CHARACTERIZATION AND MITIGATION OF VIETNAM COASTAL HAZARDS FOR SUSTAINABLE DEVELOPMENT

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Abstract

Vietnam coastal zone supplies more than 90% of aquatic products export; 100% of oil and gas; about 100% ilmenite placers; 100% of ports and maritime transport ways as well as several geotopes and tourism resources of high competition. Otherwise, Vietnam coastal areas have been facing with many hazards and other environmental problems, which threaten sustainable development of the areas. The main hazards include erosion (along the coast of Nam Dinh, Thanh Hoa, Central Vietnam and some parts of Mekong delta coast), flood (mainly in Red River mouth, Cuu Long river mouth), earthquake (Vung Tau), sand migration (Central Vietnam), channel siltation (Red River mouth, river mouths in Central Vietnam, Cuu Long river mouth), sea level rise (along coastal areas of Red River delta, Central plains, Mekong delta), water and sediment pollution (Bac Bo gulf, Ganh Rai gulf, Cuu Long river mouth). These hazards have caused not only loss of people but also damages of houses, constructions, natural resources, biodiversity, etc. Review of hazards on the coastal zone is scientific basis for proposing suitable measures of precaution and mitigation of damages, protecting environment and to support sustainable development of Vietnam.

Together with the engineering and non-engineering measures in implementation in coastal zone of Vietnam, planning for sustainable use of natural resources based on integrated assessment of risk levels, vulnerability zoning of coastal nature – social system is proposed as new approaches for environment protection and hazard precaution and mitigation toward sustainable development.

Introduction

The coastal zone of Vietnam is rich in natural resources (mineral resources, wetland, positional resources, tourism resources...), with high population density (250 people/ km^2) and concentration of many economic activities. However, this region also has a great potential of hazards such as earthquake, erosion, sand migration, channel siltation, typhoon, flood, sea level rise, water and sediment pollution... Because of low respond capability of the coastal communitythese hazards are leading to ever dramatically increase in human and property losses, as well as degradation of the natural resources in several coastal areas. That's why it is imperative to propose methods for mitigation hazards, sustainable use of the territory and territorial waters and protection of natural resources in the Vietnam coastal zone. In the mean time it is necessary also to make advance toward regional and international integration in the field of disaster research and mitigation.

1. Characteristic of Vietnam coastal area

1.1. Natural condition

a. Geography

The length of Vietnam shoreline is about 3260km which is divided into major kinds: the shoreline of plain delta region which ditributes in the Red rive delta and Mekong delta. This kind of coastalline always change and tend to advance toward the sea. In some places, the rate of sediment deposition reachs 80 – 100m/year (Ninh Binh, Ca Mau headland, etc).

The shoreline of mountainous region ditributes in section from Mong Cai to Hai Phong and from Da Nang to Ca Na. These includes many promontories of bedrocks, alternated loose sand, silty sand and clay mud. Along the coastalline distribute many islands and islets of different shapes and sizes. They tend to be arranged in a chain parallel to the shoreline (Mong Cai – Hai Phong), many promontories, gulfs and peninsula (Da Nang – Ca Na).

The shoreline of coastal plain region alternated mountainous remain ditributes in section from Thanh Hoa – Chan May promontory and from Ca Na to Vung Tau. The shoreline includes loose sediment (i.e. sand) alternated many promontories of bedrocks (Lai, Kega, Ky Van promotory, etc.)

Generally, coastline of Vietnam are variable and complicated in shape. Coastline fragments developed on rocks or consolidated materials, with their cliffs, heatlands and peninsulars are hardly eroded. Whereas coastline fragments formed by unconsolidated materials, with embayments or lagoons can limit water exchange and thus retent the pollutants [4].

b. Climate

In general, the Vietnam coastal zone lies within the tropical monsoon belt and experiences considerable seasonal variation. However, due to local topographic features and the activity of atmospheric circulation, each area has its own particular characteristic.

The annual mean temperature along the coastal zone is high, ranging from 22.8 to 26.9^{0}C. The temperature gradually increases from the North- Southward during the two seasons but, the amplitude of temperature oscillation decreases in the same direction, from 12.3^{0}C (Red River Delta) to 3.1^{0}C (Ho Chi Minh City). The northeast monsoon flows over the country from the north southward, increasing the change in temperature between the coastal localities lying at different latitudes. The coastal zone of Vietnam can be subdivided into two distinct climatic regions, the Northern climatic region (extending from Mong Cai to the Hai Van Pass), and the Southern climatic region (from the Hai Van Pass to Ca Mau Cape). Climate change leads to several exogenous hazards, such as floods (i.e. Red river delta, Cuulong river delta), blown sand (i.e. South Central coast), etc.

c. Hydrology

Vietnam has approximately 2360 rivers greater than 10 km in length, including 106 main rivers and 2254 tributaries. Within inland areas there is on average 1 km of stream for every one km2 of land. Along the coast, there is one estuary for every 20 km of shoreline. Stream and river numbers are highest in the estuarine areas of the Red and Mekong Rivers, with over 4 km/km2. Throughout Vietnam there are two distinctive seasons: dry and rainy. The flood season in Vietnam extend is three to six months on the average is four to five months. The water volume of rivers and streams during flood season constitutes 60 - 90 % of the annual total. The dry season is longer than the flood season, extending approximately six to nine months. On average, about seven to eight months of the year produce about 20 - 30 % of Vietnam's total annual water volume within the landscape, with the driest month responsible for only 1 - 2 %. During the dry season, water levels are significantly lower, so much so that people can walk across many rivers and some (extreme south Trung Bo) become completely dry. Irregular distribution of water amount and related cucrrents during the year can intensify coastal hazards like floods at the North and the South, drough and blown sand in Central Vietnam.

d. Oceanography

The oceanographic characteristics (tides, wind system, waves, currents, etc.) of the coastal zone are fairly complicated and vary by season and location.

Wave is determined by the monsoon and storms. Waves travelling in a southeast direction are fairly stable and are stronger than those from the southwest. The near shore wave heights from Nga Son to

Son Tra, and Hoi An to Vung Tau are very high and powerful during the northeast and southwest monsoon periods.

The ocean currents are controlled by monsoon activity and topography. From October to March, they are under the influence of the northeast monsoon. At this time water masses from north equatorial currents travel to the East Sea, combining with monsoon currents to form a main current system which flows south-westward to the Trung Bo and Nam Bo coasts. This current reaches a maximum velocity of 60 - 70 cm/sec. Consequently a reverse current is formed in the central area, whereby a normal anticlockwise whirl-current is created (greatest intensity in December). In some places, the velocity of the main current reaches 100 cm/s, even 150 cm/s. During winter in the Bac Bo and Gulf of Thailand, normal whirlpools are formed. This cold current flows along the west side of the Gulf of Bac Bo at a velocity of about 25 - 30 cm/s. In general, this movement is weaker in the Gulf of Thailand.

The tide in the Vietnamese coastal zone is rather diversified and outstanding: the main coastal zone area is characterized by regular and irregular daily tides and by small lagoons having regular and irregular semi daily tides. In a cycle of 19 years, the maximum tide surpasses 5 - 6 m in the Gulf of Bac Bo. In the Thuan An area and the adjacent areas of the Tho Chu Island the tide is only 50 cm high. The development of tides is diversified in a day and night, each cycle of half month, in a year and each cycle of 19 years.

1.2. Geology

a. Geological formation

Geological formations on land consist of hard formations (the intrusive complex, extrusive rock and territorial sedimental. These geological formations have made emergent relief, shoreline of abrasion erosion on hard rocks and cliffs along the shoreline and islands. Which are of high bearing capacity, high resistance to hazards (erosion, flood, salinization). Unconsolidated formations (Neogene and Quaternary formations), distributed in the sections of beaches, alternated hard geologic formations. Which are of low to moderate bearing capacity and resistance to hazards (erosion, flood, salinization, sand fly, land cracking, etc. These geological formations are sensitive to hazards like earthquake, erosion, flood, etc.

Sea bed formations consist of coralline, gravel, gravelly sand, sand, muddy sand, mud sediments forming groups with toxic element storage capacities from low to high respectively. Also, these geological formation ditributed in the sections respectively of river mouth, gulf, a few scattered Central offshore (Thanh Hoa – Vung Tau) and submerged sanddune (Red river mounth and Cuu Long river mouth) respectively.

b. Geotectonics

The main active faults of Vietnam coastal zone included: Lo river, Vinh Ninh, Chay river, Red river, Nha Trang, Western Phuc Nguyen, Tho Chu – Natuna Bac, Hon Chuoi, Western Phu Quoc, Cat Ba, Co To, Bach Long Vi, Huyen Nhai – Van Ninh, Da Bac, Phu Lam, Thuan Hai – Minh Hai, Phu Quy – Canh Duong, Gia Lam – Ha Tinh, Dong Hoi – Hon Ong, Phu Khanh, Tien Yen – Bac Hai, Bach Ho – Vung Tau,... In there, some faults is able to cause earthquake: Red river, Chay river, Thuan Hai – Minh Hai,...

1.3. Natural resources and biology

a. Mineral and other natural resouces

Miners along the coast of Vietnam are mostly placers of exorable reserves, including zircon – ilmenite, gold, zinc, construction sand and gravel, brick clay, lignite and peat. Of these, significant miners of high economic values are known as: coal miners in Quang Ninh province which contain 90% of the country reserves, metal miners in placers (Cu, Pb, Zn, Mn, Sn, V, Ti, Zr) in Quang Ninh, Thanh Hoa, Nghe Tinh, Quang Nam – Da Nang provinces, ect. Besides, there are several zircon –

ilmenite placer mines along the coast of Central Vietnam like Bau Doi, Chum Gang, Van Ke, Thien Ai, Mui Ne, Binh Nhon and Phan Thiet districts (enriched sites) of Binh Thuan province, Nghi Xuan, Thach Ha, Cam Xuyen, Ky Anh districts of Ha Tinh province.

However, exploitation of mineral and other natural resources are occurring without revalent consideration of environmental protection and hazard prevention and mitigation, thus having resulted in occurrence and intensification of hazards like erosion, blown sand, environment pollution, channel siltation, etc. [4].

b. Biology

The coastal fauna and flora of Vietnam are rather diverse and plentiful, including mangroves, sea grass, multicellular and unicellular algae species, ets. and thousands of fauna species from proteozoic to high- evoluted ones (sea birds, marine mammals, etc.). Over long time of evolution, the fauna and flora ecosystems have been becoming stable.

Marine ecosystems like mangrove, sea grass and coral reef are not only of economic importance but also significant meaning for environment protection and hazard prevention. These ecosystems act as buffers to retain pollutants, toxics and waste, diminishing marine pollution. Mangrove forests reduce the damaging power of wave, wind and typhoon, protect the sea dikes and coastal land. Submarine coral reefs can also reduce the impact of wave, typhoon and even tsunami on the coast.

1.4. Human activities

Vietnam possesses a rapid increase in population, from 23.06 million (in 1951) up to 77.68 million (in 2000) and estimatedly up to about 120 – 122 million in 2050 (National Population Committee). Of which, more than 50% are coastal residents and more than 20 million are living on the marine benefits. High population density, also generally low income and low intellectual level of coastal residents have put more and more stresses on the coastal zone, driving several unexpected changes. Depicted problems are over-exploitation and destructive fishing practices of bio-resources, destroying mangrove forest to make shrimp ponds (200.000 ha of mangrove forest area have been destroyed for shrimp cultivation in the 1990s alone), construction of industries, settlement areas, mineral exploitation sites, harbors, transportation ways and other coastal constructions and belonging activities made increase in amount of waste and pollutants. Particularly, the dramatic decrease of mangrove forest area have been leading to several ecological and environmental problems, such as loss of habitats and breeding of many species, biodiversity deterioration, destroy the function of the coastal ecosystems to prevent the marine environment from pollution and prevent the coast from the erosion and typhoon. Consequently, hazards like erosion, blown sand, environment pollution, channel siltation, etc. tend to increase in coastal zone.

2. Characteristic of Vietnam coastal hazards

2.1. Earthquake

Earthquake features in coastal zone of Vietnam have strong correlation with geological structure, tectonic regime and characteristics of historical earthquakes. Based on available documents, 3 zones that are distinctively in seismic and tectonic conditions can be determined [11] as follows:

a. Earthquake zone in the northeast of Bac Bo

This zone is located along the coastline of the Northern part of Vietnam. The main faults stretch in a northeast - southwest direction, perpendicularly to the Red River fault and are bounded by the Mong Cai – Cat Hai fault and Co To – Cat Hai fault. The recorded magnitude in October 1984 is 5.5 Richter and the maximum magnitude was estimated as 6, linked with a high occurrence frequency of this hazard.

b. Earthquake zone along the coast from Ha Tinh to Nam Bo

This zone stretch from Ha Tinh to Binh Thuan and spread southward in the fan-shape along the coast of Nam Bo. Of the 23 recorded earthquakes in this zone, 9 earthquakes have epicenter beneath 10 km and 6 earthquakes have epicenter beneath 30 km. Some other earthquakes are linked with neo-tectonic activities of young volcanoes like Hon Tro in Vietnam, which was active in 1923, causing the earthquake with the magnitude equal to 5.5 Richter. Recenly, earthquakes were recorded in Nghe An (2005) and Vung Tau (3 times in 2005).

c. The earthquake zone in Tay Nam

This zone stretches along the fault of northeast – southwest direction, from the southwestern part of the South China sea to the Thailand gulf. The intensity of earthquakes in this zone is low, with magnitudes ranging from 3 – 4 Richter.

2.2. Erosion

Recently, the erosion has been occurring intensively along almost the coast of Vietnam, with the increasing trend from north to south. Erosion is seasonally variable, and becomes prevalent in the season of northeast wind. From 1950 to 2000, the number and length of eroded coastline fragments tend to increase, from 14 coastline fragments in 1950 – 1969, to 18 coastline fragments in 1970 – 1979, 95 coastline fragments in 1980 –1989 and upto 157 coastline fragments in 1990 – 2000. Based on the length of the eroded coastline fragments, it is to distinguish the short type (< 200m) (account for 10.8%) from the rather short type (200 – 1000m) (account for 37.2%), the medium type (1000 – 2000m) (account for 18.9%), the long type (2000 – 6000m) (account for 27.5%) and the very long type (> 6000m) (account for 5.4%). The longest coastline fragments are Quan Lan (Cam Pha – Quang Ninh), Vinh Thai (Vinh Linh – Quang Tri), Thai Do (Thai Binh), Dien Kim (Dien Chau – Nghe An), Tam Hai (Quang Nam), Tan Dien (Tien Giang), Ngoc Hien, Dam Doi, Long Dien Tay (Ca Mau) [2]. Erosion leads to not only loss of hauses, roads, etc. but also pulzzing resdidents.

In many coastal areas, coastal constructions, dikes, land and property of the coastal residents are threated by erosion like Van Ly (Hai Hau), Canh Duong (Quang Binh), Phan Ri Cua and Phan Thiet (Binh Thuan), Cua Lap and Cua Loc An (Vung Tau), Can Thanh (Ha Chi Minh ctiy), Go Cong Dong (Tien Giang), Ngoc Hien (Ca Mau) and so on. For example in 1999, so long as 9 km coastline of Phan Thiet province was eroded upto 4-5 m landward, leading to falure of 37 houses, migration of more then 300 families.

2.3. Sand movement

Wind activities in the coastal zone transport landward a great amount of sand, driving to the blown sand. Sand flow, whereasoccurs usually during the heavy rain, forming long drains on the incohensive sand formations. These sand movements become hazards, just as their influence reaches to, cover or threat the settlement areas, rice fields and other manmade contructions, etc.

The coastal regions of Bac Bo and Nam Bo, thanks to their own features of climate, hydraulic condition and geology, are not subjected to the influences of sand movement. However this hazard is particularly significant in the Central coast of Vietnam, with two typical manners: blown sand and movement of sand flow. Blown sand hazard is popularly along the coast of Quang Tri, Dong Hoi – Le Thuy, Thach Khe (Quang Binh), An Hoa – Da Rang estuary, Ninh Thuan and Binh Thuan. Blown sand can form sand dunes with the height of 20 - 30 m, covering rice fields, roads and houses. Lagoons, an important type of wetland in central coast of Vietnam, are suffering from these stresses (Nuoc Ngot, Quy Nhon, Cu Mong). The coastal fresh water ponds in Ninh Thuan and Binh Thuan, which supply mainly for these drought regions, are partly covered also. One example is Bau Trang pond of Bac Binh district (Binh Thuan) with the water area reducing from 120 ha to 80 ha during 40 years of sand cover, thus impact directly on water demand of more than ten thousand surrounding residents. In addition, the drought climate in these region promote drying of the sand, make it soft and incoherent and more easily forming sand flow during rainy condition. This derived

hazard occur frequently in Dien Ngoc (Hoi An), Binh An (Tam Ky), the Nuoc Ngot lagoon and Cu Mong lagoon, Hong Chinh, Tien Thanh (Binh Thuan). The sand flow, in heavy rain or storm, may even form debris flow to cover houses, land and property of residents. In Tien Thanh hamlet alone, the debris flow occurs every year and particularly had killed 3 local residents and covered several houses and roads.

2.4. Channel siltation

The coastal estuaries of Vietnam are suffering from the channel siltation, linked with appearance of submarine sand dunes, sand bars and the narrowness of rivers. Estuaries under readily changes are Lach Tray, Red River, Cua Lo, Thu Bon, Da Rang, Kinh Dinh, Ca Na, Phan Ri, Cai river, Ca Ty river, Dinh river, Loc An, Lap, Cung Hau, Co Chien, Dinh An, Tran De, My Thanh and so on. In front of every estuary, the occurrence of submarine sand bars is the main threat for crossing transportation by boats and ships. Siltation in the estuaries is potential hazard, which may cause shipwrecks while the solution of channel dredging is rather costly. Especially, the siltation in harbour areas caused noticeable problems such as defunctioning of harbours, shipwrecks and also high cost for channel dredging. Along the coast of Vietnam, the harbours suffering from this hazard are Hai Phong, Diem Dien, Cua Lo, Thuan An, Hoi An, Cam Ranh, Can Tho, Ha Tien, etc..

2.5. Typhoon and flood

Storm and flooding in coastal zone of Vietnam happen unanticipatedly in terms of extension, frequency. In general, storms are more and more in number and intensity as well. From 1974 to 2006, there had been 146 storms landed to Vietnam with Xangsanse (number 6, happened on 1st October 2006) as the strongest one for the intensity of 13th level. In 2000, the number of storm with intensity of 6th to 12th levels was 3, but reached up to 6 in 2005 [17]. In rainy seasons, the coastal zone is suffered from flooding also. Along the Red River, there happened two great floods, in 1945 and in 1971, causing serious dike falures. Of which, the storm happened in 1971 is the greatest during the last 100 years. Floods were recorded rather frequently, in 1913, 1915, 1917, 1926, 1964, 1968, 1969, 1970, 1986, 1996, 2002... at the Red River delta, in 1961, 1966, 1978, 1984, 1991, 1994, 1996, 2000, 2001... at Cuulong river delta and in 1964, 1980, 1983, 1990, 1996, 1998, 1999, 2001, 2003... at the Central part of Vietnam. Storms and floods are not only damage massively hauses, roads, harbours, harvest, etc. but also great loss of people. From 1979 to 2003, loss of hundreds people and damages of hundreds billion VND were caused by storms and floods, annually.

2.6. Sea level rise

According to forecast of the American Environment Protection Agency, the sea level rise in comparison to 1985 will be 13 - 55cm in 2025, 23 - 117cm in 2050 and 56 - 345cm in 2100. It is estimated that the sea level will rise 0.2 – 0.4 m during the next 50 years and 0.5 – 1 m during the next 100 years, respectively. The record in Hon Dau station (Hai Phong) showed a tendency that the annually rise of the sea level was 2.24 mm/year whereas record in Phu Quy station showed a number of 2.3 mm/year correspondingly to these locals. For the whole coastal sea of Vietnam, the rate of sea level rise is roughly calculated as 2 mm/year.

Followingly in 2100, when the global sea level rise up 0.1 – 0.9 m then the loss that Vietnam has to confront is as high as 17 billion VND, with 17 million homeless peoples, 12.2% of the most fertilized land area whereas 40.000 km2 of deltaic lowland and 17 km of coastline becoming prey to flooding [1].

2.7. Oilspill

In Vietnam, oilspills occur rather frequently with more and more incident number and oil quantity as well, leading to several environmental damages. From 1997 until now, more than 50 incidents have been recorded. Oilspills are popular in areas with high density of harbours like Hai Phong, Quang Ninh, Vung Tau. In coastal zone of Vung Tau alone, from 1993 to 1998, the amount of spilled oil to sea is about 3200 tons linked to wreckes of about 30 big transport ships, together with

the unknown amount linked with wreck of small fishing boats. In 20/9/1993, the crack between Pan Harves ship of Taiwan and the Sai Gon ship of Vietnam led to about 300 tons of oilspill, covering 640km^2 of offshore sea area in Ba Ria – Vung Tau. In 20/3/2003, the oil-transport ship named Hong Anh was wrecked, spilling about 600 tons of oil to the sea, reaching as far as Go Cong in Tien Giang province. In 2004, My Dinh shipwreck in Quang Ninh – Hai Phong area led to spill of about 50 tons of DO and 150 tons of FO to the sea environment. Oilspill incidents made thoudsands time decrease of bioproductivity. Because of the west – southwest monsoon and marine currents, the area of oilspills extended landward and polluted the aquacultural areas and estuaries of Ba Ria – Vung Tau province.

Increase of oilspill incidents gives rise to the concentration of oil on the sea. Along the coastal sea of Vietnam, the oil concentration measured is 2.56 mg/l at the North, 0.45 mg/l at the Central and 0.35 mg/l at the South, which are respectively 8 times, 1.5 times 1.2 times over the environment standard [3].

2.8. Environment pollution

In coastal zone of Vietnam, it is highly concentratred by the settle area, industries, harbors, aquacultural farms, fishing area and tourism area. Economic developing activities in coastal area are not involved in reasonable environmental protection activities. Thus, water and sediment environments are objected to pollution threats by heavy metals, pesticides, herbicides, PCBs, wastes, etc.

a. Water pollution

Distribution of potential pollution along the coastline of Vietnam varies from north to south. Coastal sea water were potentially polluted by Zn, Cu in regions from Quang Ninh to Ninh Thuan but by Cu, Zn, Pb, As and Hg in regions from Binh Thuan to Ha Tien (figure 1).

Concentration of pesticide residures in coastal seawater varies and differs among the North, the Central and the South of Vietnam. Almost of these areas have concentration of pesticide residures in water higher than allowed levels of Indonesia, Malaisia and America [4](table 1).

Table 1. Concentration of pesticides and herbicides in coastal seawater of Vietnam in 2000

Location	Concentration (μg/l)						
	Lindan	**Dieldrin**	**Endrin**	**DDD**	**DDE**	**DDT**	**Total DDT**
Cua Luc	trace			trace	trace	trace	trace
Do Son	0,45000			0,1300	0,15	trace	0,2800
Ba Lat	0,48000			0,2300	0,12	trace	0,3500
Sam Son	trace			0,6200	trace	trace	0,6200
Cua Lo	trace			0,4500	0,32	trace	0,7700
Nha Trang QI	0,00410	0,0171	0,0101	0,0044	–	0,0151	0,1950
Nha Trang QII	0,00320	0,0018	0,0651	0,0118	–	0,0463	0,0581
Dinh An Q I	0,00196	0,0146	0,0138	0,0069	–	0,0356	0,0425
Dinh An QII	0,00173	0,0100	0,0048	0,0100	–	0,0275	0,0375
Indonesian standard	0,00400	0,0030	0,0040	0,0010		0,0010	
American standard (93)		0,0019	0,0023			0,0010	
Malaisian standard	0,38000	0,0080	0,0080				0,0040

Source: The report of environmental status of Vietnam in 2001

b. Sedimentation pollution

In coastal sedimentary environment, the contamination by heavy metal behaves more complicatedly than the coastal seawater environment. From north to south, the contaminations tend to extent closer to the coast and also vary in pollutant composition. Coastal sediments are polluted by Cu, Zn at the North coast and North Central coast but by Cu, Hg, As, Sb at the South Central coast. Due to high concentration of fine materials, sediments surrounding estuaries, gulfs and bays have higher pollution potential (figure 1).

3. Discussion on coastal hazard features

3.1. Tendency of distribution and extension

Features on distribution and intensity of hazards in Vietnam coastal zone depend not only on the nature but also the origin (endogenous, exogenous or anthropogenous) of hazards. Characteristics of endogenous hazards (i.e. earthquake) are linked mainly to geological structure, dynamic and techtonic features but rather independent from global changes, and loosely related to human activities. Whereas, exogenous hazards (i.e. coastal erosion, sand movement, channel siltation, etc.) and anthropogenous hazards (oilspill, environment pollution, etc.) have their characteristics dependant strongly on the following factors:

Characteristics of exogenous and anthropogenous hazards are linked with natural features of the coastal zone like topography, landscape, geomorphology of coastal land and sea, geological formations, climate, oceanograpgy, mineral resource, ecosystems, etc. For example, distribution and intensity of erosion depend on the time regime, wind regime, occurrence or in-occurrence of mangrove forest. Erosion is intensified in the northeast monsoon at the northern part of Vietnam, but in the southwest monsoon at the southern part of Vietnam. Also, erosion occurs less frequently inthe coastal areas with mangrove forest. Similarly, sand movement tends to occur more frequent and intensive in dry areas such as Ninh Thuan, Binh Thuan, especially in areas with less vegetation cover.

Exogenous and anthropogenous hazards are intensified with the global changes. Particularly, sea level rise can intensify hazards like erosion, flooding, salt contamination etc.

In addition, exogenous hazards can be intensified by coastal human activities (mineral exploitation, contruction and settlement, deforestation, aquaculture, marine transportation, etc.). Due to the lack of understanding and adjustment to coastal processes, coastal human activities not only intensify hazards but may also transform natural processes into hazards.

3.2. Tendency of occurrence, frequency and intensity

Because endogenous hazards are governed mainly by endogenous geological processes, their occurrence, frequency and intensity exhibit no tendency with time.

Otherwise, frequency and intensity of anthropogenous hazards tends to increase with the time, in correlation with global changes and human activities as intensifying factors. For example, the hazards related to global changes exhibit increasing tendency, resulted not only by natural processes like deglacier cycle or local tectonic uplifting/ subsidizing but also by anthropogenous exhaust of green house gases. In similar way, coastal erosion and environment pollution tend to increase as a result of cutting of coast-defence forest as well as contructions without adjustment with tendencies of natural processes (dikes to encroach the sea, digging or occluding rivers and channels, etc.).

3.3. Damages

Damages caused by hazards depend on their nature (i.e. origin, intensity, frequency and the time of occurrence), density and value of the impacted objects, hazard prevention and control capability of the community (i.e. appearance of economic and technical infastructures, contructions for culture,

education and health, community awareness and management capability, etc.) and the local features of natural environment (i.e. mangrove forests). In other words, damages derived from hazards depend on the vulnerability of socio – natural system. Hence, endogenous hazard such as earthquake, which happens by high intensity, frequency, however it is difficult to forecast the time of occurring hazard so the damaging by them is usually rather great.

Exogenous hazards are characterized by low frequency, forecastable time of occurrence. Besides, because their driving forces can be partly controlled, the damages can be mitigated by intime, suitable measures.

3.4. Capacity of coastal hazard prevention and mitigation

In order to mitigate damages caused by coastal hazards, it is necessary to assess not only hazard status and analysis of their causes, but also the vulnerability socio – natural system and hazard prevention and control capability as well. Damage mitigation of endogenous hazard is difficult to implement, thus appropriate measures are forecasting hazard, establishing rescue system, planning for rational utilization of the territory and territorial water based on risk level zoning and vulnerability level zoning of socio – natural system.

For exogentic and anthropogenous hazards, some measures are suitable to implement such as dike contructing to control erosion and channel siltation, mangrove planting, ect. Together with the measures mentioned for endogenous hazards. But, generally measures that are applied in Vietnam coastal zone, tend to consider hazard individually without assessing integratedly with other hazards those occur in the same region. In addition, most of measures of hazard prevention and control are involved with determination of nature, origin and frequency of hazard without associating with the assessment of environmental sensitivity, density and respondance of the impacted objects.

4. Coastal hazard mitigations in Vietnam

Coastal hazards can be mitigated based on engineering and non-engineering measures. Engineering measures include technologies to prevent, adjust hazards, to improve the resistance of the coastal zone, and to mitigate the derived damages, needed in case the residents have no choices to migrate out of the impacted area. Otherwise, non-engineering measures are active, effective, economical solutions to predict, prevent and adapt to hazards. These measures include: development and implementation of overall coastal sustainable development plans and strategies; hazard prediction for active prevention; coastal vulnerability assessment; intergrated risk assessment; sea- and land-use planning based on hazard features and vulnerability zoning; development of procedure for rescue, relief and evacuation of the impacted peoples in case of hazards; development of insurance and welfare fund to recover the hazard-derived damages; raising commune awareness of hazards by propaganda and education, etc. Of these, intergrated risk assessment and coastal vulnerability assessment are two approaches, popularly and effectively used in abroad contries but rather new in Vietnam.

4.1. Intergrated risk assessment

Following this approach, risk assessement is based on integrated information about features (i.e. extension, frequency, intensity, etc.) of all individual hazards, which occur in the studied coastal area. Sequently, a zoning map of intergrated coastal risk can be developed and the locals with different level of risk can be defined, correspondingly. Sea- and land- use plans and strategies should be based on these risk assessment results. In detail, low risk areas are suitable for settlement areas, urbans, schools, hospitals, etc and other permanent contructions. These areas are save and obtimum for evacuration in case of hazards. Medium risk areas can be planned for temporary,

simple, light material contructions, aquacultural services, aquaculture (farms on tidal flats or floating cages on sea areas) in combination with mangrove plantation, ecotourism, etc.

Plan for important contructions must be involved with solutions to improve the hazard resistance. High-risk areas are suitable for land uses like forestry and plantation, agriculture, aquaculture. Residents in the areas should be supported with suitable hazard insurance regimes and subsidization policies of capital, loan or tax reduce for alternative livelihoods. These areas, however are not suitable for settlement centers, contructions with high sensitivity to hazards or capacity to intensify hazards (i.e. factories, chemical containers, dams, waste containers, etc.) or socio-economic constructions (i.e. schools, hospitals, etc.).

4.2. Coastal vulnerability assessment

Coastal vulnerability can be determined based on assessment of risk, density and responsibility of vulnerable objects. Planning for suitable use of land and sea on the basis of coastal vulnerability assessment can contribute to the implementation of integrated coastal zone management policies and strategies; solving the socio-economic conflicts among careers, stakeholders in terms of different land-use purposes, exploitation or conservation of natural resources and biodiversity, coastal environmental protection, pollution management, comunity-based prevention and mitigation of natural hazards; raising public awareness about hazards, intensifying factors as well as resposibility solutions to hazards; management of fishery, inluding aquaculture and fish catching; improving living standards and poverty alleviation; improving management capacity by training, education and investment on infrastructure that serves the management of natural resource, environment and natural hazards. Therefore, planning for suitable use of land and sea on the basis of coastal vulnerability assessment is active, effective and economical solution to the situation of hazard in Vietnam.

5. Conclusion

1. Main hazards in coastal zone of Vietnam include: earthequake, coastal erosion, channel siltation, sand movement, storm and flooding, sea level rise, oil spill and pollution of water and sediment.
2. Extension, frequency, intensity and tendency of endogenous hazards depend on geological structure, tectonic regime without increase trend with the time. Whereas, those of exogenous hazards are linked with natural and anthopogenous processes, with clearly increase trend with the time and with the global trends.
3. Damage of hazards depends not only on the extension, frequency, intensity, occurrence time but also density and vulnerability of the coastal natural-social system.
4. Both engineering and non-engineering measures are needed to prevent and mitigate hazards. Non-engineering measures should be applied in Vietnam are: development and implementation of overall coastal sustainable development plans and strategies; hazard prediction for active prevention; coastal vulnerability assessment; intergrated risk assessment; sea- and land- use planning based on hazard features and vulnerability zoning; development of procedure for rescue, relief and evacuation of the impacted peoples in case of hazards; development of insurance and welfare fund to recover the hazard-derived damages; raising commune awareness of hazards by propaganda and education, etc. Of these, intergrated risk assessment and coastal vulnerability assessment are two active, effective, economical and promissing approaches in condition of Vietnam.

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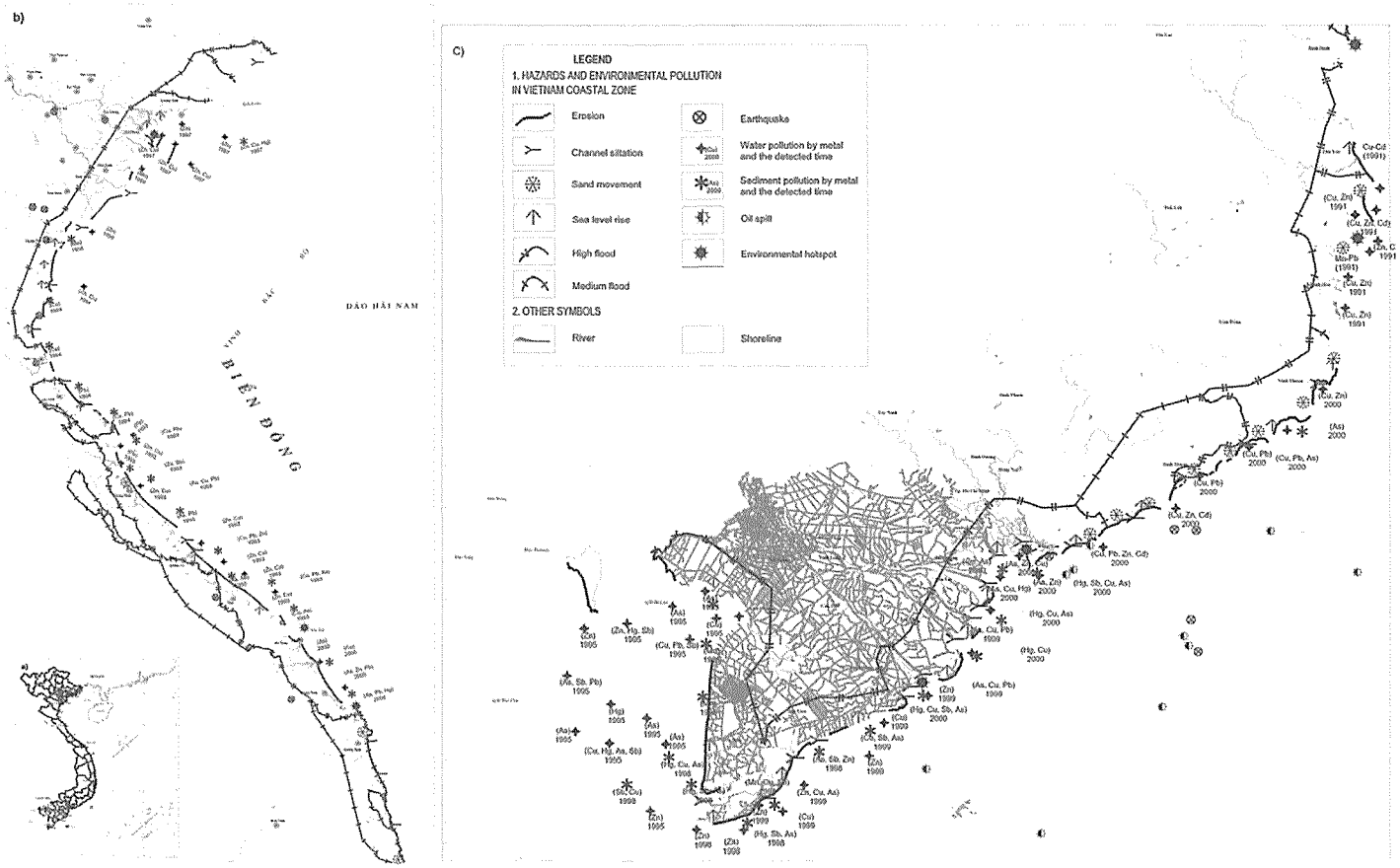

Figure 1. Distribution of main hazards in coastal zone of Vietnam

Notes: a) Entire territory and territirical sea of Vietnam, b) Coastal zone from Mong Cai ro Binh Dinh; c) Coastal zone from Binh Dinh to Ha Tien