GEOCHEMICAL SEDIMENTARY EVOLUTION FEATURES OF THE PROCESSES OF FORMATION, DEVELOPMENT AND DEGRADATION OF MANGROVE FORESTS IN NAMDINH COASTAL REGION, VIETNAM

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ABSTRACT

The formation, development and degradation of mangrove forests in Namdinh province are characterized by 3 distinctive sedimentary environments such as: the areas without mangrove, the mangrove forest and the shrimp ponds. The variation in hydrodynamic, water circulation, human impact leads to geochemical differentiation of sedimentary environment and formations. This evolution is visually reflected in the regularly changing in geochemical indices, the content of nutrients and heavy metals.

The formation and development of mangrove forests are natural sequences going with the transform of low tidal mudflat without mangroves into high tidal mudflat, with favorable condition for keeping the mangroves seeds and its development. During these processes, the content of nutrients increases (N from 0.06 upto 0.07%, P_2O_5 from 0.17 upto 0.19%, humid from 0.97 upto1.41%, $C_{organic}$ from 0.57 upto 0.83%) as a result of increasing organic material source. Analysis of heavy metals in these two sediments yielded Pb level changing from 97 upto 105 ppm, Zn from 123 upto 127 ppm..., showing the increasing capacity of mangrove sedimentary environment in keeping and storing these toxic elements. In this sense, these processes contribute much to the protection of marine environment.

Destroying of mangrove forests and creating shrimp ponds have resulted in degradation of mangroves, water and sedimentary environment. This process have led to intensive accumulation of pyrite and sulfur (S_{pyrite}: 0.07-0.13%, S_{total}: 0.21-0.28%, $S_{reduction}$: 0.13-0.18%), decreasing content of nutrients (N from 0.07 downto 0.05%, P_2O_5 from 0.19 downto 0.06%, humid from 1.41 downto 0.94%, $C_{organic}$ from 0.83 downto 0.55%), dispersion of toxic heavy metals (Cu from 118.6 downto 88.6ppm, Pb from 105 downto 87ppm, Zn from 126.9 downto 93.5ppm). Once the shrimp ponds degraded, it would be difficult not only to maintain high productivity of aquaculture, but also to replant mangrove forest.

Key words: coastal region, geochemical, mangrove, sediment

Introduction

Geochemical processes in river mouth sediments had no longer been virginal land to scientists since 1960s when Kaplan and Rittenberg the first time declared their research about geochemical cycles of C, N, S [11]. This research is followed by several scatter works of Goldhaber (1974, 1977, 1980) [8], Jorgensen (1977, 1979, 1983) [12], Appleby and Oldfield (1978), Berner (1985, 1987), Raiswell (1988, 1994, 1996), Canfield Thamdrup (1994, 1996), Bruchert (1988) [1], Glasby and Schulz (1999) [7]...which make it rather clear for understanding geochemical cycles of some elements such as Mn, Fe, Co, Ni, Cu, As. Upto 1990s, many research works on spatial distribution of geochemical parameters in sediments of some river mouths over the world had been done, regardless of chronological factor (Latimer, 1996; Budarudeen, 1996; Dean, 1998, Menon, 1998; Anikiev et al, 2000)[1], [6], [7], [20].... Thus the relation between geochemical properties of sediments and changes of sedimentary environment after time had not been understood. In Vietnam, geochemical features (salinity, pH and humic) of river mouth sediments had cursorily been discussed in some mangrove ecosystem researches by Phan Nguyen Hong [9], [10],..Nguyen Hoang Tri [21]. Since 1993, some remarkable works on geochemical processes in coastal regions with mangroves had been published [2], [3], [4], [5], [14], [17], [18].

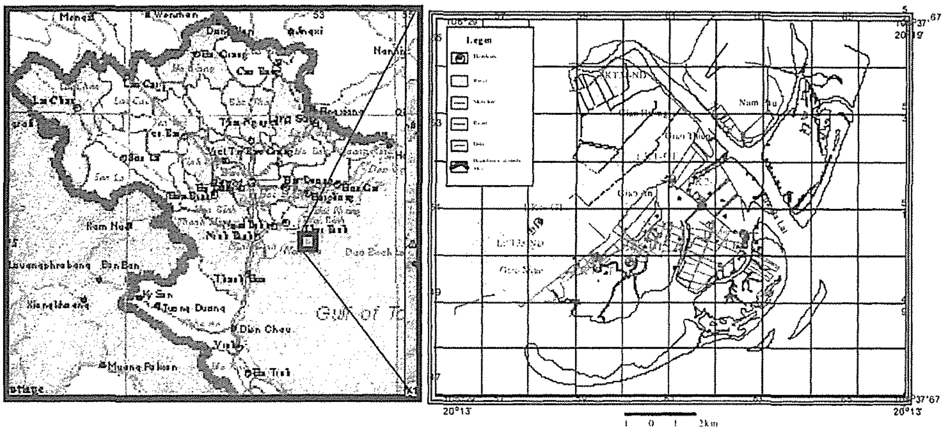

Figure 1. Map of study area

But geochemical sedimentary evolution features during the processes of formation, development and degradation of mangrove forest in Vietnam, in general and in Namdinh coastal region, in particular has not been studied yet. So, to solve this problem is the aim of our paper. The coastal region which was chosen for our research - Namdinh province (fig.1) is located on the southern part of Red River mouth area, where sedimentary environment is complexly changing due to the formation, development and degradation of mangrove forest. Stretching from $20^{0}11'15"$ to $20^{0}17'30"$N and from $106^{0}29'30"$ to $106^{0}35'15"$ E, the area is accreted permanently with Red River alluvia. Thanks to tropical climate, mangroves there are developed with variety of families such as *A. corniculatum, Brugiurea gymnodia, Acanthus ilifolius, Sonneratia caredaris, Kandelia cander, Avicenia lanata*..ect. With the height ranging from 0.5m to 3.5m, mangroves this area is of mean stature in comparison with that in south Vietnam and some other Asian countries [9], [10], [21]. The formation and development of mangrove forest on tidal mudflats has brought to the local people there sound benefits coming from agro- and aqua-products. As by-side of this advantage, mangrove cutting overly for aquaculture by local people led to degradation of mangrove forest. Successful recovering of geochemical sedimentary evolution picture of this area would be a significant contribution to sustainable mangrove management.

Methods and materials

Seven handcores relevant to 2 sampling transects covering vary sedimentary environments has been collected machine drill equipment and location determined on map by a Garmin 75 GPS (fig.1). Of these 7 handcores, 30 representive samples were chosen, taken after depth. Together with 10 bottom sedimentary samples collected along Tra river, Vop river and the shoreline, these 30 handcore samples have been stored carefully and prepared for analysis. These samples were analyzed for grain size (Laser method, Master sizer equipment of Malvern Instruments ltd, UK), mineral (X-ray method, Brucker X-ray diffactometer, Germany), geochemical indicies:Fe^{2+}, Fe^{3+}, Fe^{2+}_{HCl},Fe^{2+}_{pyrit}, S_{total}, $S_{reduction}$, S_{pyrit} (Vonkov- Octramov method), SiO_2, LOI (Mass analyzing method), Al_2O_3, FeO, Fe_2O_3 (Volume analyzing method), TiO_2 (Photometric titration method) Ca, Mg, Mn, Na, K, heavy metals: Cu, Pb, Zn, Co, Ni, Cr, Cd (Atomic Absorption Spectrophotometric method, AAS Mark II Nippon Jarreld Ash and Shimadzu AAS) and nutrients: $C_{organic}$ (Kali dichromate titration method), N (Kjedald method), P(Photometric titration method), humid.

The obtained data had been processed by statistical methods and information technique. Statistical parameters (average, minimum, maximum values), variation and correlation co-efficients were calculated. Charts and trendlines were established as well.

Results and discussions

As mentioned above, the coastal region of Namdinh province has 3 sedimentary environments differing each from others in sedimentary deposition condition, water circulation and human impact (Tab 1). Being supplied by Red River, sediments in these three environments are of tidal flat facies ($Q_{IV}{}^{3}tb_3$ amb, mb) and mainly composed of fine grain (Md = 0.007mm) with high content of silt (55-65%). Mineral composition comprises quartz (45-51%), illite (16-19%), chrorite (10-12.5%), feldspar (10-11%), kaolinite (7- 9%), cancite (1.4-2.6%) and ilmenite (1.5-1.6%) (tab.2).

Table 1 : The differentiation characteristics of modern sedimentary deposition conditions

Differentatiation characteristics	Affected level		
	Low tidal mudflat	Mangrove forests	Shrimp ponds
Hydrodynamic	Strongest	Medium	Weakest
Water circulation	Best	Medium	Worst
Time of being in water	20-24 hours per day	6-8 hours per day	24 hours per day
Mangroves	None	High density	Scatter
Human activities	Weakest	Medium	Strongest

Macro elements as well as minerals are rather regularly distributed in all three sedimentary environments (V < 15,Tab.2).

Table 2.Mineral and chemical composition of the three sedimentary formations in the study area.

		Low tidal mudflat	Mangrove forests	Shrimp ponds
Mineral composition	Cancite	2.56/11.74 *	1.41/62.15	1.66/62.87
		2.20-7.16	0.61-2.52	0.48-2.46
	Feldspar	10.5/7.51	10.1/9.91	11.51/1.21
		9.77-11.85	8.93-11.29	11.40-11.67
	Ilnenite	1.61/4.61	1.59/2.26	1.48/0.15
		1.54-3.15	1.55-1.65	1.48-1.49
	Quartz	45.09/14.24	47.86/13.07	51.11/2.14
		42.59-52.09	38.85-54.86	50.46-52.37
	Kaolinite	8.3/35.15	9.1/30.93	7.07/11.23
		7.50-20.88	4.97-13.21	6.16-7.62
	Chlorite	12.43/14.34	11.44/13.77	10.33/13.05
		11.36-13.44	9.92-13.55	9.32-11.86
		Low tidal mudflat	**Mangrove forests**	**Shrimp ponds**
	Illite	19/8.28	18.08/18.7	16.17/3.66
		18.15-20.07	15.94-25.32	15.56-16.75
Silica	SiO_2	65.99/6.2	68.18/6.047	70.55/0.833
		64.59-70.77	62.40-72.94	69.95-71.12
	Al_2O_3	13.49/12.91	13.26/12.915	11.97/5.223
		13.10-13.94	11.12-15.52	11.25-12.41
	FeO	1.186/1.22	1.03/4.93	0.90/3.49

	10.81-13.18	0.96-1.10	0.88-0.93
Fe_2O_3	4.82/1.03	4.26/16.29	4.01/5.79
	45.28-52.42	3.59-5.35	3.75-4.21
TiO_2	8.47/0.46	0.84/2.26	0.78/0.15
	8.13-8.93	0.82-0.87	0.78-0.78
CaO	1.331/1.17	1.05/17.16	0.99/34.06
	11.45-14.45	0.79-1.31	0.62-1.28
MgO	1.765/1.00	1.74/10.89	1.55/2.81
	16.80-18.15	1.54-1.99	1.50-1.58
MnO	0.1059/0.26	0.10/25.48	0.06/8.44
	10.10-17.05	0.06-0.12	0.06-0.07
Na_2O_3	1.062/0.81	0.91/2.94	1.17/5.98
	9.80-12.20	0.88-0.95	1.10-1.24
K_2O	2.168/0.83	2.06/18.7	1.84/3.66
	20.71-22.90	1.82-2.89	1.78-1.91
LOI	6.16/19.41	5.62/209.75	5.02/94.43
	5.81-12.52	4.32-7.30	4.69-5.56

Remark *: $\frac{X/V}{Min - Max}$

where X, min, max are average, minimum and maximum values, respectively, V is variation coefficient.

From low tidal mudflat via high tidal mudflat with mangroves to shrimp pond, sandy silt content is lightly increasing (fig.2). The content of macro elements and minerals is almost unchanged after depth as results of fairly stable, sedimentary source chronologically. Geochemical sedimentary evolution is visually reflected in the regularly changing in geochemical indices, the content of nutrients and heavy metals.

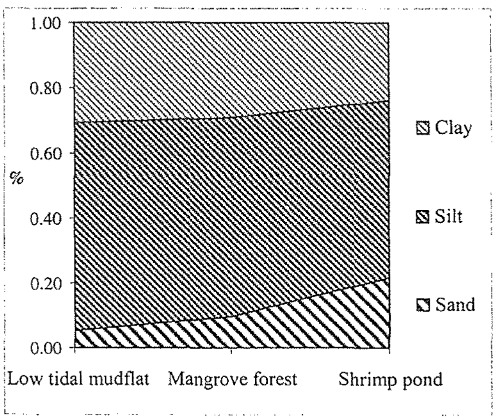

Figure 2. Changes of grain size from Low tidal mudflat via Mangrove forest to Shrimp pond

Geochemical sedimentary evolution during the formation and development of mangrove forest

Mangroves often take shape in high tidal mudflat of estuaries, in where, sedimentary environment with fine grain is favorable for mangrove seeds to be stored, spring up and photosynthesize. In return, the formation and development of mangrove forests, as a sedimentary trap, make the sedimentary environment more favorable for depositing of fine grain sediments rich in clay minerals. Sedimentary deposition rate in mangrove forest tends to be higher than in vicinity (Piet Hoekstra, 2000) [18]. Thus, these processes are natural companion of the environmental transform from low tidal mudflat without mangroves (permanently being under water) into high tidal mudflat covered with mangroves (alternatively being under water).

Table 3. Geochemical indices of the three sedimentary deposition environments

Geochemical properties (%)	**Low tidal mudflat**	**Mangrove forest**	**Shrimp ponds**
Fe_{Pyrite}	0.06/20.4	0.06/47.1	0.11/23.6
	0.04-0.07	0.04-0.08	0.08-0.13
$Fe_{Siderite}$	0.45/25.5	0.22/12.9	0.29/21.3
	0.29-0.61	0.20-0.24	0.22-0.34
Fe^{3+}	0.45/16.6	0.26/27.2	0.23/36
	0.35-0.52	0.21-0.31	0.17-0.32
Fe^{2+}	0.03/16	0.03/28.3	0.03/0
	0.02-0.03	0.02-0.03	0.03-0.03
S_{Pyrite}	0.07/17.5	0.07/40.4	0.13/19.9
	0.05-0.08	0.05-0.09	0.10-0.15
$S_{Reduction}$	0.09/14.8	0.1/37.2	0.16/16.5
	0.07-0.10	0.07-0.12	0.13-0.18
S_{Total}	0.17/8.6	0.18/12.1	0.25/15
	0.15-0.19	0.16-0.19	0.21-0.28

The transform of low tidal mudflat without mangroves into high tidal mudflat is characterized by a little increase in content of Fe_{pyrite}, S_{total}, S_{pyrite}, $S_{reduction}$ (tab.3). The raising in amount of sulfurs can be understood as consequence of higher amount of mangrove root, which is the main sulfur source. The content of sulfurs increase after sedimentary depth in low tidal mudflat is more intensively than that in high tidal mudflat (fig.3a, b).This may also relate to increasing sulfur source in tidal mudflat. In addition, variation coefficients of sulfurs content in mangrove forest sediment are higher than those in low tidal mudflat (tab.3). Thus, the transform process through these two environments leads to stronger sulfurs differentiation.

The content of nutrients in high tidal mudflat (N: 0.06%, P_2O_5 :0.17%, humid: 0.97%, $C_{organic}$: 0.57%, tab.4) is much higher than that in low tidal mudflat (N: 0.07%, P_2O_5 :0.19%, humic:1.41%, $C_{organic}$:0.83%, tab.4) (fig.4). This shows that as covered with mangroves, high tidal mudflats are richer in nutrient content than low tidal mudflat.

Table 4. Nutrient composition of the three sedimentary formation in the study area

		Low tidal mudflat	**Mangrove forests**	**Shrimp ponds**
Heavy metal composition (ppm)	**Cu**	125/31.31	118.64/29.1	88.59/1.97
		106-147	67.95-158.55	87.58-90.60
	Pb	97/37.82	105.1/25.91	86.94/27.46
		79-110	60.89-144.25	0.89-107.7
	Zn	123/26.35	126.85/27.49	93.48/6.45
		110-143	84.93-177.75	86.90-98.75
	Co	27.32/11.47	25.12/11.38	20.34/11.29
		25.94-29.02	20.25-27.17	17.78-22.23
	Cr	91/12.41	87.48/113.01	81.52/10.33
		84-96	75.60-107.73	71.82-86.94
	Ni	49.4/13.95	47.23/14.84	42.27/7.81
		47.55-53.10	36.46-57.06	39.63-45.97
	Cd	2.96/16.48	2.51/24.02	2.27/13.32
		2.23-3.01	1.57-3.14	2.10-2.62

Upward changing after depth of these nutrients content is seen as increasing tendency (fig.5a, b), relevant to the development of mangrove which supplies much more organic materials.

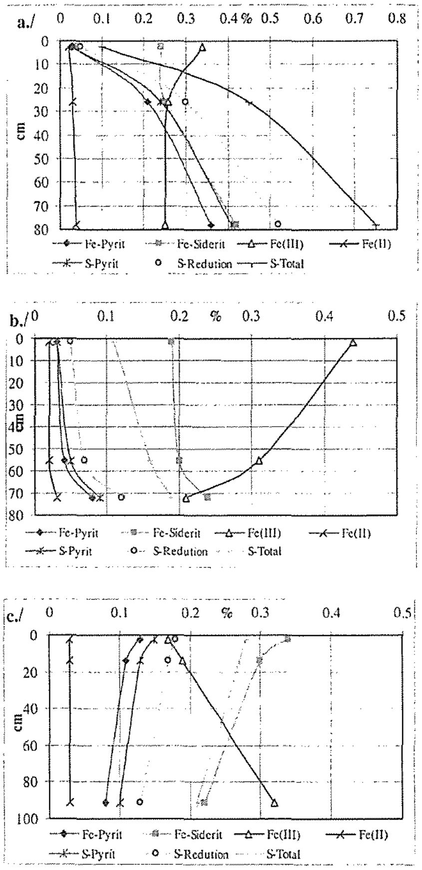

Figure 3. Changes of geochemical indices after sedimentary depth in the low tidal mudflat (a), mangrove forest (b) and shrimp pond (c).

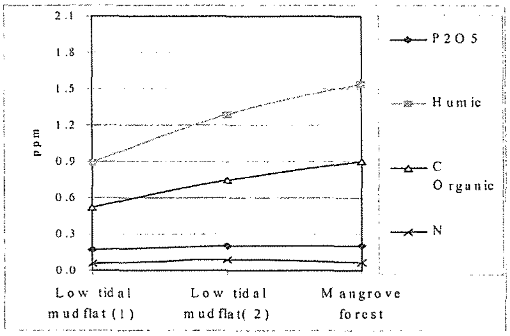

Figure 4. Nutrient content change when low tidal mudflat transform into mangrove forest

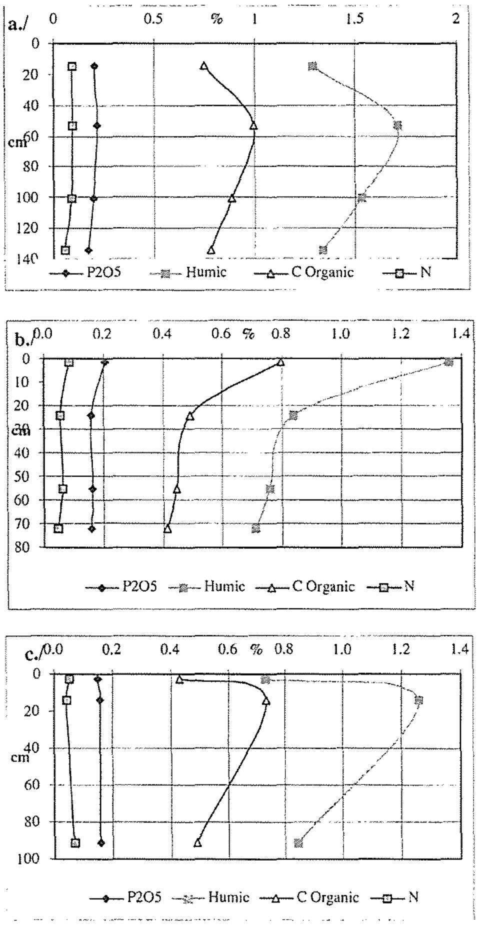

Figure 5. Changes in content of nutrients after depth in low tidal mudflat (a), mangrove forest (b) and shrimp pond (c)

In high tidal mudflats, heavy metals accumulate more intensively than low tidal mudflats (tab.5, fig.6) This increasing tendency of heavy metals content is most visual considering 20cm thick surface layers: Cu content varies from 279 ppm into 294 ppm, Pb from 216 into 265ppm, Zn from 267 into 340, Cr from 189 into 202ppm, Ni from 103 into 109ppm and Cd from 5 into 6ppm. Besides, correlation coefficients between the content of muddy - silt grain, clay mineral, nutrients and heavy metals are quite high (R: 7.0-9.9). These show that high tidal mudflats with mangroves, rich in fine grain, clay minerals and organic materials, have great capability of storing toxic heavy metals.

Figures of heavy metals are bias to increase rapidly chronologically (fig.7a, b), especially elements used widely in industry such as Cu, Pb, Zn... (fig.7b).

Table 5. Heavy metal composition of the three sedimentary formations

	Low tidal mudflat	Mangrove forests	Shrimp ponds
Cu	125/31.31	118.64/29.1	88.59/1.97
	106-147	67.95-158.55	87.58-90.60
Pb	97/37.82	105.1/25.91	86.94/27.46
	79-110	60.89-144.25	0.89-107.7
Zn	123/26.35	126.85/27.49	93.48/6.45
	110-143	84.93-177.75	86.90-98.75
Co	27.32/11.47	25.12/11.38	20.34/11.29
	25.94-29.02	20.25-27.17	17.78-22.23
Cr	91/12.41	87.48/113.01	81.52/10.33
	84-96	75.60-107.73	71.82-86.94
Ni	49.4/13.95	47.23/14.84	42.27/7.81
	47.55-53.10	36.46-57.06	39.63-45.97
Cd	2.96/16.48	2.51/24.02	2.27/13.32
	2.23-3.01	1.57-3.14	2.10-2.62

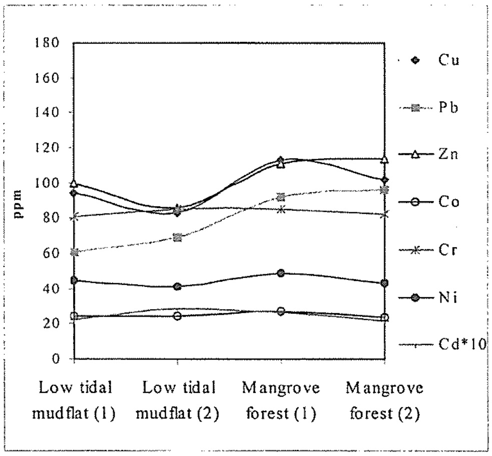

Figure. 6 Changes of heavy metals content from low tidal mudflat to mangrove forest.

Geochemical evolution of sediments during the degradation of mangrove forest

The degradation of mangrove forests may be caused by both natural processes (fresh water dominated, rapid deposition, relief evolution, etc.) and anthropogenic processes (mangroves cutting, etc.). In Namdinh coastal region, cutting mangrove forest for shrimp pond construction is the main reason.

Geochemical transformation from mangrove forest to shrimp pond is showed up with the increasing tendency of reduction indices such as Fe^{2+}, Fe^{2+}_{HCl}, Fe^{2+}_{pyrite}, S_{total} (from 0.21 into 0.28%), $S_{reduction}$ (from 0.13 into 0.18%), S_{pyrite} (from 0.07 upto 0.13%) (tab.3). and decreasing tendency of oxidation index Fe^{3+} (tab.3) (fig.8). In shrimp pond, from the deep sedimentary layer to the surface, suffers content increase intensively that differ from the mangrove forest sediments (fig.3b, c). Highly chronological and horizontal accumulation of sulfurs , perhaps, is caused by the mass degradation of mangrove roots in the shrimp pond.

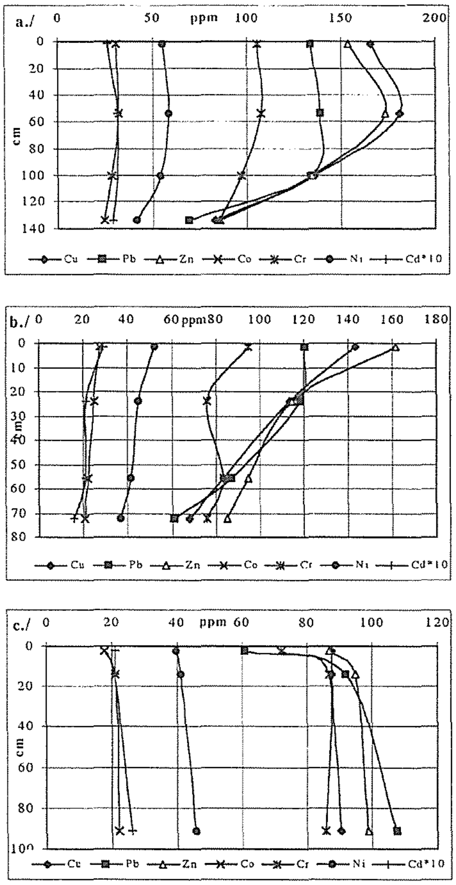

Figure 7. Changes in content of heavy metal contents after depth in low tidal mudflat (a), mangrove forest (b) and shrimp pond (c)

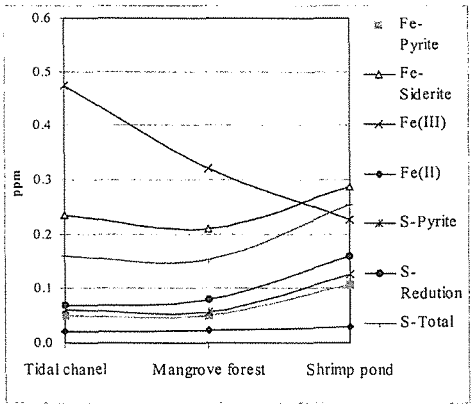

Figure 8. Changes of geochemical indices from mangrove forest to shrimp pond

In comparison with mangrove forest sediments, shrimp pond sediments are poorer in nutrients: N (from 0.07 down to 0.05%), P_2O_5 (from 0.19 down to 0.06%), humid (from 1.41 down to 0.94%), $C_{organic}$ (from 0.83 down to 0.55%, tab.4, fig.9). The rapid decrease in content of nutrients in upper sedimentary layer of shrimp ponds (fig.5b, c) may be related to removing the sediments with many mangrove root during shrimp pond construction.

It is visual that heavy metals content in shrimp pond sediment is lower than that in mangrove forest sediments: Cu content from 118.6 down to 88.6ppm, Pb from 105 down to 87ppm, Zn from 126.9 down to 93.5ppm (tab.5, fig.10).

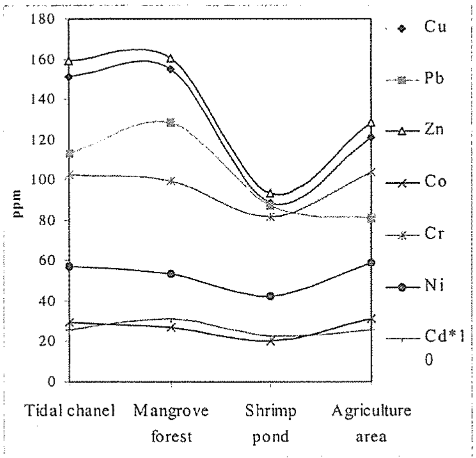

Figure 9. Changes in content of nutrients from mangrove forest to shrimp pond

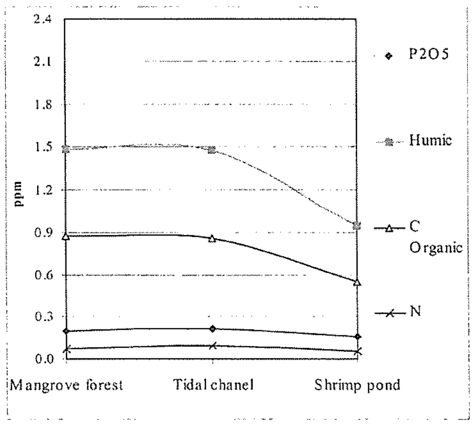

Figure 10. Changes in content of heavy metals from mangrove forest to shrimp pond

Perhaps, they are released to water and absorbed by biological organisms in the shrimp pond. Heavy metals content in the surface layer of shrimp pond sediments is much less than that in deeper layers (fig.7b, c). This can be proved by the fact that shrimp pond environments with worse water circulation, higher content of sandy-silt grain have worse ability to storing heavy metals. How ever, having smaller variation coefficients (tab.5), differentiation of heavy metal in shrimp pond is not as intensive as that in mangrove forest.

Conclusion

In coastal region of Namdinh province, the formation, development and degradation of mangrove forests are characterized by 3 distinctive sedimentary environments: the areas without mangrove, the mangrove forest and the shrimp ponds, respectively. The variation in hydrodynamic, water circulation, human impact leads to the geochemical differentiation of sedimentary environment and formations.

The formation and development of mangrove forests are geochemically characterized by the increase in content of nutrients (N from 0.06 up to 0.07%, P_2O_5 from 0.17 upto 0.19%, humid from 0.97 upto1.41%, $C_{organic}$ from 0.57 up to 0.83%) and heavy metals (Pb from 97 up to 105 ppm, Zn from 123 up to 127 ppm...). The formation and development of mangrove forests, which make sedimentary environment more favorable for storing toxic elements, contribute much to the protection of marine environment.

Destroying of mangrove forests and creating shrimp ponds have resulted in degradation of mangroves, of water and sedimentary environment. This process has made highly pyrite and sulfur accumulation (S_{pyrit}: 0.07-0.13%, S_{total}: 0.21-0.28%, $S_{reduction}$: 0.13-0.18%), lower content of nutrients (N from 0.07 down to 0.05%, P_2O_5 from 0.19 down to 0.06%, humid from 1.41 down to 0.94%, $C_{organic}$ from 0.83 down to 0.55%), toxic heavy metals dispersion (Cu from 118.6 down to 88.6ppm, Pb from 105 down to 87ppm, Zn from 126.9 down to 93.5ppm). Once the shrimp ponds degraded, it would be difficult not only to maintain high productivity of aquaculture, but also to replant mangrove forest.

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