INTEGRATED ASSESSMENT OF RISK LEVEL CAUSED BY HAZARDS IN THE COASTAL ZONE OF VIETNAM (CASES STUDY: CAM RANH - PHAN RI COASTAL ZONE)

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Abstract

The Cam Ranh - Phan Ri coastal zone is subjected to 10 kinds of hazards arranged in decreasing sequence of risk level: salinization, typhoon and flood, sedimentation causing channel changes, coastal erosion, sand drift, sea level rise, earthquake, environmental pollution by heavy metals, environmental pollution by organic compounds (PCBs) and land cracking. By studying and zoning the risk levels caused by hazards, the Cam Ranh - Phan Ri coastal zone can be differentiated into 3 areas with different risk levels: low risk area (DI<1), moderate risk area (1<DI<1,7), high risk area (1,7<DI<3,4). To mitigate these hazards, besides engineering measures, non-engineering measures are also proposed, comprising: integrated assessment of hazard risk levels, hazard forecasting, hazard risk level zoning, vulnerability assessment. It is also proposed to prepare a master plan for integrated management of the coastal zone and a land-use master plan based on the results of hazard risk level zoning and vulnerability assessment.

1. Introduction

The coastal zone of Vietnam is rich in natural resources (mineral resources, wetland, positional resources, tourist resources ...), with high population density and concentration of many economic sectors. However, the coastal zone also has a great potential of hazards such as typhoon, flood, erosion, channel changing, sand drift earthquake, land cracking, environmental pollution... seriously threatening the sustainable development. Those hazards are interrelated with each other in their causes, influencing factors or mutual intensification. Therefore, to enhance the efficiency in preventing and controlling coastal zone hazards, their integrated study and assessment are required. This is a common approach worldwide in the field of research for hazard mitigation (Cutter et all, 1996, 2000; Kasperson, 2001,...), but it is still relatively new in Vietnam (Mai Trong Nhuan et al., 2002, 2004).

The Cam Ranh - Phan Ri coastal zone (*Fig. 1*) is rich in mineral resources, positional resources, wetland and diverse marine ecosystems... These are favorable natural conditions for the development of industry, aquaculture fishing, tourism, port operation and water way transport ... However, the Cam Ranh - Phan Ri coastal zone is also affected by many hazards such as: earthquake, land cracking, slumping, coastal erosion, sedimentation causing channel changes, sand drift, typhoon and flood, sea level rise and some geochemical hazards. These hazards, together with the low capability of the community to respond, prevent and control hazards cause ever increasing human and property losses, as well as degradation of the natural resources in the coastal zone...

Therefore, it is necessary to carry out integrated assessment of hazard risk levels in Cam Ranh - Phan Ri coastal zone with the aim to identify priority areas for investment in prevention and mitigation of losses, sustainable use of the territory and territorial waters, protection of natural resources to serve the sustainable development In the mean time it is necessary to make advance toward regional and international integration in the field of disaster research and mitigation. This paper presents the results of the research in this direction in the Cam Ranh – Phan Ri costal zone.

2. Some factors affecting the geohazards in the coastal zone

Geologic formations

The intrusive, sedimentary, volcano-sedimentary, terrigenous rocks and Quaternary sediments in the Cam Ranh - Phan Ri coastal zone are divided into two main groups in terms of their resistance to hazards.

Group of solid formations with high resistance to hazards

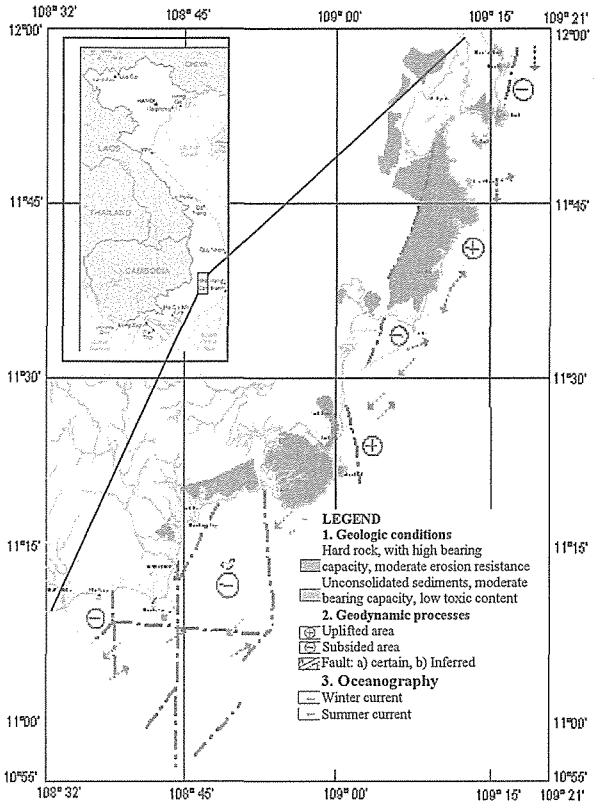

Fig. 1 Geological, structural and oceanographic characteristics of Cam Ranh-Phan Ri coastal zone

The geologic formations of this group consist of sedimentary, volcano-sedimentary rocks aged Middle Triassic, Jurassic, Cretaceous and magmatic intrusions of Cu Mong (Gb/E*cm*), Phan Rang (G^p/E *pr*), Dinh Quan (GDi/$J_3đq$), Deo Ca (GDi/K_2 *đc*) and Ca Na (G/K_2cn) complexes. These magmatic complexes occur in Ba cape, Dinh mountain, Da Chong mountain, to the west of Cam Ranh bay, Cam Linh cape, Hon Chut, Quyt cape, Sop cape, Da Hang mountain... Parts of these solid geologic formations have created firm islands and coast line which are of high resistance to hazards (*Fig. 1*).

Group of unconsolidated formations with low resistance to hazards

The geologic formations of this group consist of unconsolidated Quaternary sediments occurring along the coast from Hon Ngoai - Hon Tai, Ca Tien, Hon Do - Ninh Chu, Dong Hai - Vinh Hao, Lagan cape to Phan Ri and around Binh Da, Binh Hung peninsulas. These formations form coast sections which are strongly affected by erosion hazards.

Geologic structure and geodynamic conditions

The Cam Ranh - Phan Ri coastal zone belongs to the margin of Indochina uplifted block and the East Sea subsided block with two main fault systems. The NE-SW trending fault system passes through the area of Phan Rang town, slightly dipping SE-wards and has undergone right strike-slip in Paleogene - Miocene. The NE- SW trending fault system dips SW and is a normal fault. ... Step-down faulting activities are clearly expressed in the thickness of the marine sediments, the dissection, destruction of Pre-Cenozoic formations and indications of seismic activities.

Hydrography

In the Cam Ranh - Phan Ri offshore area there are two main sea-wave directions: W - SW in summer and E - NE in winter. The waves here are highest in the whole country (0.9 - 1.1m), in the rainstorm season waves can reach a height of 7 - 8m even 10m. The tide is of irregular diurnal regime, with the duration of rising tide longer than that of the falling tide. The tide amplitude during the high tide period reaches 1.5 - 2m and increases southward. The sea currents in the study area are of predominantly E - NE direction. They tend to run along the coast in N-S direction.

Human activities

The Cam Ranh - Phan Ri coastal zone is populated by many ethnic groups, mainly the Kinh people. The population is unevenly distributed, concentrated in plain, river mouth, coastal port areas, along roads and in towns and townships (Cam Ranh town, Phan Rang town, Ca Na town ship, Phan Ri Cua township...). The main occupations include mining, tourist service, aquaculture and fishing, salt production, processing industry, etc. Human activities such as extraction of corrals to make souvenirs, extraction of sand from the sea beach, etc., intensifies some hazards such as erosion, slumping, flood, some geochemical hazards...

3. Characteristics of geohazards

Geodynamic hazards

Earthquake: According to Nguyen Dinh Xuyen et al., (1996) in the Cam Ranh - Phan Ri coastal zone there is possibility of earthquakes of magnitude 8 with M = 6.1 - 6.5, focal depth of h =15 - 20km along the 109 meridian fault. Earthquake of magnitude 7 with M = 5.1 - 5.5, h =10 - 15km may occur in Ba river, Bato - Cung Son areas... Most of the remaining area is the earthquake transmission area with maximum intensity of I_{max}=6 - 7 (*Fig.3*).

Land cracking: Due to the impacts of the Nha Trang - Tanh Ninh and Mui Dinh - Vung Tau fault systems, in the Ca Na valley, which is an intramontane graben, about 1 - 3km. Wide block has been separated and subsided. This disturbed zone extends further to the north within the Phan Rang plain. At Dinh cape, a sub-latitudinal fracture system also split the mountain, creating parallel or alternate joint systems.

Coastal erosion: The coastal sections in the Cam Ranh - Phan Ri coastal zone being eroded are not great in number, but the erosion evolves in a complicated manner and is concentrated in some key areas. Ninh Thuan province has 11 coast section being erode, with a total length of 10 km, accounting for 2.6% of the total length of the coast. The coast of Phan Rang area is being most intensively eroded, usually reaching a rate of over 10 m/year. The coast from the end of the Ninh Chu tourist area to Khanh Hai has been eroded over a length of 2,000 m and with a width of 500m. In 1990 - 1992, the sea invaded some residential houses in Ninh Chu village, forcing some households to resettle. The coast from Khanh Nhon to Khanh Tuong (Ninh Hai district) during the last 10 years has been eroded inland 10 - 15m, threatening the Dam Vua industrial park (*Fig. 2*).

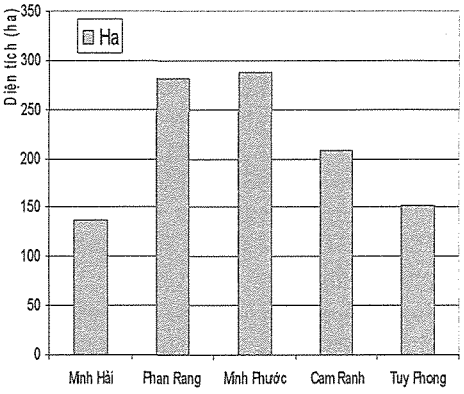

Fig. 2: Erosion areas in some localities of Cam Ranh-Phan Ri coastal zone

The coast to the Long Song river mouth, since 1965 to present has invaded 200 m inland, in 1967 - 1990 period it invaded 70 m inland. At present, the coast in this area is being strongly eroded with a rate of 2 - 3 m/year. In the Long Song river mouth area in the period 1930 - 1993 the 1000 m long western bank has been eroded 250 m inland, the 1500 m long Eastern bank has been invaded by the sea 303 m inland.

Sedimentation causing channel changes: In the Ca Na river mouth the sedimentation has made it impossible for the ships to access the Ca Na port during the ebb tide and they must wait for the rising tide to enter the port for mooring. Some other river mouths such as Dam Nai, Kinh Dinh, Phan Ri river mouths have been also affected by sedimentation, causing channel changes and difficulties for navigation..

Sand drift: Sand drift hazard is common in the areas from Khanh Nhon to Khanh Hai, from Ninh Chu to Tu Thien and from Ca Na to Phan Ri (*Fig. 3*). The material building up the shore in these areas are quartz sand with grain size from medium to fine, with low coherence, thus moves easily under the action of wind. Sand is accumulated by the wind into dunes with height up to 10 m along the coast. These sand dunes are continuous formed and move inland. The moving velocity of these sand dunes is 2 - 4 m/year. The sand dunes moves into population and cultivation areas, burying houses, rice fields, gardens, etc., causing adverse impacts on the lives of the local people.

Typhoon and flood: From 1954 to 1990, 10 typhoons landed on the area from Cam Ranh to Binh Thuan, in average there was a typhoon in every three years. Although the typhoons landing on the area are not great in number, they cause strong winds of force 7 - 8 in the offshore area, drowning boats, ships, causing human and property losses to the fishing people. The typhoon on 17 December 1964 caused a historic flood on the Cai river - Phan Rang, some places were 2 - 4 m under water, the water level measured was 6.07m above sea level. In November 1979, the flood peak in Phan Rang was 4.6 m. On 19 December 1993, the typhoon No 11 caused a flood on the Cai river with water level of 4.75 m, exceeding the alarming level 3; the average flood rise was 10.6 cm/h.

Hazards related with the global sea level rise: According to Nguyen Ngoc Thuy (1995), in the coastal zone of Vietnam, the average annual rate of sea level rise is 2mm/year. According to the calculations of scientists, in 100 years the sea water will rise by 1 m and its area of influence will include the low land areas with elevation below 10m. The area with direct impacts of the 1 m sea level rise in the study area will comprise most of the Binh Thuan and Ninh Thuan plains to the elevation of 10 m.

The group of geochemical hazards

Environmental pollution by heavy metals: The water environment in the area is being polluted by Cu and Zn in both bottom and surface layers. The areas with sea water in the surface layer being most strongly polluted by Cu include Noi island - Cam Linh cape, La Gan cape - Phan Ri, Sung Trau cape - Cau island and the area at the entrance of Cam Ranh bay with pollution intensity from moderate to high (pollution coefficient $T_{tc} = 1.2 - 2.8$; $T_{tc} = C_x/C_{tc}$: *where C_x is the content of an element in the environment; C_{tc} – is the maximum permissible limit in the Vietnam standard for the corresponding environment, Mai Trong Nhuan, 2001).* The area with highest Zn pollution is Phan Rang and the area south of Cau island, with pollution coefficient up to 3.2. Besides, Zn pollution is also found at the entrance of Cam Ranh bay and the area from Sung Trau cape to Cau island with pollution coefficient $T_{tc} = 1.1 - 1.16$. The superficial sediments in the study area are being polluted by Cu and Hg with an intensity from low to high. The sediments which are most strongly polluted by Cu are those in the area at he entrance of Van Phong bay with pollution coefficient of 1.65, less in the area of Phan Rang bay and some other areas ($T_{tc} = 1.01 - 1.65$). Nearly all superficial sediments on the sea bed of Cam Ranh - Phan Ri area are being polluted by Hg, especially the sediments at the entrance of Cam Ranh bay, Da Vach cape and Phan Rang bay with highest pollution coefficient $T_{tc} = 4.6$. To the south, the concentration of Hg in the sediments decreases but still causes pollution with $T_{tc} = 1.15 - 3.85$.

Pollution by pesticides and polychlobipheny: The total concentration of pesticides in the sediments varies within 0.13 - 10.85 ng/g, the common concentration is 1.26 - 3.68 ng/g. The area with highest concentration of pesticides in the sediments is to the east of Sop cape - at the entrance of Cam Ranh bay and in Phan Rang bay. The total concentration of polychlobiphenyl (PCBs) in the sediments varies within 8.36 - 26.32 ng/g, the most common one is 15.5 - 21.47 ng/g. The highest PCB concentration characterizes the areas NE of Ca Tien cape, inside Cam Ranh bay, and at the entrance of Cam Ranh bay. Although they have not reach the threshold level, pesticides and PCBs may cause harms to man by through bottom dwelling animals.

Salinization: Salinization of surface water takes place in all river mouths in the study area. In the rainy season, the salinization boundary is only 1 - 2 km away from the river mouth, but in the dry season the salinization boundary is pushed 5 - 7km inland, with relatively high TDS, 3 - 30g/l, therefore water in many places cannot be used for agricultural production. The whole area of Phan Rang - Thap Cham urban area is salinized, 75% of the area of Ninh Thuan and Binh Thuan plains are also salinized, especially the coastal areas such as Ca Na, Lien Huong, Phuoc The, Phan Ri...

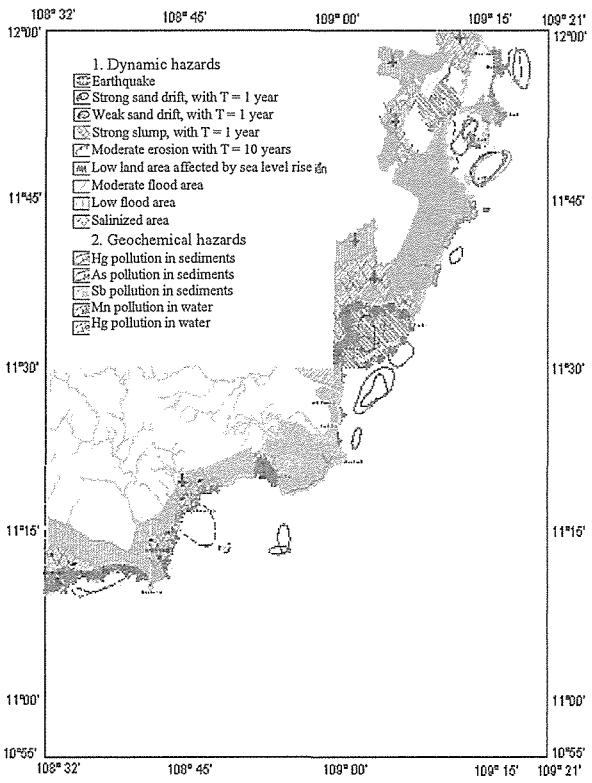

Fig. 3: Distribution of some hazards in the Cam Ranh-Phan Ri costal zone

4. Hazard risk level zoning

The previous researches on hazards only provided individual and qualitative information on possible impacts of one or some hazards within a certain area. These information are still not of sufficient scientific basis to propose measures for preventing and mitigation of hazards. Therefore, this paper will introduce the method of zoning risk level due to many hazards and consequently proposes measures for territory and territorial water planning which can help to avoid risks caused by hazards and meet the requirement for sustainable development

The hazards risk level zoning is implemented in 5 stages as follows:

Stage 1: Establishing a field survey network, with area $1km^2$ or 4 km^2, corresponding with the rectangular grid of the 1:50,000 or 1:100,000 scale maps.

Stage 2: Identifying hazards on the survey network and giving them point values in terms of risk level based on various indicators (type, intensity, frequency etc.) for each kind of hazards according by the formula:

G = (F+A)*M (1), where G is the total point value of the hazard; F is the frequency; A is the area affected; M is the intensity of the hazard.

Stage 3: Identifying hazards and calculating the total point value of hazard risk level in each rectangular cell of the map, by the formula:

$DI_i = SH_i/SH_{tb}(2)$, where: DI_i is the risk level for each cell,; SH_i is the total point value of risk level in the i^{th} cell; SH_{tb} is the total point value for risk level of the whole study area.

Stage 4: Plotting the result of calculating the risk level on the cells of the map.

Stage 5: Delineating areas with different hazard risk levels: if $DI_i < 1$ the area is of the area is of low risk; if $1 < DI_i < 1.7$ the area is of moderate risk; if $1.7 < DI_i < 3.4$; the area is of high risk and if $DI_i > 3.4$ the area is of very high risk.

The Cam Ranh - Phan Ri coastal zone is affected by 10 kinds of geohazards, which include earthquake, land cracking, coastal erosion, sedimentation causing channel changes, sand drift,, typhoon and flood, sea level rise, environmental pollution by metals, environmental pollution by organic compounds and salinization. Applying the formula (1) one can calculate the risk level for each kind of hazard and arrange the hazards in decreasing sequence of risk level *(Table 1)*.

Table 1: Hazard risk levels in the Cam Ranh - Phan Ri coastal zone

No	Hazards	F	A	M	G
1	Salinization	5	5	5	50
2	Typhoon and flood	3	5	5	40
3	Sedimentation causing channel changes	5	3	4	32
4	Coastal erosion	4	3	4	28
5	Sand drift	3	4	4	28
6	Sea level rise	4	5	3	27
7	Earthquake	1	5	4	24
8	Environmental pollution by heavy metals	3	3	4	24
9	Environmental pollution by organic compounds	3	2	4	20
10	Land cracking	3	2	3	15

As a results of calculating the point value of individual hazard and giving the point value on each rectangular cell of the 1: 50,000 scale map, the Cam Ranh - Phan Ri coastal zone is divided into 3 areas with different risk levels (*Fig. 4*): ***The low risk area (DI < 1):*** consisting of areas from Da Vach cape to Hon Do cape, from Dinh cape to Sung Trau cape and the area of La Gan cape. The shore is composed of solid bedrock which has high hazard resistance. The human activities are moderate. Geohazards have occurred locally with intensity from low to moderate. The water and superficial sediments are practically not polluted. ***Moderate risk area (1 < DI < 1,7):*** Consists of the coastal zone from the South of Cam Ranh township to Kenh Nam flood plain of Dinh river, Vinh Tuong, Ca Na to Ca Tha cape and the whole offshore area with 10 - 30m water depth. The coast is composed of unconsolidated sediments which are of low resistance to hazards. Human activities are mainly aquaculture and fishing together with ecological tourist service which is fairly developed. Hazards occur locally, with moderate intensity. The sea water is not polluted, the superficial sediments show indications of pollution. ***High risk area (1,7 < DI < 3,4):*** Comprises the area at the entrance of Cam Ranh bay, Ninh Chu - Vinh Tuong bay, the area of Phan Ri Cua. The coast is composed of unconsolidated sediments. The superficial sediments are mainly of fine fraction (sandy and clayey mud). Human activities include a military port, aquaculture ponds, cultural, educational, transport facilities, etc.. Dynamic hazards include many types such as sedimentation, erosion salinization in local to wide extent, with intensity from high to very high. Environmental pollution of water and sediments takes place with very high pollution coefficient.

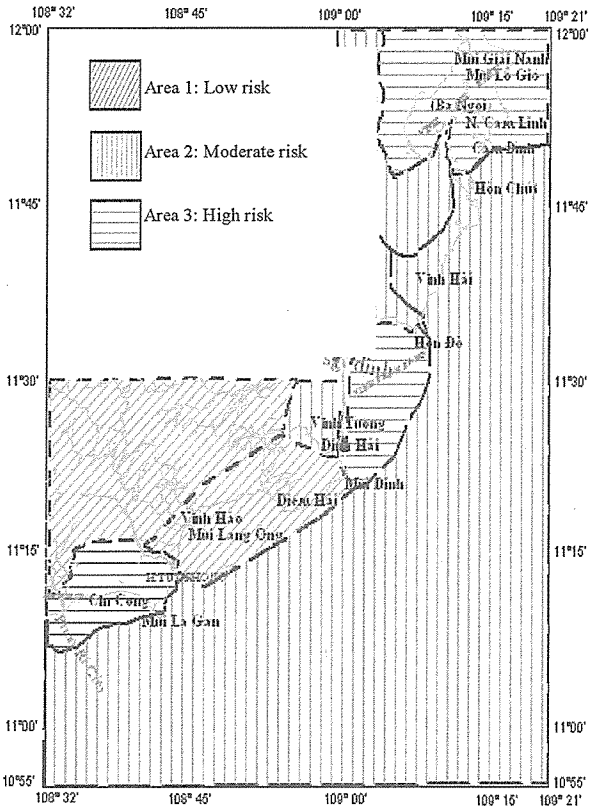

Fig. 4: Hazard risk level zoning of Cam Ranh-Phan Ri coastal zone

5. Recommendation of measures for geohazards mitigation

To mitigate natural hazards in general and geohazards in particular, the two main directions should be follows:

- Applying engineering measures for mitigating hazards.
- Applying non-engineering measures for mitigating hazards, adapting to or avoiding hazards.

In the Cam Ranh - Phan Ri coastal zone in general, many engineering measures have been applied against hazards, such as construction of stone revetment against erosion and sedimentation in Ninh Chu - Khanh Hai, Khanh Nhon - Khanh Tuong, Tri Hai, Nhon Hai, Phuoc The, Hoa Phu, Long Song river mouth, Phan Ri river mouth... However, the hazard mitigation efficiency of these measures is very limited *(Fig. 2)*, causing the waste of resources.

Therefore it is recommended to apply more consistent measures for preventing and avoiding hazards by non-engineering measures. This group of measures need a long time, but it is of high economic efficiency and large capability to mitigate hazards for the coastal zone. Non engineering measures applied to Cam Ranh - Phan Ri coastal zone include:

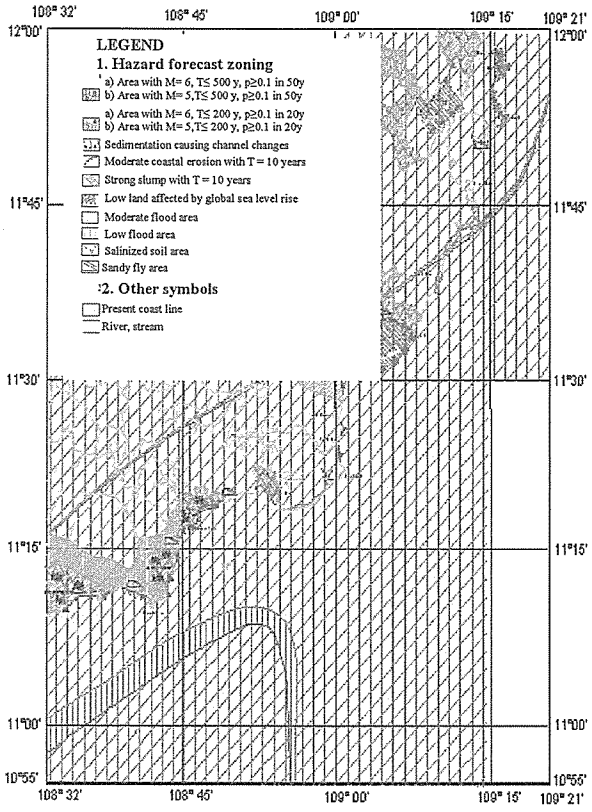

Fig. 5 Schematic forecasting map of some hazards in Cam Ranh-Phan Ri coastal zone

6. Forecasting for preventing and avoiding

Hazards were investigated and delineated based on the risk level of each kind of hazard and are shown on the schematic forecasting map of some hazards in Cam Ranh - Phan Ri area (*Fig. 5*). Master plans for rational use of the territory and territorial waters of localities of the Cam Ranh - Phan Ri coastal zone must be based on the hazards risk level zoning map and coastal zone hazards forecasting map. In low risk areas it is possible to build permanent buildings requiring high safety level, which are the best place for evacuation and escape when hazards occur. Population areas, urban areas, schools, hospitals etc., may be established, but it is]necessary to enhance the capability of preventing and controlling hazards. The area with moderate risk can be planned for construction of temporary, simple, compact facilities, aquaculture service stations, for maintaining aquaculture (along the coast and in cages) in parallel with the plantation of mangrove forests, and establishment of ecological tourist areas. If it is planned for construction of important facilities such as an urban area, chemical plant, residential area, etc. measures for strengthening the capability to resist hazards must be adopted. For high risk areas, it recommended not to invest in development of high density population areas and socio-economic facilities such as schools, hospitals, etc. but only exploit and use the territory for agricultural and aquaculture production.

On the basis of the study and integrated assessment of hazards, it is necessary to compile a socio-natural system vulnerability map for the Cam Ranh - Phan Ri coastal zone as the first stage in the process of integrated coastal zone management (ICZM) *(Mai Trong Nhuan et al.,)*

7. Conclusion

1) The Cam Ranh - Phan Ri coastal zone has 10 kinds of hazards with decreasing risk level as follows: Salinization, typhoon and flood, sedimentation causing channel changes, coastal erosion, sand drift, sea level rise, earthquake, environmental pollution by heavy metals, environmental pollution by organic compounds, land cracking.

2) As a result of the integrated study and assessment of the hazards in the Cam Ranh - Phan Ri coastal zone, three areas with different risk levels have been differentiated in this coastal zone: low risk area, moderate risk area and high risk area.

3) Engineering measures for preventing and controlling hazards in Cam Ranh - Phan Ri costal zone are still not effective. Non-engineering measures such as working out hazard risk level zoning maps, hazard forecasting map, vulnerability map of the socio-natural system, which will serve as an important basis for integrated management of the coastal zone.

References

1. Mai Trong Nhuan. Environmental geochemistry (2001). Hanoi National University Publishing House.
2. Mai Trong Nhuan, Dao Manh Tien et al., (2002). Geohazard map of the Cam Ranh – Phan Ri shallow offshore area (0 - 30 m water depth). Archive of the Marine Geology Union.
3. Mai Trong Nhuan, Dao Manh Tien et al., (2002). Environmental geology map of the Cam Ranh – Phan Ri shallow offshore area (0 - 30 m water depth). Archive of the Marine Geology Union..
4. Mai Trong Nhuan et al., (2002). Vulnerability assessment of the socio-natural system of coastal zone (case study: Khanh Hoa province). Science Journal of the Hanoi National University No 3 : 25 - 33.
5. Mai Trong Nhuan, Dao Manh Tien et al., (2004). Environmental geology status map of the Phan Thiet – Ho Tram shallow offshore area (0 - 30 m water depth). Archive of the Marine Geology Union.
6. Cutter, SL, (1996). Vulnerability to Environmental Hazards. Progress in Human Geography 20: 529 – 539.
7. Cutter, SL. et al., (2000). Revealing the Vulnerability of People and Places: A case study of Georgetown County, South Carolina. Annals of the Association of American Geographers, 90(4), 2000: 713 - 737.
8. Kasperson, R., (2001). Vulnerability and Global Environmental Change. *IHDP, V. 2/01*: 2 – 3.
9. NOAA (1999). Community Vulnerability Assessment Tool CD – ROM. NOAA Coastal Services Center.
10. Toms, G. et al., (1996). Viet Nam Coastal Zone Vulnerability Assessment. Viet Nam VA Project – Final Report: 11 – 13.