded dead plants was left much on the forest ground (Fig. 4).

The LOI value was positively correlated with Cd concentration (Table 4). The LOI in the sediment core from TK16-03 ranged from 31.41% to 37.02%, where remained much-decayed tree of *Rh. mucronata* on the forest ground. In this area, Cd concentration reached a maximum value of 0.16 ppm (Table 3 and Fig. 4). The Cd accumulation in sediments of the CGM resulted higher than those measured in other areas, because mangrove roots could induce changes of Cd concentration in the mangrove sediments (Jingchun, Chongling, Ruifeng, Haoliang, Guangqiu, 2008; Zhang, et al., 2009).

3.2. Assessment of the sediment quality

Results of *EFs* indicated a none enrichment for Cd, Cr, Cu, Ni and Zn, with an exception of slight enrichment of Cd in unit 2 of TK16-03 with *EF* = 1.9 and Zn in unit 1 (TK16-02, TK16-03, TK16-06) and in unit 2 (TK16-02, TK16-05, TK16-06 and TK10-11). Most *EFs* of Pb presented a minor enrichment. Results of *Igeo* showed that sediments were uncontaminated for Cd, Cu and Zn with an exception of Cd at unit 2 (TK16-03 with *Igeo* = 0.5), and uncontaminated to minor contaminated for Cr, Ni and Pb. Both results from EFs and Igeo (Table 5) showed the enrichment and contamination of Cr, Ni and Pb in the sediments. The observed Pb enrichment and the contamination of Cr, Ni and Pb maybe come from the release of industrial and urban wastewater of the megacity, ship transport and aquaculture farming or worn out tires of oyster-raising activities.

We strongly stated that two background values were chosen, *i.e.* the average upper continental crust (Wedepohl, 1995) and the SG3 site (Strady, et al., 2016) in this study, in case, Dong Nai-Sai Gon basin have not got a consensus of background geochemical composition.

Table 5. EF and Igeo values in sediment cores of the CGM; Wedophold's UCC used as a background for EF and m-ERM-q calculation, Emilie's SG3 site used as a pristine value for Igeo calculation

Sample ref.	EF_{Cd}	EF_{Cr}	EF_{Cu}	EF_{Ni}	EF_{Pb}	EF_{Zn}	$Igeo_{Cd}$	$Igeo_{Cr}$	$Igeo_{Cu}$	$Igeo_{Ni}$	$Igeo_{Pb}$	$Igeo_{Zn}$	n-ERM-q
TK16-01_1	0.3	0.7	0.9	0.7	1.6	1.4	-1.5	0.5	0.0	0.9	0.4	-0.5	0.29
TK16-02_1	0.3	0.7	0.9	0.8	1.6	1.6	-1.6	0.5	0.0	1.0	0.4	-0.3	0.31
TK16-03_1	1.0	0.7	1.1	0.8	1.6	1.7	-0.1	0.3	0.0	0.8	0.1	-0.5	0.28
TK16-04_1	0.6	0.7	0.9	0.7	1.6	1.5	-0.6	0.4	0.0	0.9	0.4	-0.4	0.29
TK16-05_1	0.4	0.7	0.9	0.8	1.6	1.4	-1.4	0.5	0.0	0.9	0.4	-0.4	0.30
TK16-06_1	0.5	0.7	0.9	0.8	1.6	1.7	-1.0	0.5	0.0	1.0	0.4	-0.2	0.31
TK10-07_1	0.5	0.7	1.0	0.7	1.6	1.3	-0.9	0.4	-0.1	0.7	0.3	-0.7	0.26
TK10-10_1	0.5	0.7	0.9	0.8	1.6	1.5	-1.1	0.4	-0.1	0.8	0.3	-0.5	0.28
TK10-11_1	0.9	0.8	1.1	0.8	1.7	1.5	-0.3	0.4	0.0	0.8	0.3	-0.6	0.28
TK10-12_1	0.7	0.7	1.0	0.8	1.7	1.4	-0.7	0.3	-0.1	0.7	0.2	-0.7	0.26
TK04-16_1	0.6	0.8	1.0	0.8	1.6	1.4	-0.7	0.6	0.1	0.9	0.4	-0.5	0.30
TK01-18_1	0.7	0.7	1.0	0.8	1.7	1.4	-0.5	0.4	0.0	0.8	0.3	-0.7	0.28
TK03-22_1	0.4	0.7	0.9	0.8	1.5	1.4	-1.3	0.6	0.1	1.1	0.4	-0.4	0.32
TK16-01_2	0.7	0.7	0.9	0.8	1.6	1.3	-0.5	0.3	-0.1	0.9	0.2	-0.7	0.28
TK16-02_2	0.3	0.7	0.9	0.8	1.5	1.5	-1.4	0.6	0.1	1.1	0.3	-0.3	0.32
TK16-03_2	1.9	0.7	1.2	1.2	1.5	1.8	0.5	0.0	-0.2	1.0	-0.3	-0.7	0.28
TK16-04_2	0.6	0.7	0.9	0.8	1.6	1.5	-0.7	0.5	0.0	1.0	0.4	-0.4	0.31
TK16-05_2	0.5	0.7	0.9	0.8	1.6	1.6	-0.8	0.5	0.1	1.0	0.4	-0.3	0.31
TK16-06_2	0.6	0.7	0.9	0.9	1.6	1.7	-0.6	0.5	0.1	1.2	0.5	-0.2	0.35
TK10-07_2	0.7	0.7	0.9	0.7	1.7	1.3	-0.6	0.3	-0.2	0.7	0.2	-0.7	0.26
TK10-10_2	0.5	0.7	0.9	0.8	1.6	1.6	-1.1	0.5	0.0	1.0	0.3	-0.3	0.30
TK10-11_2	0.9	0.8	1.0	0.8	1.6	1.6	-0.2	0.4	0.0	0.9	0.2	-0.5	0.29
TK10-12_2	1.1	0.7	1.0	0.9	1.7	1.2	0.0	0.2	-0.2	0.8	0.1	-1.0	0.25
TK04-16_2	0.4	0.7	0.9	0.8	1.5	1.4	-1.1	0.6	0.0	1.0	0.4	-0.5	0.31
TK01-18_2	0.7	0.7	0.9	0.9	1.7	1.4	-0.9	0.1	-0.5	0.8	0.0	-0.9	0.25
TK03-22_2	0.4	0.7	0.9	0.8	1.5	1.4	-1.1	0.5	0.0	1.0	0.4	-0.4	0.31

In comparison with the common SQG values for brackish or freshwater using TEC, PEC and for marine sediment using ERL, ERM indexes, we probably estimated ecological conditions at risk for the sediments of the CGM. Both indexes of SQGs used for freshwater and marine sediments implied the Cd, Cu, Pb and Zn concentrations ranged below the value that may not cause adverse effects (Lower than TEC and ERL), with an exception of Zn concentration of 5 sediment samples was greater than TEC index in freshwater sediments. Whereas, all of Cr and Ni concentrations ranged above which the adverse effects are not expected to occur (Table 6).

Table 6. Assessment of sediment quality based on guidelines for freshwater (TEC, PEC) and marine water (ERL, ERM) ecosystems in each sampling site, n is the number of samples for each element

		Cd	Cr	Cu	Ni	Pb	Zn
Guidelines	TEL	0.99	43.4	31.6	22.7	35.8	121
	PEC	4.98	111	149	48.6	128	459
	n < TEC	26	0	26	0	26	21
TEC < n of Can Gio < PEC		0	21	0	11	0	5
Guidelines	ERL	1.2	81	34	20.9	46.7	150
	ERM	9.6	370	270	51.6	218	410
	n < ERL	26	1	26	0	26	26
ERL < n of Can Gio < ERM		0	25	0	15	0	0
	n > ERM	0	0	0	11	0	0

3.3. Comparison of sediment quality between the CGM and other studies

Based on similar conditions of the mangrove forests and the socio-economic development, the trace elements in sediments of the mangrove forests from Southeast Asia, India and China were chosen to compare with the present study (Table 7 and Table 8). The results showed that sediments in the CGM displayed at levels of uncontaminated (Cd, Cr, Cu and Ni) to minor contaminated (Pb and Zn) concentrations. The trace element concentrations in this study were lower from 1.3 times (Zn) to 5 times (Cd), but higher a half (Cr) in compared earlier research in sediments from Ba Lat estuary, Northern of Viet Nam (Tue, Quy, Amono, 2012). In Chao Phraya mangrove sediment, concentrations of Cd, Pb, Zn and Cu showed a higher concentration from 2 to 4 times than those in the CGM sediments (Qiao, et al., 2015). Incredibly, the trace element concentrations measured in China and Hong Kong were very much higher than those in the CGM, for example, Cd concentrations in Mai Po and in Futian were 17 times and 33 times higher than the CGM, respectively (Ong Che, 1999; Li, et al., 2015). Similarly, the trace element concentrations in sediments of two the mangroves of India showed higher than those in the CGM, particularly, Cu concentration being 3.2 to 4.0 times higher than the CGM (Chatterjee, et al., 2012; Kalaivanan, Jayaprakash, Nethaji, Arya, Giridharan, 2017).

Table 7. Comparison of trace element concentrations in sediments of the CGM with other studies in Southeast Asia, India and China

Country	The mangrove forests	Trace element concentrations in ppm						References
		Cd	Cr	Cu	Ni	Pb	Zn	
Vietnam	***Can Gio***	***0.07***	***102.5***	***26.5***	***50.6***	***26.6***	***107.2***	**In this study**
Vietnam	Ba Lat	0.35	65.3	69.6		82.9	136.5	Tue et al, 2012
Hongkong	Mai Po	1.2	33.0	67.1	70.8	135.0	222.0	Ong Che, 1999
China	Futian	**2.3**	55.4	31.7		47.8	296.3	Rongyu et al, 2015
India	Sundarban	0.16	18.0	85.0	23.0	21.0	188.0	Chatterjee et al, 2012
India	Tamil Nadu		183.0	105.5	87.9	64.7	152.8	Kalaivanan et al, 2017
Thailand	Chao Phraya	0.16	138.9	102.3		50.8	214	Shuquing et al, 2015
Singapore	Bongsu	0.27	32.1	32.0	11.7	31.0	120.2	Cuong et al, 2005

Table 8. Comparison of Igeo indexes among mangrove sediments in Southeast Asia, India and China. All indexes were calculated with the same background value of Weldepohl's UCC, 1995

Locations	Igeo (value and level)												References
	Cd		Cr		Cu		Ni		Pb		Zn		
Vietnam (Can Gio)	***-1.1***	***0***	***-0.9***	***0***	***-0.50***	***0***	***-0.7***	***0***	***0.3***	***1***	***0.1***	***1***	*In this study*
Vietnam (Ba Lat)	1.2	**2**	-1.5	0	0.9	1			1.9	**2**	0.5	1	Tue et al, 2012
Hongkong (Mai Po Mangrove)	3.0	**3**	-2.5	0	0.8	1	-0.2	0	2.6	**3**	1.2	**2**	Ong Che, 1999
China (Futian mangrove)	3.9	**4**	-1.8	0	-0.2	**0**			1.1	**2**	1.6	**2**	Rongyu et al, 2015
India (Sundarban mangroves)	0.1	1	-3.4	0	1.2	**2**	-1.9	0	-0.1	0	0.9	1	Chatterjee et al, 2012
India (Tamil Nadu mangrove)			0.0	0	1.5	**2**	0.1	1	1.5	**2**	0.6	1	Kalaivanan et al, 2017
Thailand (Chao Phraya mangrove)	0.1	1	-0.4	0	1.4	**2**			1.2	**2**	1.1	**2**	Shuquing et al, 2015
Singapore (S. Khatib Bongsu)	0.8	1	-2.6	0	-0.2	0	-2.9	0	0.5	1	0.3	1	Cuong et al, 2005

4. Conclusions

Although, previous study reported that urban areas of HCMC could be major sources of pollution in estuarine environment, however the trace element concentration measured in sediment cores of the CGM were still low, being from uncontaminated (Cd, Cu, Zn) to minor contaminated (Cr, Ni, Pb) in comparison to sediment quality guidelines and indexes of TEC, PEC, EF, Igeo and m-ERM-q. These can be explained that the trace element accumulation could be mainly influenced by the suspended particle sizes (compacted coherently, concentrated at 5 µm to 10 µm) and the mangrove plant development. The concentrations of trace element measured in the sediments of the CGM were quite lower than those in the sediments of other mangrove areas in Southeast Asia, India and China.

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