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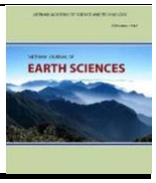

Characteristics of marine environmental geochemistry from Ha Tinh to Quang Nam (60-100 m water depth)

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ABSTRACT

The aim of this study is to elucidate the characteristics of marine environmental geochemistry from Ha Tinh - Quang Nam (60-100m water depth) based on analysis of geochemical parameters of seawater and surface sediments. Surface sediments that are high in absorbed capacity of toxic substances mainly accumulated in northern study area. Seawater dominantly characterized by weak alkaline-weak oxidation and contained biodegradable organic materials. Almost anion and chemical element concentrations in seawater tended to decrease with depth, with an exception for SO_4^{2-}, Br^-, I^- concentrations that had an opposite trend, increasing with depth and B, Hg concentrations displayed a complex variation. Sedimentary environments were highly predominant by weak alkaline-strong oxidizing features and carbonate-rich materials. Concentrations of anions and chemical elements tended to be higher in central area in comparison to northern and southern regions, and positively correlated with fine sediment compositions. Organochlorine pesticides (OCPs) concentration decreased with sediment depth, whilst polychlorinated biphenyls (PCBs) concentration had no clear trend. The organic material, heavy metal, OCPs and PCBs concentrations in seawater and sediments were all lower than environmental standards. The present results have provided important baseline data for monitoring marine environment quality and protecting the marine ecosystem of Ha Tinh - Quang Nam Sea.

Keywords: Marine environmental geochemistry; Seawater; Marine sediment; Ha Tinh, Quang Nam.

1. Introduction

Marine resources play important roles for socio-economic development. However, the high development of socio-economic development on the mainland often causes many impacts on the marine environment such as degradation of seawater and marine sediment environments (Helsinki Commission, 2004; Naser, 2013, Valavanidis and Vlachogianni, 2010). Marine pollution by heavy metals and organic components (i.e., OCPs, PCBs) has been critical issues due to the toxicity, persis-

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tent and bioaccumulation in trophic levels of the food chain (Aderinola et al., 2009; Esslemont, 2000; Vizzini et al., 2013). Heavy metals can be released from sediments to seawater and vice versa due to the changing of environmental geochemistry. Therefore, study of the contamination of heavy metals and organic components in marine environments is necessary for protecting the marine ecosystems. Many researchers have been conducted to study the marine geoenvironment, for example, origin of organic matters in seawater and sediments (Hedges and Clark, 1988) and geochemical characteristics (Glasby and Schulk, 1999). Recently, some environmental geochemistry researches have been conducted to assess the seawater and marine sediment quality, particularly the trace element contaminations in the nearshore region (Addo et al., 2011; Anderinola et al., 2009; Buccolieri et al., 2006; Carman et al., 2007) and coastal gulfs (Wang et al., 2010; Majer et al., 2014).

In Vietnam, environmental geochemistry researches have been integrated in several basic marine geological research programs (Nguyen, 1999; Pham, 2009; Tran, 2004; Vu, 2004). However, the marine environmental geochemistry of Ha Tinh - Quang Nam (60-100 m water depth) has not been reported so far. Therefore, the purposes of the present study are to examine the marine environmental geochemistry characteristics of seawater and marine sediments by analyzing the sediment grain sizes, pH, Eh, heavy metals, persistent organic pollutants (polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs), and other environmental parameters. The results from the present study will provide important baseline data for assessing the status quo of and monitoring the marine environmental quality in the future.

2. Materials and Methods

2.1. Study area

The study area is located in Ha Tinh - Quang Nam Sea (60-100 m water depth), encompassing by depth contours of 60 m and 100m, respectively (Figure 1). The marine environments of the study area receive freshwater flows and materials from the mainland by several large estuaries, including Han River estuary, Thuan An estuary, Nhat Le estuary, Viet estuary, Tung estuary, Dai estuary and Gianh estuary. The main human activities in this sea include urban development, fishing and marine transportation, which can have some impacts on marine environments. The coastal zone of the study area concentrates many large cities and industrial zones such as Dong Hoi, Hue and Da Nang cities, and Vung Ang and Chan May economic zones. Thus, the marine environments of the study area could be impacted by domestic and industrial sewages from above economic zones and cities. Moreover, the coastline of the study area has a large seaport system, which includes Vung Ang, Chan May, Da Nang international seaports. Additionally, the marine transportation has highly dense maritime routes of both national and international levels. Thus, the study area is highly sensitive with oil-spills from marine transportation and wrecks. Recent report showed that the study area was impacted by 14 serious oil-spills in the period from 2004-2012. The oil-spills caused a contamination of seawater by oils and impacts on the aquaculture and tourism on coastal areas (http://www.songthu.-com.vn).

Seawater temperature ranges from 28-30 ºC and 22-25 ºC in the summer and winter, respectively. Sea waves in this area are controlled by monsoon and storms. In which, southeast waves are often stable and higher intensity than northwest waves. The largest waves with height from 6-7 m have been observed offshore of the study area.

The tides from Deo Ngang - Son Tra are very complicated by changing tidal regime four times per month: mixed diurnal tide, mixed semi - diurnal tide, diurnal tide and then repeated mixed semi - diurnal tide. Tides from from Son Tra - Quang Nam are mixed semi-diurnal tide. The sea currents from Ha Tinh - Deo Ngang annually flow following a

direction from the northeast to southwest with flow velocity from 25-50 cm/s. From Deo Ngang - Son Tra, the sea currents in both winter and summer have a direction from north to south and flow velocity varies by shoreline geomorphology. From Son Tra - Quang Nam, the sea currents have a direction to the southwest in the period from October to April, and the rest of the year flow toward the northwest. The flow velocity of sea currents is 10-25 cm/year in summer and higher in winter, being 50-70 cm/s.

2.2. Fieldwork and sampling

The present study was conducted in Ha Tinh - Quang Nam Sea (60-100 m water depth) from April to July, 2012. A total of 1,341 sampling sites were surveyed and designed for collecting seawater and marine sediment samples (Figure 1). Seawater samples were collected from 804 sites, using a niskin bottle from three deep layers (surface, middle and bottom layer). Rich fine-grained sediment samples were collected from 465 sites for pH, Eh analysis; 165 sites for cation exchange, iron ions, and carbonate analysis; 524 sites for elemental analysis; 1,093 sites for grain size analysis; and 402 sites for PCBs and OCPs. Sediment samples were collected by using an ocean grab sampler and a gravity corer. All samples were immediately kept on ice in cool boxes. The samples were then transported to laboratory for processing and analyzing at VNU University of Science and Institute of Industrial Chemistry.

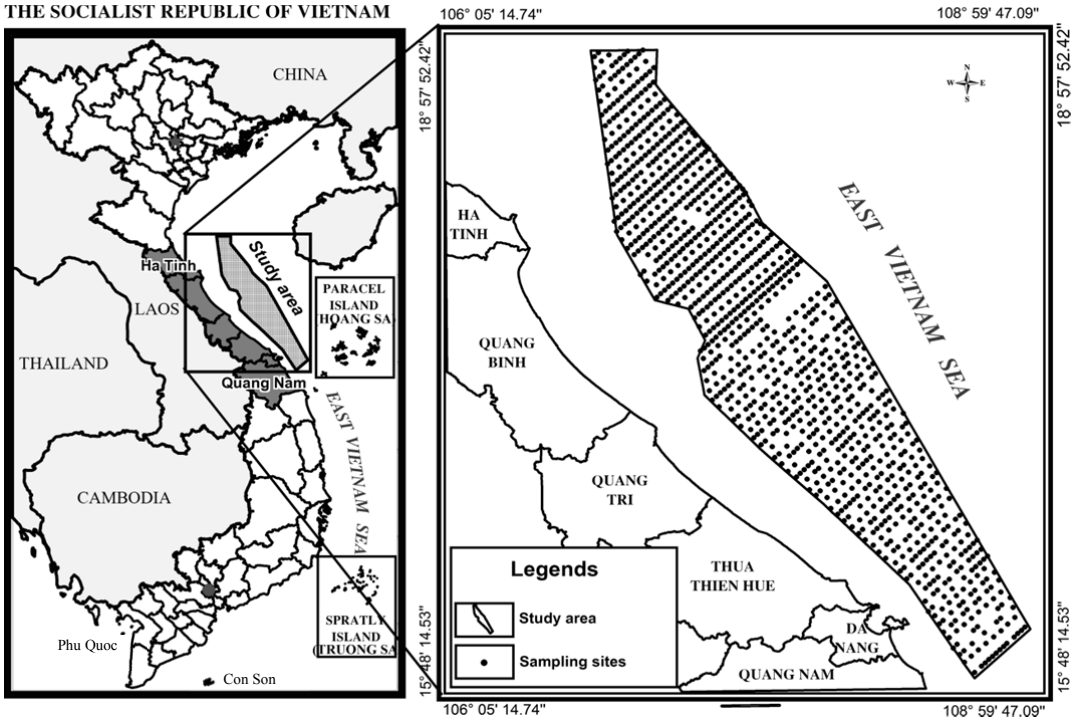

Figure 1. Map shows the location of Ha Tinh - Quang Nam Sea (60-100 m water depth) and sampling sites

2.3. Sample analysis

In the laboratory, Eh, pH and salinity of seawater samples were measured using a pH, Eh, and salinity meter, respectively. The Mn, B, Br, I, PO_4^{3-}, NO_3^-, SO_4^{2-} concentrations were determined using colorimetric methods. Total organic carbon (TOC) was measured

using Knop method. The K, Na, Cu, Pb, Zn, Sb, As, Hg concentrations were analyzed using an atomic absorption spectroscopy (Perking Elmer AA 800). The analytical accuracy and precision were evaluated by comparing the analyzed results with reference materials following a guideline of the Ministry of Natural resources and Environment (MONRE, 2011). The OCPs and PCBs concentrations were Soxhlet extracted and analyzed using an Agilent Technology 7890 gas chromatograph (GC) interfaced with a high resolution mass spectrometer (HRMS). Similar to element analysis, the accuracy and precision organic compound analysis were assessed following the guideline of MONRE (2011). The sediment grain size composition was measured by both sieve and pipette methods.

2.4. Statistical analysis

The analytical results are statistically processed using a statistical software SPSS. Talasofil coefficient (Ta) and concentration factor (Td) are used to evaluate the concentration level of chemical elements in the seawater and marine sediments, respectively. Both the Ta and Td were calculated by a ratio of mean concentration of the chemical element and its concentration in the world mean concentration. Spatial variation of the geochemical parameters is presented using MapInfo software.

3. Results and Discussion

3.1. Characteristics of surface sediments

The study area has many sediment types, being fine to coarse grain sizes. According to the absorbed capacities of sediments to toxic substances, surface sediments can be divided into 3 groups (Figure 2): The sediments with low absorbed capacity to toxic substances are composed less than 20% of the fine-grained fraction, and the main components are sand and gravel. The total sandy gravel and TOC are 87.34% and 0.92%, respectively. This sediment type distributes a small area within 60-65 meter in depth. The sediments with medium absorbed capacity to toxic substances have proportions of fine-grained fraction ranging from 20 to 60%, being sandy mud. This sediment type distributes in a small area in the north and a sizable strip in the south. The main components of this group include 19.1±9.32% mud, 25±10.83% silt, 53.56± 10.21% sand and 0.87±0.23% TOC. The sediments with high absorbed capacity to toxic substances have fine-grained fraction >60%, distributing mainly in the northern study area. The main compositions of this sediment group include mud, muddy sand and clay. The main components are 34.66±19.13% clay, 52.85 ±23.15% silt, 12.41±11% sand and 0.8±0.21% TOC.

3.2. Characteristics of marine environmental geochemistry

3.2.1. Seawater environment

Seawater salinity in the study area was 32.2‰ and tended to slightly increase from the surface to bottom water column and slightly to decrease towards the south. Results indicated that seabed topography of the northern area was more gently steep slope that made the northern sampling sites with the same depth located at more offshore and less effect by freshwater flows from main land in comparison to the southern sampling sites. Additionally, the southern part of the study area is received the flows of several relative big estuaries, including Dien Huong, Tu Hien, Thuan An, Dai estuaries. Means of pH and Eh parameters of seawater were 8.26 and 117.5 mV, respectively and tended to less vary with depth and horizontal space. This pattern indicated that seawater can be categorized as alkaline-weak oxidation. The concentration ranges of COD and BOD_5 were 1.60-3.76 mg/l and 1.23-2.10 mg/l, respectively. The little difference between

COD and BOD_5 indicated that the organic matter content in seawater was composed mainly by bio-degradable organic materials. Thus, seawater environment from Ha Tinh - Quang Nam (60-100 m depth water) was less influenced by freshwater flows from main lands in the northern areas and contained mainly bio-degradable organic materials.

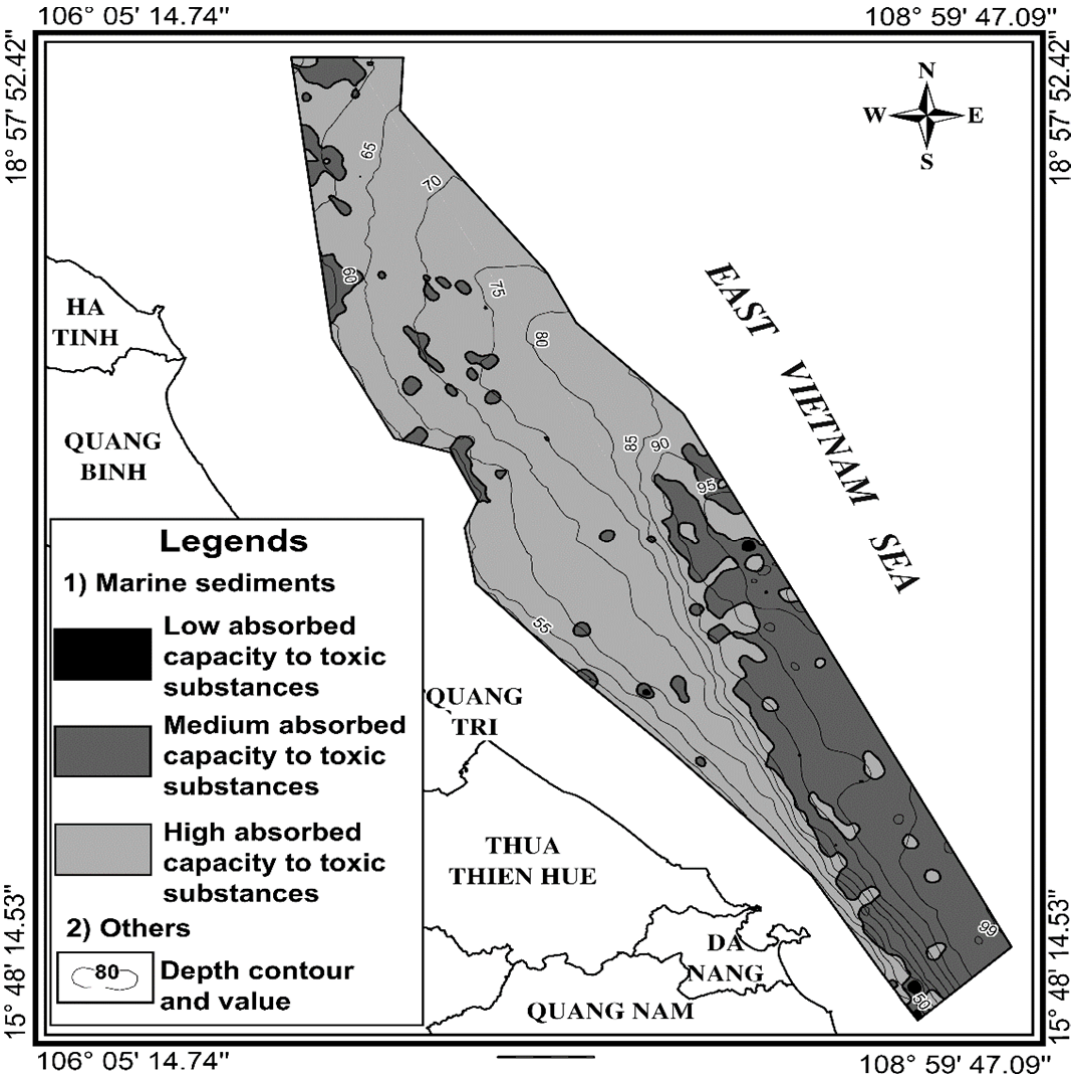

Figure 2. Spatial distribution of surficial sediments in Ha Tinh - Quang Nam Sea (60-100 m water depth)

The major anions SO_4^{2-} and NO_3^- evenly distributed in the seawater of the study area with the variation coefficients were 7.0 and 2.6%, respectively. The average concentration of SO_4^{2-} was 2,447.9 mg/l and was higher than that in seawater from Tra Co - Son Tra region (2,374.9 mg/l) and tended to increase with depth. The average concentration of NO_3^- was 0.595 mg/l, being lower than that in seawater from Tra Co -

Son Tra region (0.82 mg/l) and tended to decrease with depth (Mai, 2011).

The mean concentration, the variation coefficient and the Ta of selected elements in seawater from Ha Tinh - Quang Nam (60-100 meter depth) is shown in Table 1. The Ta of Mg, Sb, As, I, B and Br were <1, classifying as less concentrated elements in seawater. The variation coefficients of these elements ranged from 2.0-12.0%, indicating that they evenly distributed in the seawater (Figure 3). Concentrations of Mg, Sb and As tended to decrease with depth. But, the concentrations of I and Br tended to increase with the depth. Concentration of B displayed an unclearly trend, being the highest and lowest in the mid-dle and surface layer, respectively (Table 1).

Table 1. Statistical parametric concentration (mg/l) and Talasofil coefficient (Ta) of selected elements in seawater from Ha Tinh - Quang Nam Sea (60-100m water depth) (n = 804)

	Ctb(tm)	Ctb(tg)	Ctb(tđ)	Ctb	V (%)	Ta
Mg	1,323.5	1,308.6	1,287.1	1,306.4	12.0	0.96
Sb	0.000435	0.000426	0.000424	0.000428	5.9	0.96
As	0.00309	0.00301	0.00296	0.00302	11.7	1
I	0.0550	0.0556	0.0560	0.0550	5.5	0.85
B	4.078	4.100	4.094	4.091	5.2	0.84
Br	59.24	59.30	59.43	59.32	2.0	0.85
Mn	0.00273	0.00263	0.00249	0.00262	39.6	1.3
Cu	0.00347	0.00341	0.00328	0.00339	41.3	1.1
Zn	0.0154	0.0146	0.0144	0.0148	14.5	1.5
Cd	0.000177	0.000174	0.000164	0.000172	43.0	1.7
Hg	0.000038	0.000035	0.000036	0.000036	36.6	1.2
Pb	0.000260	0.000253	0.000250	0.000255	29.7	8.5

Note: Ctb(tm), Ctb(tg), Ctb(td) and Ctb are the average concentration of surface, middle, bottom layer and whole area, respectively; V is variation coefficient; Ta is Talasofil coefficient

The Ta of Mn, Cu, Zn, Cd, Hg ranged from 1 to 2, indicating that they were weak concentrated elements in seawater. In which, Zn distributed very uniform with the variation coefficient of 14.5%; Mn, Hg evenly distributed with respective variation coefficients of 39.6 and 36.6% and Cu, Cd distributed relatively uniform with the variation coefficients of 41.3 and 43.0%. Concentrations of Mn, Cu and Cd decreased with the water depth. The variation of Hg concentration was an unclearly trend with the highest concentration within the surface layer and the lowest concentration at the middle layer.

The Ta of Pb was 8.5, indicating for the strong concentration level in seawater. Concentration of Pb evenly distributed in seawater with the variation coefficient of 29.73% (Figure 3). The concentration of Pb slightly decreased with depth, being $0.26.10^{-3}$ mg/l, $0.253.10^{-3}$mg/l and $0.25.10^{-3}$mg/l for the surface, middle and bottom layer, respectively.

3.2.2. Marine sediment environment

Means of pH and Eh in sediments were 8.19 and 105.0 mV, respectively. The pH and Eh ranged from 7.15-8.95 and from -183 to 200 mV, respectively. The geochemical environment of sediments was relatively complex and could be divided into weak alkaline-strong oxidation, weak alkaline-weak oxidation; weak alkaline-strong reduction. In which, weak alkaline-strong oxidation environment was the most dominant.

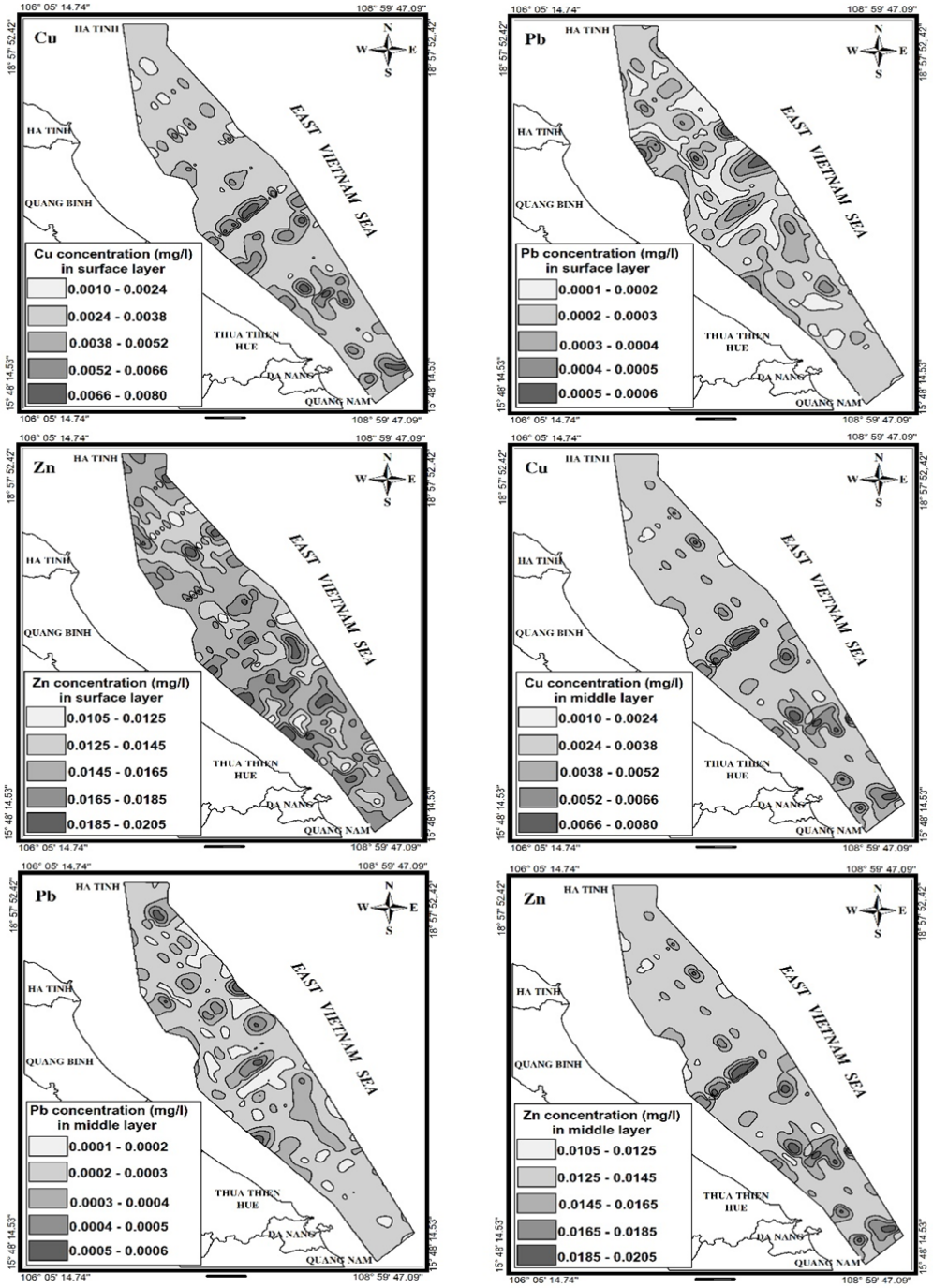

Figure 3. Spatial distribution of selected metal concentrations in different seawater layers from Ha Tinh - Quang Nam (60-100 m water depth)

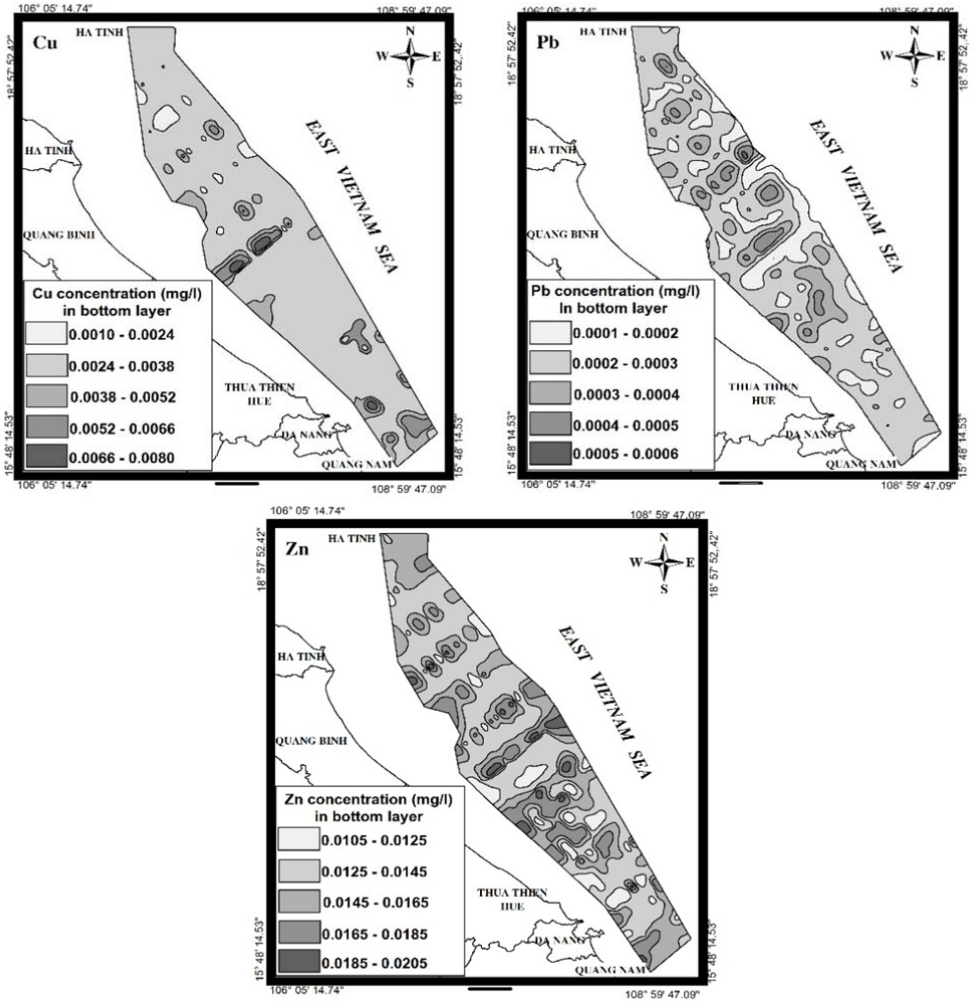

Figure 3.

The major anions had different distribution characteristics in the marine sediment (Table 2). SO_4^{2-} and PO_4^{3-} displayed a highly uniform variation with the variation coefficients ranged from 11.7 - 13.5%; NO_3^- distributed evenly with the variation of 20.8% and CO_3^{2-} unevenly distributed with the variation coefficient of 57.4%. SO_4^{2-}, PO_4^{3-} and NO_3^- concentrations tended to be higher in the central region of the research area and decreased towards the northern and southern regions. The decreasing gradient seemed to be faster in the south. The concentrations of major anions positively correlated with fine-grained sediment fraction (r = 0.42 - 0.46). CO_3^{2-} concentration tended to be higher in the northern and southern regions, and lower in the central region of the study area. The CO_3^{2-} concentration negatively correlated with the fine-grained sediment fraction (r = -0.3) (Table 2). Comparison to the marine sediments from Tra Co - Son Tra area, the concentrations of SO_4^{2-} and NO_3^- were lower, but the concentrations of PO_4^{3-} and CO_3^{2-} were relatively similar (Mai, 2011).

According to concentration factor (Td), the element concentrations in marine sediments can be divided into three groups as follows: less concentrated elements (Td <1) were Mn, Zn, Pb, Cu, Sb and As; weak concentrated elements (1<Td<2) were Hg and Pb; strong concentration elements (Td ≥ 3) were Br and I. The element concentrations tended to increase in the central area and decrease towards the nothern and southern regions (Figure 4). The tendency of element concentrations was similar to the fine-grained size sediments, resulting the correlation coefficient between element concentrations and fine-grained size sediments ranged from 0.41-0.58 (Table 2). The variation coefficients of the heavy metals and halogen elements ranged from 12.7-29.3%, indicating that they distributed highly uniform in marine sediments. The high concentration levels of Br and I could be explained by their high concentration in marine biological substances (i.e., phytoplankton, seaweeds). The distributing patterns of these elements in the present study were relative similar to those of Tra Co - Son Tra area (Mai, 2011).

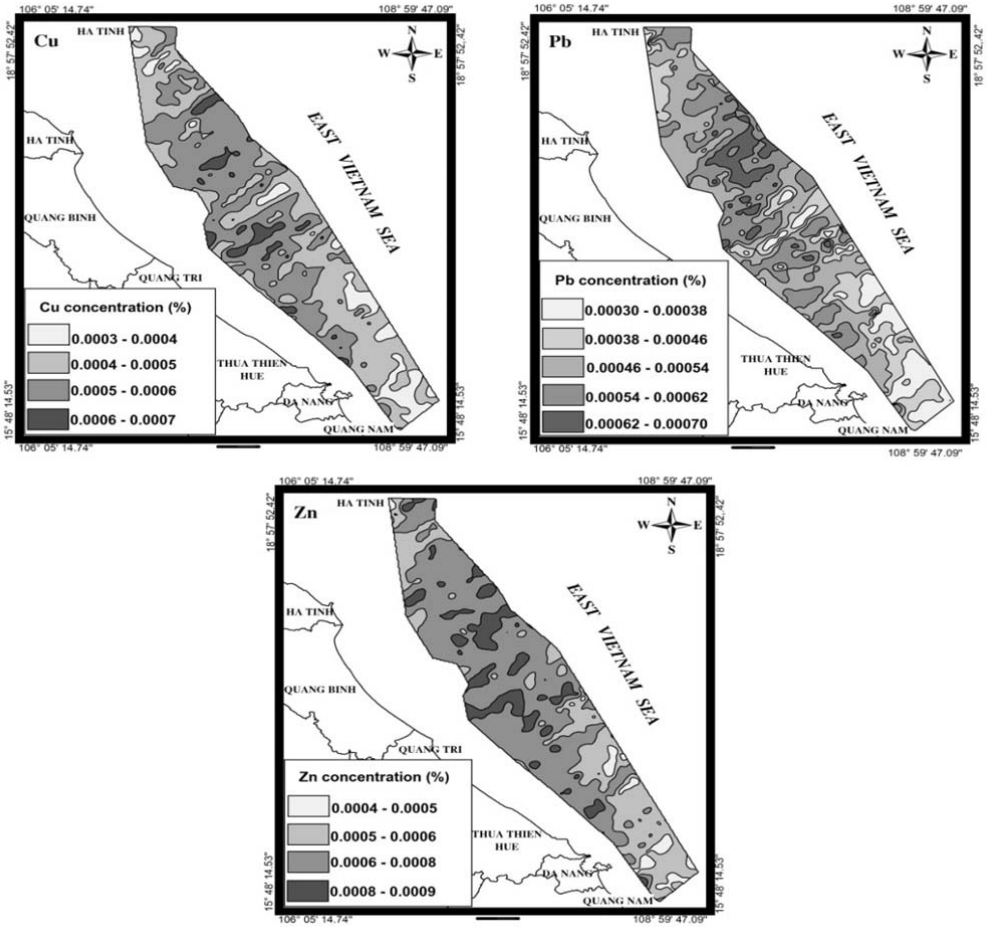

Figure 4. Spatial distribution of selected elements in marine sediments from Ha Tinh - Quang Nam Sea (60-100 m water depth)

Table 2. Statistical parametric concentration and Td coefficient of selected elements in marine sediments from Ha Tinh - Quang Nam (60-100 m water depth) (n = 524)

	Unit	Cmax	Cmin	Cmean	V(%)	HLTBTG	Td	r
Mn^{2+}	%	0.053	0.023	0.037	16.7	0.085	0.43	0.44
Zn^{2+}	10^{-3}%	0.87	0.43	0.69	14.3	2	0.35	0.58
Pb^{2+}	10^{-3}%	0.69	0.39	0.54	12.7	2	0.27	0.56
Cu^{2+}	10^{-3}%	0.69	0.32	0.49	14.8	4	0.12	0.52
Sb^{3+}	10^{-3}%	0.046	0.02	0.032	17.6	0.14	0.23	0.49
As^{3+}	10^{-3}%	0.14	0.05	0.08	22.8	0.1	0.82	0.41
Hg^{2+}	10^{-3}%	0.0092	0.0028	0.0056	22.5	0.003	1.88	0.49
SO_4^{2-}	%	0.033	0.018	0.025	13.5			0.42
PO_4^{3-}	%	0.033	0.018	0.026	11.7			0.46
NO_3^-	%	0.019	0.005	0.009	20.8			0.45
CO_3^{2-}	%	15.90	0	5.11	57.4			-0.30
B^-	10^{-3}%	5	1.4	3	26.5	2	1.51	0.55
Br^-	10^{-3}%	6.8	1.9	3.7	27.1	0.6	6.2	0.55
I^-	10^{-3}%	3.6	0.9	1.8	29.3	0.11	16.55	0.50

Note: Cmax, Cmin, Cmean are the maximum, minimum, average concentration, respectively; V is variation coefficient; HLTBTG is the world average concentration; Td is concentration coefficient; r is correlation coefficient with fine-grained size sediment fraction

The total concentration of PCBs ranged from 0.36 - 5.18 ng/g with an average of 2.78 ng/g. In which, the main congeners were 2,2',3,4,5,6'-hexachlorobiphenyl with an average concentration of 0.88 ng/g; 2,2',3,4,4',5-hexaclorobiphenyl with an average concentration of 1.02 ng/g, total 6Cl with an average concentration of 1.99 ng/g. Other congeners had lower concentration, ranging from 0-0.43 ng/g (Table 3, Fig. 5a).

The concentration of OCPs ranged from 0.03-0.39 ng/g. In which, the 44DDD and 44DDT congeners had the highest concentration, ranging from 0.005-0.13 ng/g and from 0.005-0.18 ng/g, respectively. Other congener concentrations were lower, ranging from 0-0.07 ng/g (Tables 4, Figure 5b).

Table 3. The PCB congener concentrations (ng/g) in marine sediments from Ha Tinh-Quang Nam (60-100m water depth) (n = 402)

Congener	Cmin	Cmax	Cmean
2,4,4' - triclorobiphenyl	0.05	0.28	0.12
2,2',5,5' - tetraclorobiphenyl	0.03	0.42	0.1
2,2',4,5,5' - pentaclorobiphenyl	0.06	0.35	0.21
2,3,4,4',5 - pentachlorobiphenyl	0.07	0.34	0.28
2,2',3,4,5,6'- hexachlorobiphenyl	0.05	1.81	0.88
2,2',3,4,4',5 - hexaclorobiphenyl	0.05	1.72	1.02
2,2',3,4,4',5,5' - heptaclorobiphenyl	0.01	0.13	0.03
Total 2Cl	0.03	0.07	0.05
Total 3Cl	0.06	0.9	0.14
Total 4Cl	0.06	0.56	0.13
Total 5Cl	0.09	0.93	0.43
Total 6Cl	0.09	4.04	1.99
Total 7Cl	0.02	0.7	0.06
Total 8Cl	0.01	0.7	0.02
Total 9Cl	0.01	0.09	0.02
Total 10Cl	0	0	0
Total PCBs	0.36	5.18	2.78

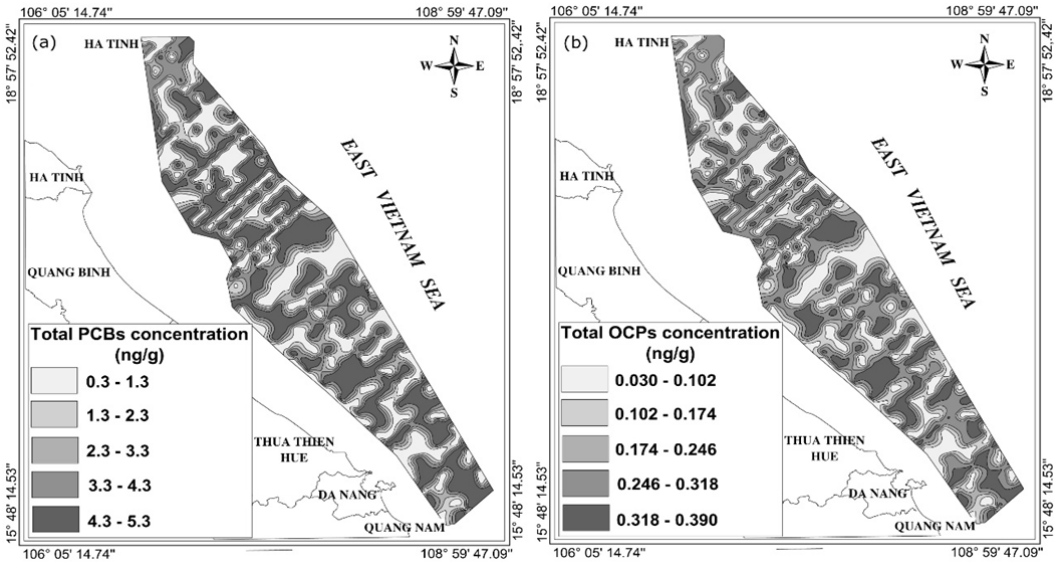

Figure 5. Spatial distribution of total OCPs and PCBs in surface sediment from Ha Tinh - Quang Nam Sea (60-100 m water depth)

Table 4. Concentration of OCP congeners (ng/g) in marine sediments from Ha Tinh - Quang Nam (60-100 m water depth) (n = 402)

	αBHC	γBHC	βBHC	δBHC	44DDE	44DDD	44DDT
Cmin	0	0.008	0	0.006	0.01	0.005	0.005
Cmax	0.016	0.041	0.02	0.03	0.07	0.13	0.18
Cmean	0.006	0.015	0.01	0.018	0.03	0.068	0.089

Among 18 sampling sites were selected for analyzing PCBs and OCPs concentrations in different sediment layers. The total concentration of PCBs concentration was 5.5 ng/g, being the highest in the sediment layers of 40-80 cm in depth from offshore Cua Nhuong estuary and was 0.83 ng/g, being the lowest in the sediment layers of 0-40cm in depth from offshore from Ly Hoa estuary (Figure 6a1, b1).

The total concentration of OCPs was the highest in sediment layers of 80-100cm in depth from offshore Cua Sot estuary, of 40-80 cm in depth from offshore Thuan An estuary with both mean of 0.46 ng/g. In Cua Sot estuary, the congener concentration was 0.01 ng/g (γBHC), 0.02 ng/g (δBHC), 0.03 ng/g (44DDE), 0.14 ng/g (44DDD) và 0.26 ng/g (44DDT). In Thuan An estuary, the congener concentration was 0.01 ng/g (γBHC), 0.02 ng/g (δBHC), 0.04 ng/g (44DDE), 0.15 ng/g (44DDD), and 0.24 ng/g (44DDT). The lowest total concentration of OCPs was 0.063 ng/g in sediment layers of 0-40cm in depth offshore the Lai headland. The congener concentrations were 0.016 ng/g (γBHC), 0.01 ng/g (βBHC), 0.006 ng/g (δBHC), 0.018 ng/g (44DDE), 0.08 ng/g (44DDT). Generally, the concentration of OCPs tended to increase with the sediment depth with an exception of sampling sites from the offshore (75-76 m water depth) Gianh estuary, Ly Hoa estuary (64-65 m water depth) and Le Thuy offshore (63-64 m water depth) tended to decrease with depth (Figure 6a2, b2).

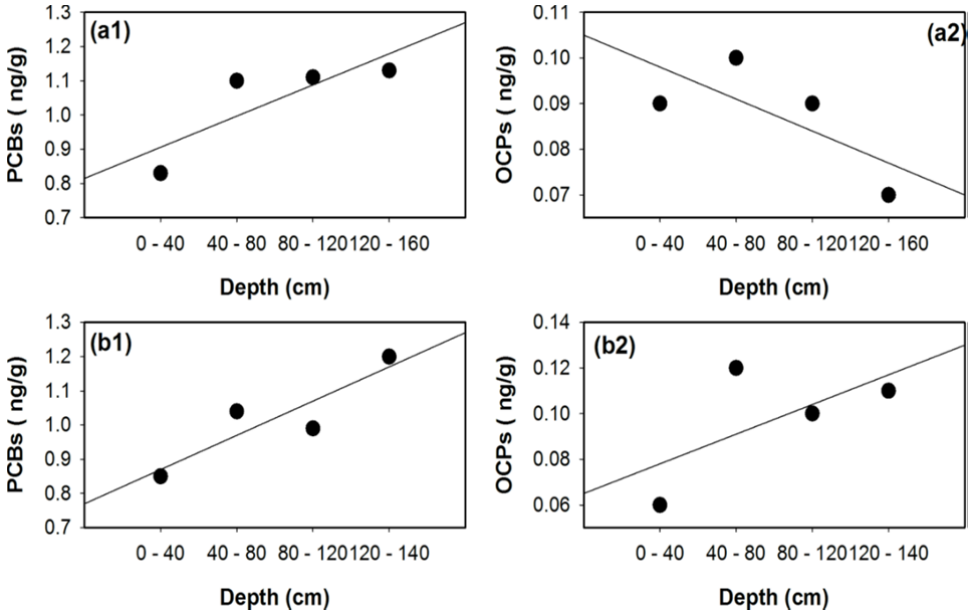

Figure 6. The variation of total PCBs and OCPs concentration with sediment depth from selected sampling sites in Ha Tinh - Quang Nam Sea (60-100 m water depth) (a1, 2 is a sample at 75 m water depth from the offshore Gianh estuary, b1, 2 is the sampling site at 62 m water depth from the offshore An Cu gulf)

4. Quality assessment of marine sediment and seawater environments

National technical regulation on coastal water quality (MONRE, 2008) and National technical regulation on off-shore water quality -QCVN 44:2012/BTNMT (MONRE, 2012a) are used to access the seawater quality. The concentrations of As, Cd, Pb, Cu, Zn, Mn, Hg, Sb were lower than the permitted values of QCVN44:2012/BTNMT (MONRE, 2012a), indicating the seawater environment from Ha Tinh - Quang Nam was not polluted by these metals (Table 5).

Interim sediment quality guidelines (ISQGs) (CCME, 2002) and National Technical Regulation on Sediment Quality-QCVN 43:2012/BTNMT (MONRE, 2012b) are used to access sediment quality. Results showed that the concentrations of Cu, Pb, Zn, Sb, As and Hg were lower than the permitted values of QCVN 43:2012/BTNMT and ISQGs, indicating that marine sediments from Ha Tinh - Quang Nam (60 - 100 m water depth) was not contaminated by above metals (Table 6).

Table 5. The average concentrations (mg/l) of selected metals in seawater of world, study area (n = 804) and their permitted limit values by QCVN 10:2008/BTNMT and QCVN 44:2012/BTNMT

Element	World	QCVN 10:2008			QCVN44:2012/BTNMT	Ha Tinh - Quang Nam Sea
		Beach	Aquaculture	Other		
As	0.003	0.04	0.01	0.05	0.005	0.00302
Cd	0.0001	0.005	0.005	0.05	0.001	0.000172
Pb	0.00003	0.02	0.05	0.1	0.005	0.000255
Cu	0.003	0.5	0.03	1	0.01	0.00339
Zn	0.01	1.0	0.05	2.0	0.02	0.0148
Mn	0.002	0.1	0.1	0.1		0.00262
Hg	0.00003	0.002	0.001	0.005	0.000016	0.000036
Sb	0.0005					0.0000428

Table 6. The average concentrations (10^{-3} %) of selected metals in marine sediments of world, study area (n = 524) and their permitted limit values by ISQGs and QCVN 43:2012/BTNMT

Pollution level		Standard	Cu	Pb	Zn	Sb	As	Hg
World			4	2	2	0.14	0.1	0.003
Potential		>3*TBTG	12	6	6	0.42	0.3	0.009
ISQGs	Weak	>Tel	1.87	3.2	12.4		0.724	0.013
	Average	>1.5*Tel	2.81	4.8	18.6		1.086	0.0195
	Strong	>2*Tel	3.74	6.4	24.8		1.448	0.026
	Very strong	>3*Tel	5.61	9.6	37.2		2.172	0.039
	Influence level	>Pel	10.8	11.2	27.1		4.16	0.0696
QCVN 43:2012/BTNMT			10.8	11.2	27.1		4.16	0.07
Ha Tinh - Quang Nam Sea			0.49	0.54	0.69	0.032	0.08	0.0056

The concentrations of total OCPs and PCBs had not exceeded the TEL thresholds of ISQGs and were still lower than the permitted value of QCVN43:2012/BTNMT, indicating that the marine sediments of the study area were not polluted by OCPs and PCBs compounds.

5. Conclusions

Seawater is characterized by alkaline-weak oxidation and less effect by flows and activities from main lands and mainly contained of organic biodegradable materials. Surficial sediments of Ha Tinh - Quang Nam Sea (60-100 m in water depth) contained fine- to coarse- grained size fractions. In which, the sediments with high absorbed capacity to toxic substances were mostly dominant and mainly distributed towards the northern study area. Sediment environment is characterized by weak alkaline - strong oxidation and rich in carbonate. The major anions and heavy metals in marine sediments highly concentrated in fine-grained size sediments. According to the seawater and marine sediment quality guidelines, the seawater and marine sediments of Ha Tinh - Quang Nam Sea had not been polluted by heavy metals, PCBs and OCPs compounds.

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