

## Country report

### Study and monitoring on the marine environment radioactivity in Vietnam

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## 1. INTRODUCTION

Vietnam has a coastline of 3,260 km, with 112 estuaries and 4,000 large and small islands, many straits, lakes, marshes and out, with plenty of seafood products. The exclusive economic zone is over one million km<sup>2</sup> wide. Vietnam's seas are to be able to revive the region due in tropical ecology and less pollution. Fisheries have played an important role in the economic development of Vietnam. The government has recognized this and is pushing to develop the fisheries sector as a key economic sector in the economy of the country. It can be divided into four basic types of habitat for aquatic species: offshore, inshore, brackish and inland waters (fresh water). According to scientific research, marine resources of Vietnam: 75 species of shrimp, 25 species of squid, 7 species of octopus, 653 species of seaweed, which accounts for 14% of economic algae (90 species), coral with 298 species of 76 varieties, 16 families and over 10 species of coral horns. Fish has more than 2,100 species, of which more than 100 species of economic value.

Total fish production has increased from 1.06 million tons in 1991 to 5.16 million tons in 2010. Currently seafood caught 56% of total output, while the proportion of aquaculture is increasing. In the period 1991 - 2010, total fish production in Vietnam increased 2.6 times, of which the total value of aquaculture production increased by 4.9 times. The statistics figures are shown on Table 1 and Fig. 1. Fig. 2 presents the coastal marine environmental observation and monitoring station system.

Table 1. Fishery production and its export value in the economy in Vietnam from 1991 to 2010.

Year	Total seafood production (million tons)	Marine fishing (million tons)	Livestock production (tons)	Export turn-over (billion USD)
1991	1.06	0.71	0.35	0.27
1992	1.10	0.75	0.35	0.31
1993	1.12	0.79	0.33	0.37
1994	1.21	0.88	0.33	0.46
1995	1.34	0.91	0.42	0.55
1996	1.37	0.96	0.41	0.67
1997	1.57	1.09	0.48	0.78
1998	1.67	1.13	0.54	0.86
1999	1.83	1.22	0.61	0.97

2000	2.00	1.28	0.72	1.48
2001	2.23	1.35	0.88	1.78
2002	2.41	1.43	0.98	2.01
2003	2.54	1.43	1.11	2.20
2004	3.07	1.92	1.15	2.40
2005	3.43	1.99	1.44	2.74
2006	3.69	2.00	1.69	3.36
2007	4.15	2.05	2.10	3.76
2008	4.58	2.13	2.45	4.51
2009	4.85	2.28	2.57	4.25
2010	5.16	2.45	2.71	5.03

Source: Ministry of Agriculture and Rural Development (MARD)

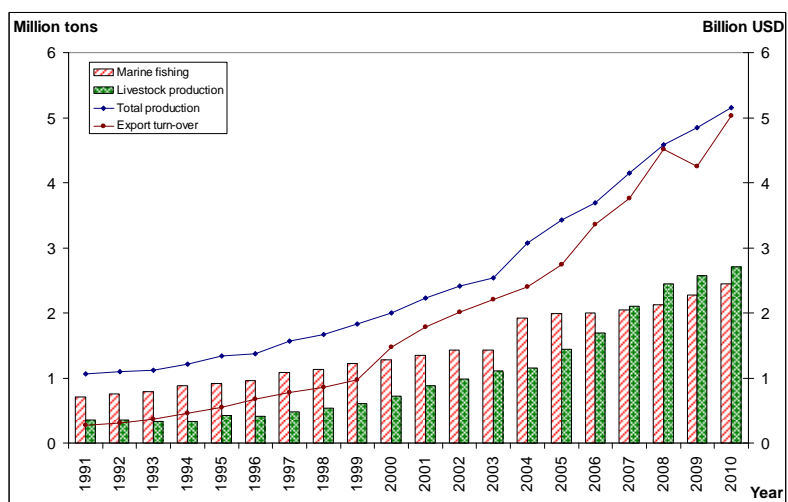


Fig.1. Fishery production and export turn-over of Vietnam in the past twenty years.

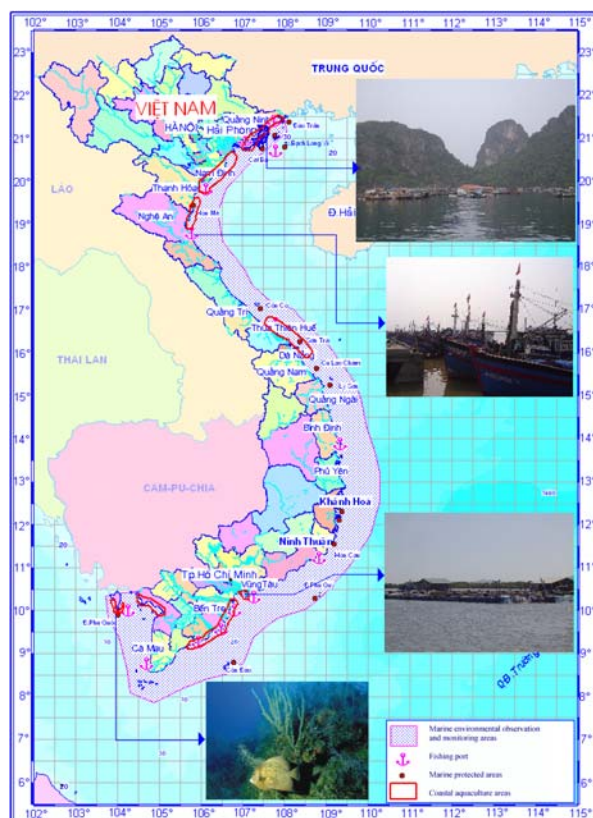


Fig. 2. Coastal marine environmental observation and monitoring station system.

The national agencies to be responsible for management and licensing of discharges of radioactive substances, marine monitoring including sample collection and analysis and risk and dose assessments are the followings: Vietnam Environment Administration (VEA) under the Ministry of Natural Resources and Environment (MONRE), Vietnam Agency for Radiation and Nuclear Safety (VARANS) and Vietnam Atomic Energy Institute (VAEI) under the Ministry of Science and Technology (MOST). The cooperation in marine sample collection program planning plays an important role by the Institute of Oceanography.

VEA is a subsidiary body to advise and assist the MONRE in the field of environment management and to provide public services in compliance with the laws.

State agencies on environment management: (1) Vietnam Environment Administration (MONRE/VEA); (2) Environmental Management Agencies of other Ministries; and (3) Branches of VEA.

VEA has following missions: (1) Developing and submitting to relevant authorities for promulgation of laws and regulations, policies, strategies, plans, national target plans, programs and projects on environment; (2) Organizing implementation of preventive measures in order to prevent, mitigate and respond to environmental contamination caused by environmental accidents; (3) Controlling environmental quality in urban, rural and mountainous areas, river basins and coastal zones; industrial areas, etc. Controlling transboundary environmental pollutions; (4) Assessing and appraisal of reports of strategic environmental assessment, environmental impact assessment, integrated environmental impact assessment, transboundary environmental impact assessment, environment protection commitment; providing guidance to examine, evaluate and appraise equipment, environmental

treatment facilities before operation; (5) Managing waste, promoting environment quality; protecting environment in river basins and coastal zones and handling environmental pollution hot-spots; (6) Implementing nationwide survey, inventory, monitoring, assessment of biodiversity; assessing trans-provincial or transboundary degraded ecosystems and proposing measures to conserve, rehabilitate and maintain sustainable use of biological resources; (7) Inspecting, examining and handling of violations of environmental laws; (8) Implementing international co-operation environmental programs and projects. Performing functions of the focal points to international conventions on: biodiversity, biosafety, wetlands of international importance; controlling the transboundary movement of hazardous wastes, persistent organic pollutants, etc.; (9) Studying and applying scientific and technological advancements in environmental protection; developing and implementing target environmental projects applying scientific and technological measures; researching and advancing the science on environmental management; (10) Developing the master plan for national environmental monitoring network; developing and managing national environmental data, environmental statistics; formulating environmental status reports; (11) Consulting on environmental protection; studying, implementing and transferring environmental technologies; carrying out environmental public services; (12) Establishing, managing, utilizing, and developing environmental database, data and environmental information system; and (13) Coordinating with mass media to perform environmental propaganda programs; developing and disseminating printed matters for environmental propaganda; organizing Vietnam environmental competitions and prizes. The organization chart of VEA is presented on Fig. 3.

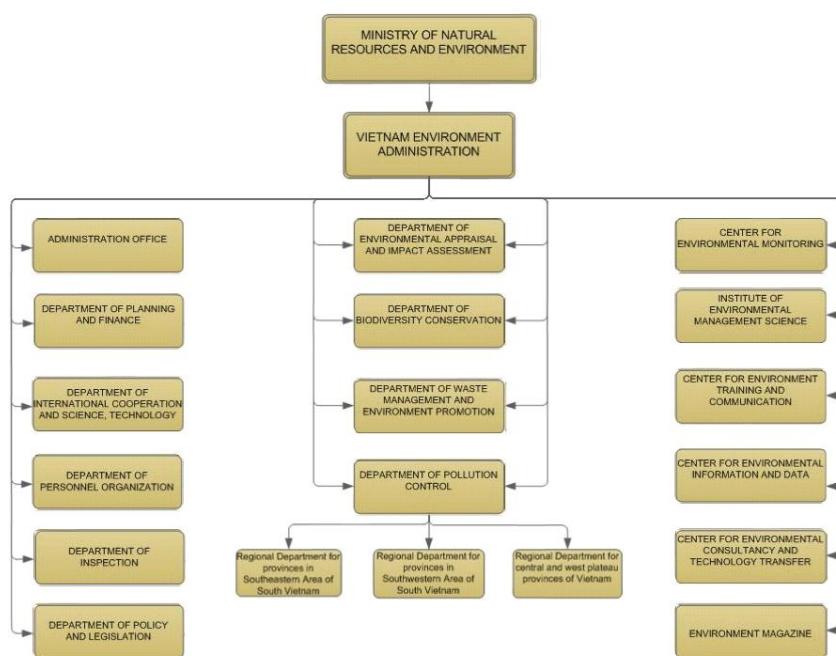


Fig.3. The organization chart of VEA.

VARANS is a regulatory body with the duty of assisting the Minister in the state management on radiation and nuclear safety & control. VARANS has following duties and powers: (1) To organize and participate in the building of legislative documents, code of practice, procedures and regulations for radiation and nuclear safety & control; to participate in the building of standards on radiation and nuclear safety, specific regulations and policies for those who work directly with the radiation; (2) To make and then submit to the Minister

policies, development orientations, priorities, programs, annual and 5-year plans on radiation and nuclear safety & control; to organize and implement approved plans; (3) To organize and implement the notification, registration, license, renewal, amendment and withdrawal of licenses for radiation and nuclear establishments, radioactive sources, radiation personnel and works related to radiation and nuclear; to organize the assessment of sites, designs, construction, and justifications for ensuring the radiation and nuclear safety and the security of radiation and nuclear establishments; (4) To guide and direct the Local Departments of Science & Technology on radiation and nuclear safety & control; to co-ordinate with Ministries, Branches to perform the State management on the radiation and nuclear safety & control under the MOST's direction; (5) To conduct regulatory inspections on radiation and nuclear safety according to law; to resolve complaints, denunciations; to deal with violations of regulations on radiation safety and control according to law; (6) To perform the State management of radioactive wastes; to organize radiation environment monitoring, to develop emergency response and handling for radiation and nuclear incidents; to control radiation doses and assess the safety of occupational, public and medical exposure; (7) To organize activities of safeguard; (8) To establish an record system of data, information on radiation and nuclear safety; (9) To organize research for applying scientific and technological advances in the field of radiation safety & control; (10) To co-organize training courses, propaganda and dissemination programs on legislation, radiation & nuclear safety and safety culture; (11) To organize and develop international cooperation activities in radiation and nuclear safety as assigned by the Ministry; to participate in the execution of the International Treaties and other international agreements on radiation and nuclear safety; and (12) To perform other duties assigned by the Minister of Science and Technology; to manage cadres, assets, files and documents of the Agency according to the ministry arrangement and regulation.

VAEI has following duties: to study on formulation of policies, strategies, planning and plans for atomic energy development in Vietnam; to conduct fundamental and applied research on nuclear science and technology, nuclear reactor technology, nuclear reactor fuel and material, radiation protection and nuclear safety, radioactive waste treatment and management technology; to develop technology, production and technical services in atomic energy field and related areas in service of social and economic development; to co-ordinate and participate in the implementation of international co-operation activities in the field of atomic energy, and participate in the implementation of international treaties pledged by Vietnam; to provide technical support to the state management body on radiation protection and nuclear safety in the assessment and appraisal of radiation protection and nuclear safety, carry out radioactive environment monitoring, calibrate radiation dosimeters and nuclear facilities, provide radiation dose measuring service, develop technical infrastructure for the preparedness and response to radiological and nuclear accidents; and to participate in the planning, education and training of scientists and technicians in the field of atomic energy.

The organization of Dalat Nuclear Research Institute (DNRI), Vietnam Atomic Energy Institute (VAEI) belonging to The Ministry of Science and Technology are shown in Fig. 4&5.

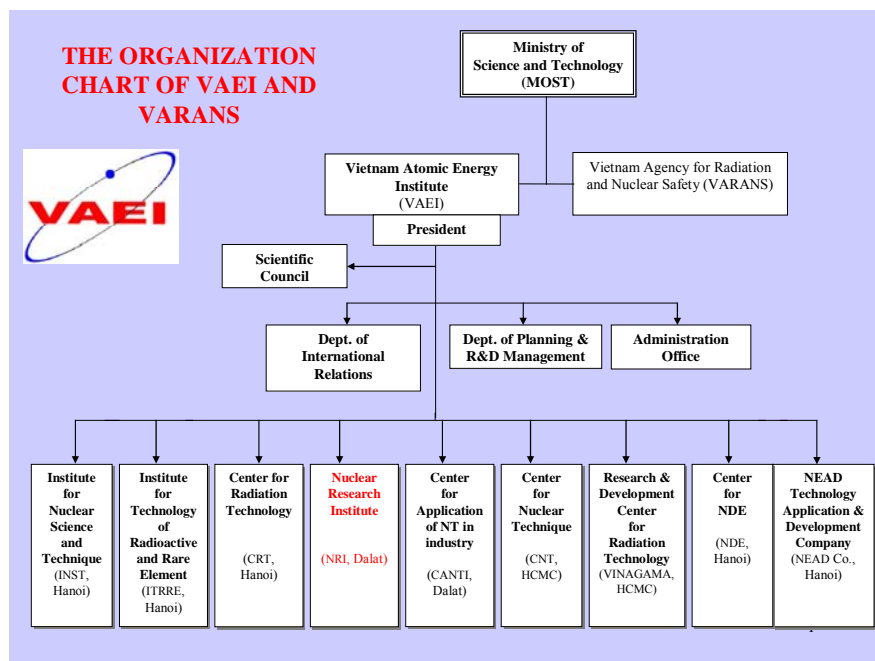


Fig. 4. Organization scheme of VAEI

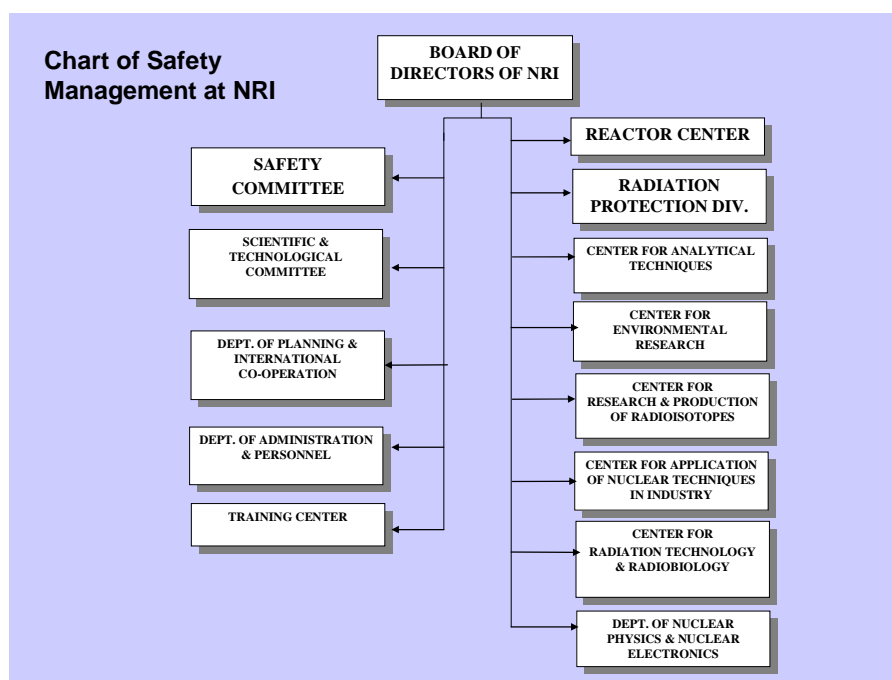


Fig. 5. DNRI Organizational Structure

Past RCA projects focused on the application of nuclear and isotopic techniques to coastal pollution issues of VAEI:

- RAS/8/080 on “Better Management of Environment and Industry Through Isotope and Radiation Techniques”;



- RAS/7/011 on “Enhancing the Sustainability of the Marine Coastal Environment”;
- RAS/7/016 on “Establishing a Benchmark for Assessing the Radiological Impact of Nuclear Power Activities on the Marine Environment in the Asia Pacific Region”;
- RAS/7/019 on “Harmonizing Nuclear and Isotopic Techniques for Marine Pollution Management at the Regional Level”;
- RCA-UNDP Project ROK/06/001 on Mitigation of coastal impact of natural disasters like tsunami, using nuclear or isotope-based techniques (post-tsunami environment impact assessment).
- TC Regional Project RAS/2/010 on Quality Control and Quality Assurance for Nuclear Analytical Techniques (Time period 2001-2002).

Past national projects related to marine environment:

- Applied research of nuclear and related analysis techniques for evaluation air and marine environmental pollution (1997-1998, Dalat, 4 / 1999).
- Research and application of nuclear and related analytical techniques mainly for evaluating the status of the marine environmental radioactivity in Vietnam (1999-2000, BO/00/01-01, Dalat 3 / 2001)
- Research and application of nuclear and related analytical techniques mainly for evaluating the status of the marine environmental radioactivity in some typical regions of Vietnam (2001-2002, BO/00/01-04, Dalat 3 / 2003).
- Summarization and investigation on marine environmental radioactivity; preliminary assessment of collective dose caused by consumption of seafood in some typical regions of Vietnam (2003, Dalat 2 / 2004).
- Statistics and investigation of radioactive and heavy toxic elements in common food and foodstuff of Vietnam (2004-2005, Dalat, 5 / 2006).
- Research and investigation of accumulated fallout of  $^{90}\text{Sr}$ ,  $^{137}\text{Cs}$  and  $^{239,240}\text{Pu}$  radionuclides in soils and sediments in the South of Vietnam (2005-2006, BO/05/01-02, Dalat 12/2007).
- Investigation and assessment of Marine Environmental Radioactivity Status for selected sites of Nuclear Power Plant in the near future and Establishment of Transfer Factors for Marine Organisms (3/2008-2/2010).

The Institute of Oceanography has implemented many worth studies that have contributed significantly to the exploitation and conservation of the East Sea. There are 1,100 published studies in which, 62.6% on marine biodiversity; 11.6% on marine physics; 7.6% on ecology and environment; 5.4% on marine geology, geomorphology and 4.4% on marine chemistry and biochemistry. On January 2005, the ship named Oparin Academician with the length of 70m and wide of 15m was designed fully marine sample collection equipment offshore. Approximately 200 samples were collected for the marine research.

## 2. MARINE RADIOLOGICAL POLLUTION ISSUES

### 2.1. Fukushima Daichi nuclear power plants (NPP) accident

An earthquake followed by a tsunami that occurred at the Fukushima Daichi NPP in Japan on March 11, 2011 caused release of radionuclides into the environment (Brumfiel and Cyranoski, 2011; Butler, 2011; Reardon, 2011). Following the continuing air releases of radionuclides after the accident, starting on March 12, 2011, traces of short-lived fission products were recorded in the air by a number of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) radionuclide monitoring stations. First they were detected on March 12 in the Takasaki monitoring station in Japan (220 km away from the Fukushima Daichi NPP), followed by eastern Russia on March 14 and US west coast two days later (CTBTO, 2011). Air parcel trajectories calculated using the NOAA HYSPLIT model (Draxler and Rolph, 2011) shown that after the accident, radioactive air from Fukushima mostly headed East to North America, North Atlantic and further. The southward flows that bring the fallout to Southeast Asia rarely occurred. The first southward flow after the accident occurred on March 16. The nuclear accident has also caused global effects, as suggested by the first measurements of  $^{133}\text{Xe}$  that were conducted at the Pacific Northwest National Laboratory (USA) ( $46^{\circ}16'47''\text{N}$ ,  $119^{\circ}16'53''\text{W}$ ) located more than 7000 km from Fukushima ( $37^{\circ}25'17''\text{N}$ ,  $141^{\circ}1'57''\text{E}$ ) (Bowyer et al., 2011). First detections of  $^{133}\text{Xe}$  were made starting early March 16, only four days following the accident, and then high concentrations of  $^{133}\text{Xe}$  were determined daily. The dispersion of the radioactivity was detected at Iceland on March 19-20 (IRSA, 2011) and a first German station reported  $^{131}\text{I}$  in an air sample collected from March 21-23 (DWD, 2011). On March 22, 2011, the U.S. Environmental Protection Agency (EPA, 2011) reported that analysis of samples captured by RadNet air monitor filters in the states of California and Washington on March 18 detected fission product radionuclides ( $^{137}\text{Cs}$ ,  $^{132}\text{Te}$ ,  $^{132}\text{I}$ ,  $^{131}\text{I}$ ). On March 23, 2011, radioactive air was detected by the CTBTO station in Manila, Philippines, about 3000 km south of Fukushima (CTBTO, Philippines, 2011). The first data on radioactive fallout in Greece were reported by scientists of Aristotle University of Thessaloniki ( $40^{\circ}38'\text{N}$ ,  $22^{\circ}58'\text{E}$ ) (Manolopoulou et al., 2011). From March 24 through April 9, radionuclides ( $^{134}\text{Cs}$ ,  $^{137}\text{Cs}$ ,  $^{131}\text{I}$ ) released in the nuclear accident were recorded in air samples collected at Thessaloniki. The only isotope detected in rainwater and in the sheep milk collected on March 29-30, 2011 in Greece was  $^{131}\text{I}$  (Manolopoulou et al., 2011). On March 26, 2011, high values of fission product radionuclides were observed in the prefecture of Yamagata, Japan as high as  $7500 \text{ Bq/m}^2$  for  $^{131}\text{I}$  and  $1200 \text{ Bq/m}^2$  for  $^{137}\text{Cs}$  (IAEA, 2011). On March 28, 2011, the highest values of the above radionuclides were observed in the prefecture of Fukushima with  $23000 \text{ Bq/m}^2$  for  $^{131}\text{I}$  and  $790 \text{ Bq/m}^2$  for  $^{137}\text{Cs}$  (IAEA, 2011). Subsequently, the cloud containing radioactivity moved over the entire northern hemisphere.

On April 12, 2011, the Nuclear and Industrial Safety Agency of Japan (NISA) submitted a provisional International Nuclear and Radiological Event Scale Level 7 rating for the Fukushima accident (IAEA, 2011). The only other accident to have an INES Level 7 rating was the Chernobyl accident in 1986. However, NISA estimates that the Fukushima nuclear releases to the atmosphere were approximately 10% of the Chernobyl accident (IAEA, 2011).

In Vietnam, about 4500 km southwest of Japan, the fallout radionuclides from the Fukushima reactor accident had been detected since March 27 in Hanoi and since March 28 in Dalat and Ho Chi Minh City (HCMC). After April 20 the fallout radionuclides had gone



below the detection limits. The radioactivity peaked on March 31 and April 10 with the arrival of radioactive air starting from Fukushima on March 23 and April 2-3.

The monitoring station in Hanoi (the capital of Vietnam) is of 21°03'N, 105°48'E, 15m a.s.l., about 100 km west of the East China sea and 200 km to the northern boundary with China. HCMC (10°47'N, 106°40'E, 11m a.s.l.) is the most crowded city of Vietnam, about 1200 km south of Hanoi. Dalat (11°57'N, 108°26'E, 1500 m a.s.l.) is a resort place in the Central Highland of Vietnam, about 300 km north of HCMC. The monitoring station in Dalat is equipped with a high flow rate air sampler in order to timely detect any abnormal release of airborne radioactivity from the reactor and radioisotope production facilities. Recently, with Vietnam government's decision to embark nuclear power, three monitoring stations in Hanoi, Dalat and HCMC have been assigned as pilots for the nation-wide environmental radioactivity monitoring network, which is going to be built in coming years.

Airborne radioactivity was collected on chlorinated vinyl polychloride Petrianov filter FPP-15-1.5 by using high-volume air samplers. At the three monitoring stations, air sampling is usually done in working hours (from 9AM to 5PM) and the filter is changed every week. After the Fukushima reactor accident we started an intensive monitoring campaign with 24-hour filter exposure followed by a cooling time of 10 hours and gamma spectrum measurements for 12-15 hours. The typical air volume filtered in daily samples was about 60,000 m<sup>3</sup> in Dalat and 15,000 m<sup>3</sup> in Hanoi and HCMC. By the end of the monitoring campaign, the filter exposure time was occasionally extended to 2 – 4 days.

Before March 27, 2011 no fission products were detected at the three sites and all the visible gamma lines could be attributed to known background radioactivity from the uranium and thorium decay chains, <sup>40</sup>K, and cosmogenic <sup>7</sup>Be. A national project focused on research and investigation of accumulated fallout of Sr-90, Cs-137 and Pu-239,240 radionuclides in soils and sediments in Vietnam in the period 2005-2006. The undisturbed soil samples (with two layers 0-30 and 30-50 cm depth) at 20 different locations in southern Vietnam had been collected and analyzed Sr-90, Cs-137 and Pu-239,240. The density of accumulated fallout varied in the range from 57.4 to 244.3 Bq/m<sup>2</sup> for Sr-90, from 143.1 to 1491.9 Bq/m<sup>2</sup> for Cs-137 and from 6.38 to 23.43 Bq/m<sup>2</sup> for Pu-239,240. The averaged ratios of activity of Cs-137/Sr-90, Cs-137/Pu-239,240 were 3.67 and 38.8, respectively. The densities of accumulated deposited fallout of Cs-137 in undisturbed soil at 292 locations throughout the whole territory of Vietnam were presented on Fig. 6.

From March 27, characteristic gamma lines of <sup>131</sup>I (364.5 keV), <sup>137</sup>Cs (661.7 keV), and <sup>134</sup>Cs (604.7 keV) became visible for the samples collected in Hanoi. On March 28 the stations in Dalat and HCMC started to detect <sup>131</sup>I, but the cesium isotopes photopeaks appeared later, only since April 1 in Dalat and since April 2 in HCMC. The activity concentrations of these radionuclides in air at the three sites are given in Fig 7.

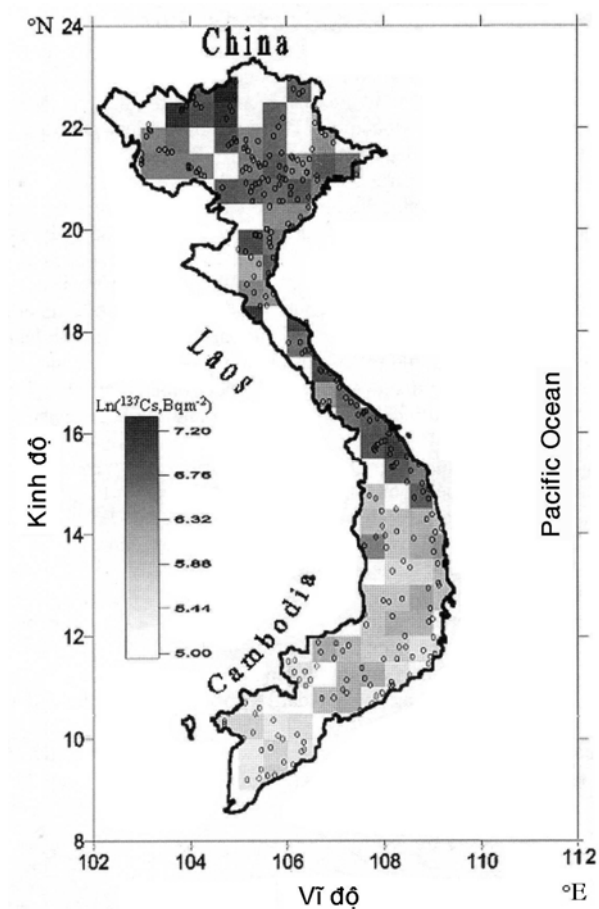


Fig. 6. The densities of accumulated deposited fallout of Cs-137 in undisturbed soil at 292 locations throughout the whole territory of Vietnam.

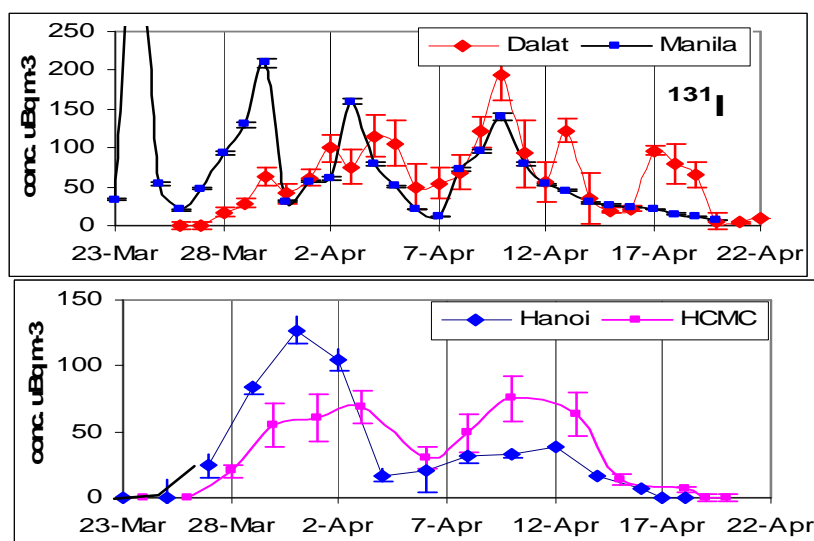


Fig 7. Activity concentrations of  $^{131}\text{I}$  in air measured at three monitoring sites in Vietnam. For comparison, monitoring data in Manila from the CBTBO network are also shown.

The daily activity concentrations of  $^{131}\text{I}$  in Manila peaked on March 23, March 30, April 4, and April 10. These peaks were found to be related to the arrival of southward air flows that started in Fukushima seven days earlier. The Philippines is upstream of Vietnam in regard to the southward air flows from Fukushima to Southeast Asia. Thus, the stations in Vietnam recorded peaks of  $^{131}\text{I}$  on March 31, April 5 and April 10-11, about one day after the second, third and fourth peaks observed in Manila. Most of these peaks also occur with the activity concentration of  $^{137}\text{Cs}$  (Fig. 8). The stations in Vietnam did not find radioactive air in the first southward air flows from Fukushima to Southeast Asia, which left a huge concentration peak of  $420\text{ }\mu\text{Bq m}^{-3}$  for  $^{131}\text{I}$  in Manila (Fig. 7). The trajectories of air parcels from Fukushima calculated using atmospheric dispersion modeling by the Department of Atmospheric and Climate Research (ATMOS) at the Norwegian Institute for Air Research (NILU); CTBTO; and the NOAA HYSPLIT model shown that the observed peaks at the four sites and their relationships with the southward air flows from Fukushima are presented in Fig. 9, 10 and 11.

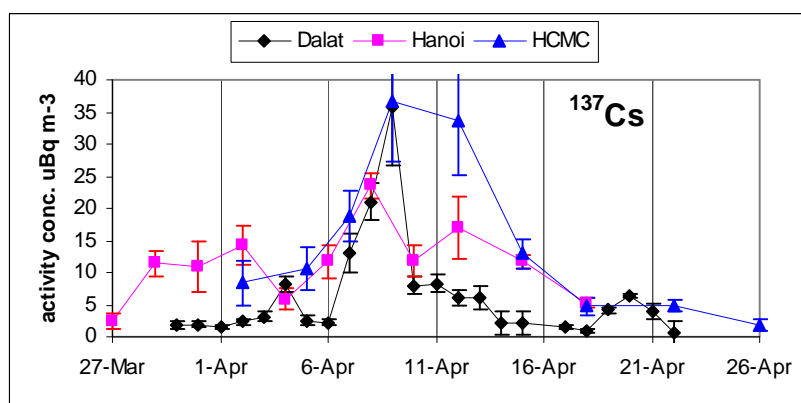


Fig. 8. Activity concentrations of  $^{137}\text{Cs}$  in air measured at three monitoring sites in Vietnam

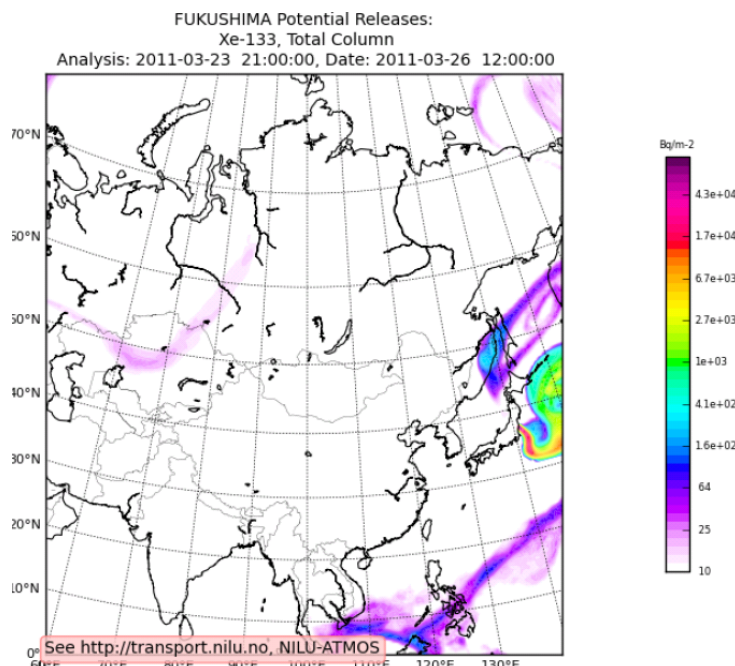
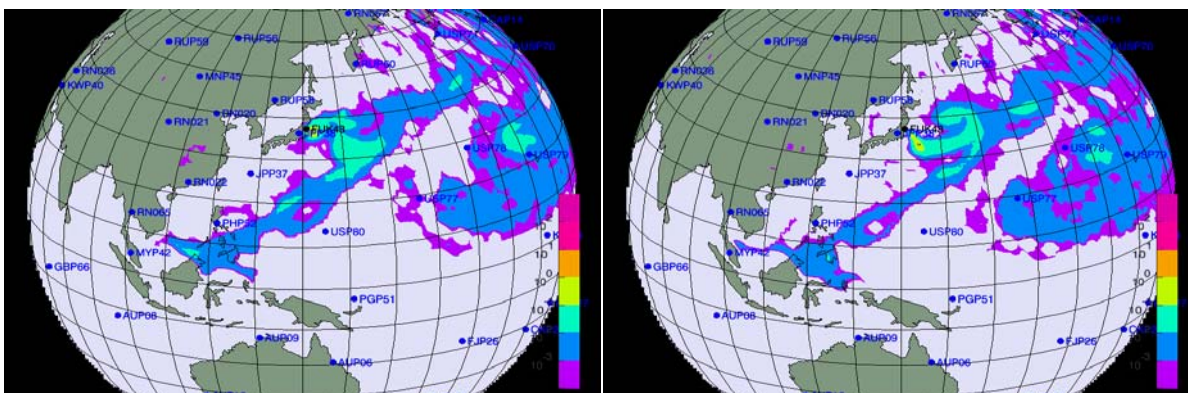
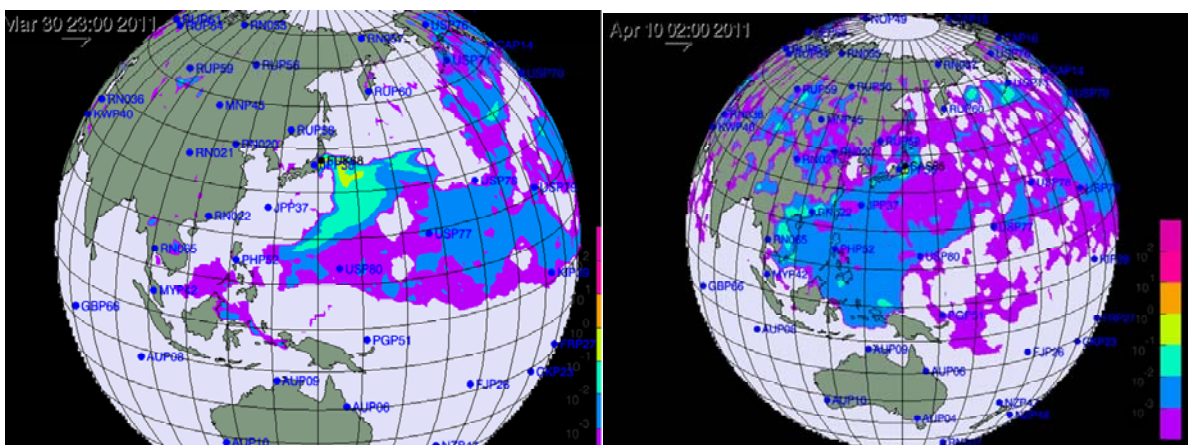


Fig. 9. The trajectories of air parcels from Fukushima calculated using atmospheric dispersion modeling by NILU



Atmospheric dispersion modeling of the accident calculated by CTBTO on 25/3/2011

Atmospheric dispersion modeling of the accident calculated by CTBTO on 26/3/2011



Atmospheric dispersion modeling of the accident calculated by CTBTO on 30/3/2011

Atmospheric dispersion modeling of the accident calculated by CTBTO on 10/4/2011

Fig. 10. The trajectories of air parcels from Fukushima calculated using atmospheric dispersion modeling by CTBTO



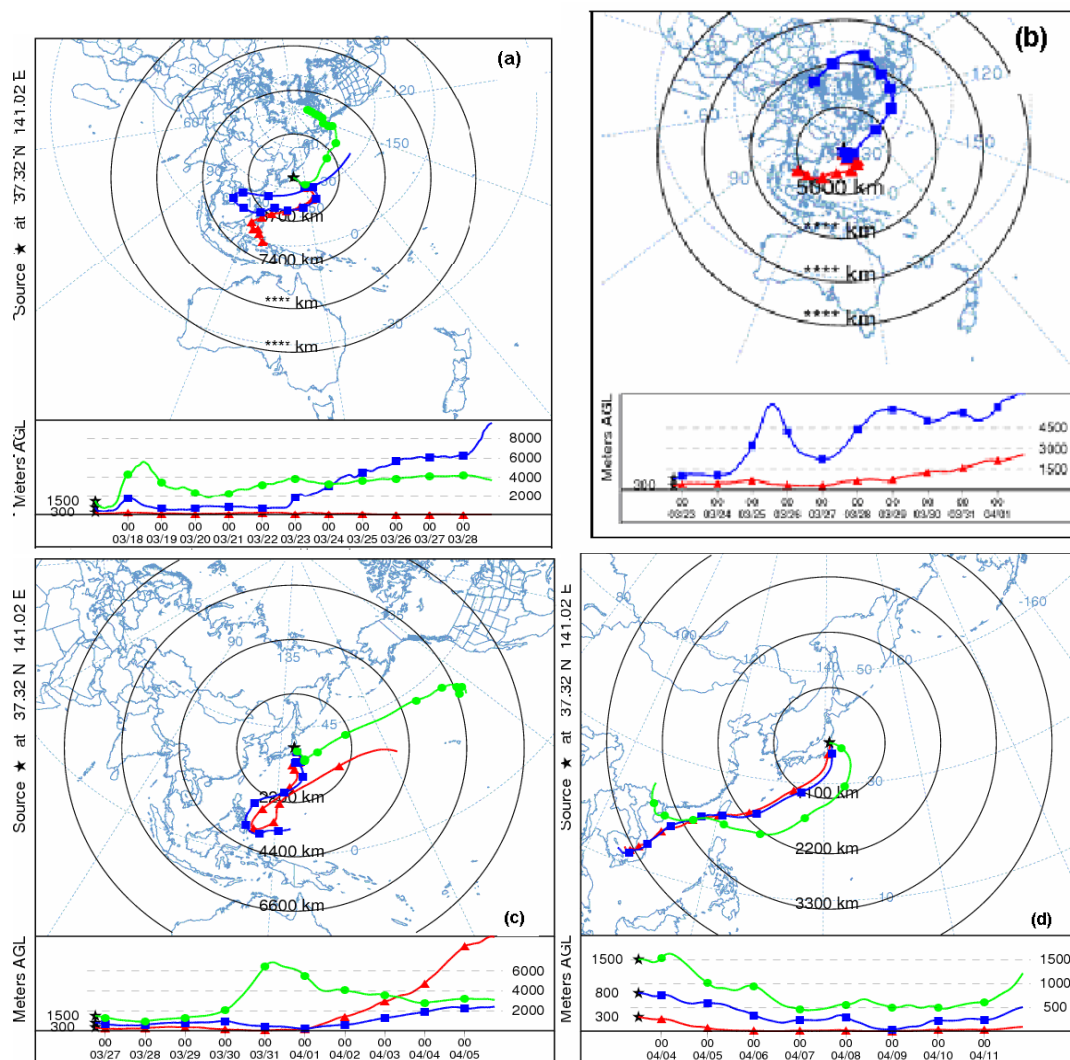


Fig. 11. NOAA HYSPLIT trajectories for air parcels released from Fukushima

- at 00:00 UTC 17 March 2011 and arrived in Vietnam on 25 March 2011,
- at 18:00 UTC 22 March 2011 and arrived in Vietnam on 31 March 2011,
- at 18:00 UTC 26 March 2011 and changed their direction by arriving in the Philippines,
- at 00:00 UTC 3 April 2011 and arrived in Vietnam on April 11.

Rain water, sea water, soil, and pine needle samples were collected and analysis, however, the radioactivities of some artificial radionuclides caused by Fukushima accident had gone below the detection limits.

## 2.2. Some selective applied researches and some typical results in marine radiological pollution issues

*The survey on elemental composition of sediments in the estuarine areas:*

In recent time, increasing of sedimentation rate at some navigable estuaries and waterways in Vietnam can be considered as an evidence of environmental degradation caused by the destruction of tropical rain forests in the mountain areas and protective mangrove swamps along the coastline.

The growing industrialization nowadays of the country, especially the rapidly expanding oil and gas exploration and exploitation, certainly cause another adverse impact to the coastal ecosystem.

Thus, there is a growing concern about the unfavorable environmental change in the coastal and harbor areas adjacent to the highly populated industrial centers, such as HoChiMinh City and HaiPhong.

- Concentrations of 35 elements in the sediment samples were determined by INAA, RNAA, PGNA and XRFA methods at the DNRI. In general, the trace element compositions of the collected bottom sediments are still of geochemical origin and rather similar to those of alluvium transported by the Red and Mekong rivers. The concentrations of some ecologically relevant heavy metals are far lower than those in some polluted estuaries of industrialized countries (see Table 2).

Table 2. Concentration of some ecologically relevant heavy metals (in ppm) in Haiphong and Saigon estuarine areas. (relative error is given as a percentage in parentheses)

Element	Haiphong estuary	Saigon estuary
Cu	13 (20)	20 (15)
Pb	52 (15)	10 (15)
Se	1.5 (15)	1.4 (15)
Cr	100 (5)	94 (5)
As	20 (7)	8.5 (10)
Zn	500 (7)	400 (10)
Cd	3.7 (10)	0.15 (20)
Sb	3.2 (6)	1.3 (8)

- The obtained data can be considered as a background reference allowing the assessment of any elemental concentration variation of anthropogenic origin in the future.
- Characterization of the elemental compositions has revealed the features involved in the processes of sediment formation and transportation.
- Trace element analysis has also provided a basic for identifying suitable activable tracer, instead of using radioactive traces in sediment transport studies, i.e. among the trace elements with concentrations in the sediment at the sub-ppm levels, In and Se have been selected for this purpose.
- The typical concentration of  $^{137}\text{Cs}$  in the sediment samples is  $1.5\div 3.5$  Bq/kg d.w. It is hopeful to say that careful sampling with appropriate corer would determine the sedimentation rate in the estuarine area at various sites.



- C-14 dating technique has been recently used to determine the sedimentation rate at the shelf area, about 120 Km from the estuaries of the Mekong river ( $0.5 \text{ m}/10^3 \text{ years}$ ) where oil exploitation is being intensively conducted.

***Marine pollutant research and monitoring:***

- The goals of the project are:
  - To develop nuclear and nuclear-related analytical methods for Marine pollutant monitoring by important radionuclides and trace elements ( $^{90}\text{Sr}$ ,  $^{137}\text{Cs}$ , U, Th,  $^{226}\text{Ra}$ ,  $^{239,240}\text{Pu}$ ,  $^{210}\text{Pb}$ ,  $^{210}\text{Po}$ , As, Cd, Co, Cr, Cu, Pb, Hg, Ni, Zn, Se, etc.).
  - To acquire baseline data for main radionuclides and toxic trace elements in Marine environmental materials (water, sediments and biota) collected from suitable key coastal locations: Cat Ba ( $20^{\circ}40\text{N}$ ,  $107^{\circ}05\text{E}$ ), Cua Lo ( $18^{\circ}46\text{N}$ ,  $105^{\circ}46\text{E}$ ), Nha Trang ( $12^{\circ}15\text{N}$ ,  $109^{\circ}16\text{E}$ ), Phan Thiet ( $10^{\circ}54\text{N}$ ,  $108^{\circ}22\text{E}$ ), Vung Tau ( $10^{\circ}14\text{N}$ ,  $107^{\circ}09\text{E}$ ), Cua Dai ( $10^{\circ}11\text{N}$ ,  $106^{\circ}48\text{E}$ ) – (Fig. 12).
- 700 data of  $^{238}\text{U}$ ,  $^{232}\text{Th}$ ,  $^{210}\text{Po}$ ,  $^{90}\text{Sr}$ ,  $^{137}\text{Cs}$ ,  $^{239,240}\text{Pu}$  radionuclides concentration in 120 sea water, sediment, fish, mollusks, crustaceans, oyster and weeds samples collected in 6 various locations of Vietnam during 2000 -2005 are obtained.
- The radionuclides concentration data could be adequate to insert into the data bank of the Nation and Region, and be a fundament of further input assessments of these radionuclides.
- In general, the data of artificial radionuclides concentration obtained in this project are tendentiously lower than respective data from other authors in the Asian-Pacific region. Thus is explained that Vietnam marine have been little influenced by released emissions from the countries with developed nuclear industry.
- The activity ratios of  $^{239,240}\text{Pu}/^{137}\text{Cs}$  and  $^{137}\text{Cs}/^{90}\text{Sr}$  in the sea sediment were higher than those in undisturbed terrestrial soils.
- The primary data set obtained from this project is available to contribute to the Asia-Pacific Marine database (ASPAMARD)- (see Table 3, 4 & 5).
- The bio-accumulative factors in Seaweeds and Oyster of almost radionuclides are high. Therefore, these results should be investigated further in application of this biota as bio-fingerprint indicators for marine environment radioactivity pollution problems aimed to simplify the procedures and monitoring programs (see Table 6 and Fig. 12).

Table 3. Trace elements concentration of marine samples in some typical sea regions of Vietnam.

Sample	Concentration (ppm in dry weight basis)				
	As	Cd	Co	Cr	Cu
Sea water (*)	72.67 ± 8.72			22.3 ± 3.3	
Gulfweed	44.89 ± 6.39	0.24 ± 0.06	0.62 ± 0.08	1.7 ± 0.5	7.0 ± 1.0
Red laver	23.83 ± 2.38	0.27 ± 0.06	0.38 ± 0.11	11.2 ± 1.3	28.4 ± 1.7
Tube gracilarit		0.85 ± 0.20			6.6 ± 1.1
Widgeon	5.05 ± 0.71	0.26 ± 0.07	0.38 ± 0.06	18.7 ± 1.7	1.8 ± 0.4
Lizard-fish	11.63 ± 1.58	0.27 ± 0.06	1.52 ± 0.19	0.9 ± 0.2	15.4 ± 1.4
King-fish	6.99 ± 1.16	0.17 ± 0.04	0.05 ± 0.02	0.5 ± 0.1	4.7 ± 0.7
Mackerel tuna fish	4.10 ± 0.93	0.31 ± 0.08	0.08 ± 0.03	0.5 ± 0.1	6.5 ± 0.8
Squid	88.84 ± 12.75	0.64 ± 0.15	0.06 ± 0.02		13.7 ± 1.6
Shrimp	45.48 ± 6.53	0.48 ± 0.12	0.11 ± 0.04	2.3 ± 0.4	77.2 ± 13.9
Oyster	11.63 ± 1.58	1.02 ± 0.24	1.52 ± 0.19	0.9 ± 0.2	15.4 ± 1.4

(\*) Unit:  $\mu\text{g/l}$ .

Table 3. Trace elements concentration of marine samples in some typical sea regions of Vietnam (Cont.).

Sample	Concentration (ppm in dry weight basis)				
	Hg	Mo	Sb	Se	Zn
Sea water (*)	1.92 ± 0.48	114.2 ± 10.6	5.00 ± 0.60	20.76 ± 1.66	
Gulfweed	0.22 ± 0.06	8.9 ± 0.9	0.71 ± 0.11	1.78 ± 0.30	14.3 ± 1.5
Red laver	0.15 ± 0.04	6.2 ± 0.6	0.29 ± 0.06	1.39 ± 0.34	42.8 ± 2.6
Tube gracilarit		0.85 ± 0.20			6.6 ± 1.1
Widgeon	0.04 ± 0.01	3.6 ± 0.4	0.40 ± 0.07	0.95 ± 0.17	33.9 ± 3.0
Lizard-fish	0.34 ± 0.08	2.4 ± 0.3	0.06 ± 0.02	1.75 ± 0.30	23.3 ± 1.4
King-fish	0.14 ± 0.02	2.2 ± 0.3	0.27 ± 0.05	1.19 ± 0.20	21.5 ± 2.1
Mackerel tuna fish	0.18 ± 0.04	4.7 ± 0.5	0.25 ± 0.05	2.21 ± 0.33	39.2 ± 3.5
Squid	0.19 ± 0.04	2.7 ± 0.3	1.00 ± 0.14	1.47 ± 0.24	48.2 ± 3.8
Shrimp	0.15 ± 0.03	4.7 ± 0.5	0.60 ± 0.08	1.96 ± 0.31	62.50 ± 4.2
Oyster	0.08 ± 0.04	3.1 ± 0.3	0.17 ± 0.05	2.40 ± 0.36	70.9 ± 4.9

(\*) Unit:  $\mu\text{g/l}$ .

Table 4. Natural radionuclides concentrations of marine samples along the coast of Vietnam

No.	Samples	$^{238}\text{U}$		$^{232}\text{Th}$		$^{210}\text{Po}$		$^{226}\text{Ra}$	
1	Sea water*	34.94±3.50	** (35)	1.27±0.35	(35)	0.80±0.16	(3)	4.19±0.94	(15)
		21.40±59.69		0.23±4.35		0.58±1.02	(5)	1.33±5.35	
2	Sediment*	27.14±5.36	(35)	27.75±5.55	(35)	142.52±28.40	(5)	30.68±4.93	(15)
		4.51±77.03		3.73±56.80		56.00±240.00	(3)	23.09±40.21	
3	Fish (5 kinds)*	0.395±0.465	(20)	0.208±0.098	(40)	2.072±0.410	(4)	0,234±0,047	(15)
		0.032±3.630		0.009±0.810		1.244±3.686	(7)	0,073±0,648	
4	Mollusca*	0.111±1.290	(5)	0.043±0.080	(5)	5.062±1.012	(3)	0,025±0,006	(5)
		0.009±0.212		0.035±0.051		1.911±9.726	(3)	0,010±0,049	
5	Shrimp*	0.593±0.251	(10)	0.476±0.294	(10)	3.153±0.480	(3)	0,137±0,030	(10)
		0.038±1.440		0.219±0.620		0.874±3.894	(5)	0,053±0,252	
6	Oyster*	3.490±1.734	(15)	0.821±0.404	(15)	22.486±5.100	(5)	0,674±0,135	(10)
		0.017±22.620		0.093±2.590		4.101±58.642	(3)	0,139±1,493	
7	Red laver*	2.441±1.263	(10)	3.612±1.414	(10)	5.935±1.187	(4)		
		0.221±5.840		0.218±6.660		2.108±9.761	(7)		
8	Seaweeds* (4 other kinds)	0.793±0.388	(20)	1.510±0.450	(20)	8.302±0.161	(3)	1.230±0.217	(20)
		0.404±1.920		0.263±4.182		8.140±8.460	(3)	0.283±6.206	

\* Unit: Water (Bq/m<sup>3</sup>); Sediment (Bq/kg dry); Biota (Bq/kg fresh weight).

\*\* With number of observations in brackets.

Table 5. Artificial radionuclides concentrations of marine samples along the coast of Vietnam.

No.	Samples	$^{90}\text{Sr}$		$^{137}\text{Cs}$		$^{239,240}\text{Pu}$	
1	Sea water*	1.53±0.24	* * (35)	1.575±0.215	(35)	0.006±0.001	(35)
		0.91±3.60		0.669±3.600		0.002±0.014	
2	Sediment*	0.14±0.03	(35)	0.37±0.23	(35)	0.326±0.084	(35)
		0.05±0.41		0.02±2.62		0.012±0.683	
3	Fish (5 kinds)*	0.05±0.13	(15)	0.601±0.299	(40)	< 0.0001	(40)
		0.04±0.06		0.064±1.856			
4	Mollusca*	0.03±0.06	(5)	< 0.001	(5)	< 0.0001	(5)
		0.02±0.03					
5	Shrimp*	0.05±0.06	(10)	0.041±0.021	(10)	0.0006±0.0002	(10)
		0.04±0.05		0.004±0.077		0.0002±0.0006	
6	Oyster*	< 0.01	(10)	0.233±0.154	(15)	0.0032±0.0016	(15)
				0.002±0.678		0.0003±0.0080	
7	Red laver*	0.05±0.01	(10)	0.047±0.030	(10)	0.0075±0.0050	(10)
		0.03±0.07		0.003±0.115		0.0020±0.0226	
8	Seaweeds*(4 other kinds)	0.291±0.087	(10)	0.116±0.055	(20)	0.0144±0.0028	(20)
		0.017±0.815		0.005±0.432		0.0003±0.0711	

\* Unit: Water (Bq/m<sup>3</sup>); Sediment (Bq/kg dry); Biota (Bq/kg fresh weight).

\*\* With number of observations in brackets.

Table 6. Bio-accumulative factors of some radionuclides in marine biota in Vietnam.

Matrix	Bio-accumulative factor					
	U	Th	<sup>210</sup> Po	<sup>90</sup> Sr	<sup>137</sup> Cs	<sup>239,240</sup> Pu
Fish (Lizard-fish, King-fish, Mackerel tuna fish, Horse-sead fish, Anchovy fish)	11.3	163.8	2590.0	32.7	381.6	0
Mollusca	3.2	33.9	6327.5	19.6	0	0
Shrimp	17.0	374.8	3086.3	32.7	26.0	100.0
Oyster	99.9	646.5	28967.5	0	147.9	533.3
Red laver	69.9	2844.1	7418.8	32.7	29.8	1250.0
Seaweed (Widgeon weed, Needle gracilarit, tube gracularit)	22.7	1189.0	10377.5	0	73.7	0

Bio-accumulative factor:  $K = \frac{A_s}{A_n}$

Where:  $A_s$  - specific radioactivity in marine biota (Bq/kg fresh weight)

$A_n$  - specific radioactivity in sea water (Bq/l)

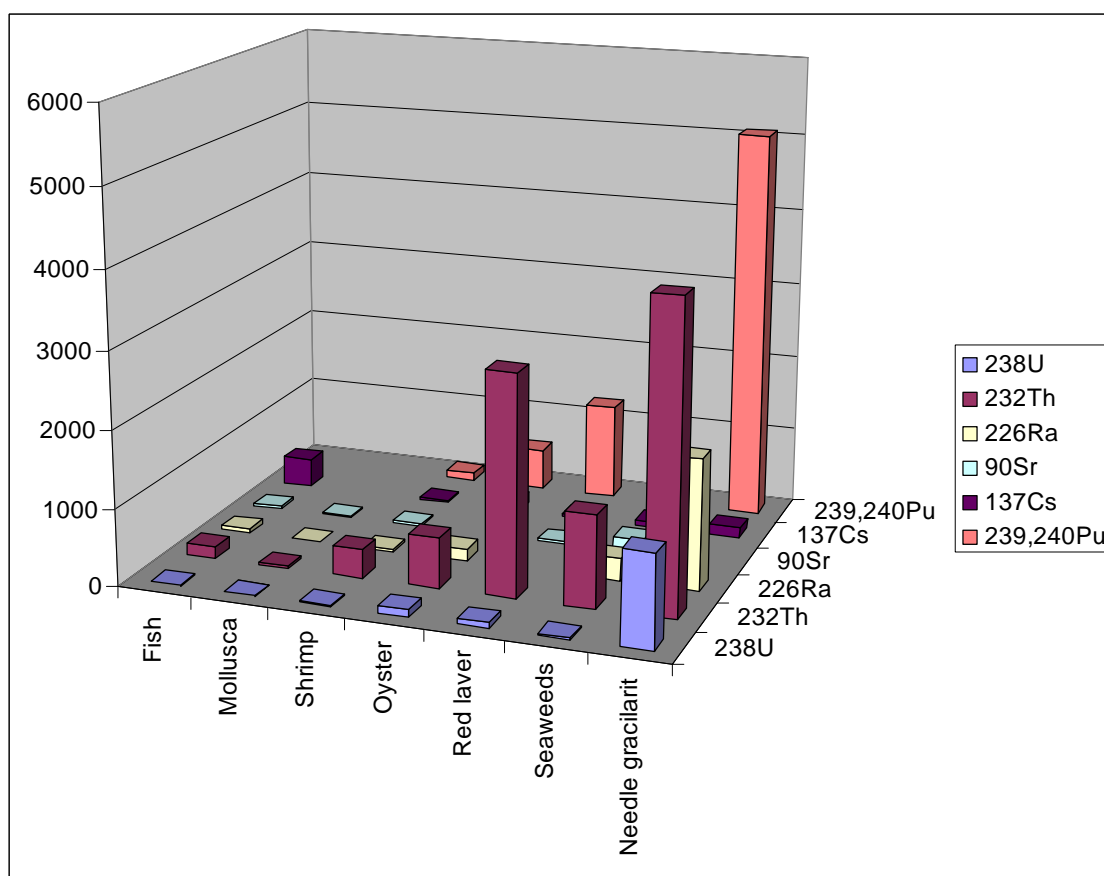


Fig.12. Bio-accumulative factors of some radionuclides in marine biota in Vietnam

### 2.3. Foods & foodstuffs research:

During the two years to implement the project on “Investigation on radionuclides and toxic elements concentration in the main kinds of foods & foodstuffs of Vietnam”. The obtained typical results are as follows:

- Establishment of some standard procedures for collection, preparation and preservation of food & foodstuff samples.
- The primary data set (1251 data) of present level of some major radionuclides ( $^{40}\text{K}$ ,  $^{210}\text{Pb}$ ,  $^{210}\text{Po}$ ,  $^{226}\text{Ra}$ , U, Th,  $^{90}\text{Sr}$ ,  $^{137}\text{Cs}$ ,  $^{239,240}\text{Pu}$ ) in the collected samples.
- The primary data set (1244 data) of present level of some major toxic elements (As, Cd, Co, Cr, Cu, Pb, Hg, Ni, Zn, Se) in the collected samples.
- Technical assistance for the Government management on radionuclide and toxic element control in foods & foodstuffs by consumption of Vietnamese at home as well as export and import.
- Primary assessment the public committed effective doses/ collective doses caused by consumption of foods & foodstuffs in some regions Khanh Hoa, Binh Thuan, Ba Ria - Vung Tau.

### 3. NATIONAL PROJECT TEAM AND NATIONAL FACILITIES

National project team are as follows:

**Vietnam Environment Administration (MONRE):** 2 persons to be responsible for management of monitoring stations in the national marine environment monitoring network:

1. Mr. Nguyen Duc Hung, Department of Pollution Control
2. Mr. Tran Lam Hao, Department of Pollution Control

**Vietnam Agency for Radiation and Nuclear Safety (MOST):** 1 persons to be responsible for management and licensing of discharges of radioactive substances in the marine environment:

1. Dr. Nguyen Hao Quang, Department of Technical Assistance for Radiation and Nuclear Safety.

**Institute of Oceanography:** 2 persons in the cooperation in marine sample collection program planning:

1. Mr. Vu Tuan Anh, Department of Marine Environment Monitoring Station
2. Mr. Nguyen Dinh Dan, Department of Oceanographic Data

**VAEI (MOST):** 19 persons to be responsible for carrying out the whole project, including sample collection, analysis, data processing, and risk and dose assessments:

**Nuclear Research Institute (Dalat, Vietnam):**

1. Mr. Nguyen Thanh Binh, Deputy Director of the Dalat Nuclear Research Institute

2. Mr. Nguyen Trong Ngo, Head of Planning and International Cooperation Department
3. Mr. Phan Son Hai, Head of Center for Environment Research and Monitoring
4. Mr. Truong Y, Deputy Director of Center for Environment Research and Monitoring
5. Mr. Le Nhu Sieu, Center for Environment Research and Monitoring
6. Mr. Nguyen Van Phuc, Center for Environment Research and Monitoring
7. Mrs. Nguyen Thi Linh, Center for Environment Research and Monitoring
8. Mr. Nguyen Dinh Tung, Center for Environment Research and Monitoring
9. Mr. Tran Dinh Khoa, Center for Environment Research and Monitoring
10. Mr. Nguyen Dao, Center for Environment Research and Monitoring
11. Mr. Nguyen Van Phu, Center for Environment Research and Monitoring

*Institute for Nuclear Science and Technology (Hanoi, Vietnam):*

1. Dr. Trinh Van Giap, Director of the Institute for Nuclear Science and Technology
2. Mr. Nguyen Quang Long, Deputy Director of Center for Radiation Protection and Environment Monitoring
3. Mrs. Tran Thi Tuyet Mai, Center for Radiation Protection and Environment Monitoring
4. Mrs. Dinh Thi Bich Lieu, Center for Radiation Protection and Environment Monitoring
5. Ms. Ha Lan Anh, Center for Radiation Protection and Environment Monitoring

*Center for Nuclear Techniques (Ho Chi Minh City):*

1. Mr. Nguyen Van Mai, Head of Radiation Protection and Environment Monitoring Department
2. Mr. Ninh Duc Tuyen, Center for Radiation Protection and Environment Monitoring Department
3. Mr. Nguyen Hoang Long, Center for Radiation Protection and Environment Monitoring Department

VAEI has the responsibility for implementing a comprehensive program of the environment radioactivity monitoring, sampling, radioanalysis, and quality assurance. This program includes: (1) field monitoring and sampling; (2) laboratory radioanalysis; (3) radiation detection instrumentation with calibration and maintenance; and 4) integrated program of quality assurance and quality control following Vietnam Standards ISO/IEC 17025:2005.

At the present, VAEI is implementing a national project on Investigation, supplement of the national database of artificial radioactivity in the environment of Vietnam.



Overall objective: To obtain database of the inventory of artificial radioradionuclides in important environmental components in Vietnam aiming to the environmental impact assesment caused by the nuclear facility operations and incidents, released to the territorial and marine environment of Vietnam.

Background levels of artificial radionuclides in environmental objects by the release of nuclear activities, especially the long-lived radionuclides, enduring exist, significant redistribution environment (highly dynamic mobility of the atmosphere and hydrosphere). The behavior of these artificial radionuclides in the environment is complex, depending on many factors: time and form of existence, characterized by physico-chemical environment, isotope carriers, similar elements, the process-of-living chemical in the environment, etc. The tentative schedule program is presented in Table 7.

Table 7. The tentative schedule program of the national project.

Activity	2011				2012				2013			
	1	2	3	4	1	2	3	4	1	2	3	4
<i>Quarter</i>												
Sumarization, further analysis of the obtained investigations of artificial radionuclide contamination of the status environment, including the isotope composition, sample objects, sampling density distribution in order to reconize some gaps and to establish detailed additional research programs				×	×	×						
Research and establishment of simultaneous analytical method of Actinide group artificial radionuclides ( $^{237}\text{Np}$ , $^{238}\text{Pu}$ , $^{239\&240}\text{Pu}$ , $^{241}\text{Am}$ , $^{242}\text{Cm}$ ) by ion exchange chromatography technique accompanied with $\alpha$ spectrometer.					×	×						
Research and establishment of method of separately determination of $^{239}\text{Pu}$ and $^{240}\text{Pu}$ by ICP-MS; and international cooperation to determine the specific radioactivity of these radionuclides of soil, sediment and marine selected organism samples in Vietnam aiming to identify pollution sources.					×	×	×					

Designing the sampling program: Soil sampling at reference site (non disturbed soil, low background radioactivity of U, Th and K); marine sediment, local marine organisms (high bio-accumulative factors: brown algae, bivalves, crabs) in sea water.							×	×	×	×		
Detailed analysis of the collected samples of $^{90}\text{Sr}$ , $^{137}\text{Cs}$ , $^{237}\text{Np}$ , $^{238}\text{Pu}$ , $^{239+240}\text{Pu}$ , $^{241}\text{Am}$ , and $^{242}\text{Cm}$ radionuclides.							×	×	×	×	×	
Application of advanced statistical techniques to process the obtained experimental data: specify the inventory of the artificial radioactivity and identify their pollution sources based on the ratio of isotopes ( $^{137}\text{Cs}/^{90}\text{Sr}$ , $^{137}\text{Cs}/^{239+240}\text{Pu}$ , $^{240}\text{Pu}/^{239}\text{Pu}$ , etc ...) - these important information for environmental impact assessment, especially before starting construction of the first NPP in Ninh Thuan province.						×	×	×	×	×	×	×
Building up the basic database, mapping the distribution of residual density of artificial radionuclides in environmental objects.							×	×	×	×	×	×

Some facilities are operated relevant to environmental surveillance:

- Radio-spectrometry laboratory,
- Environmental chemical laboratories,
- Sample preparation laboratory,
- Sample reservation cabinet,
- Air sampling stations in Hochiminh city, DaLat, and Hanoi are in the framework of the National Monitoring Network.

The used measurement approaches are presented on Fig. 13.

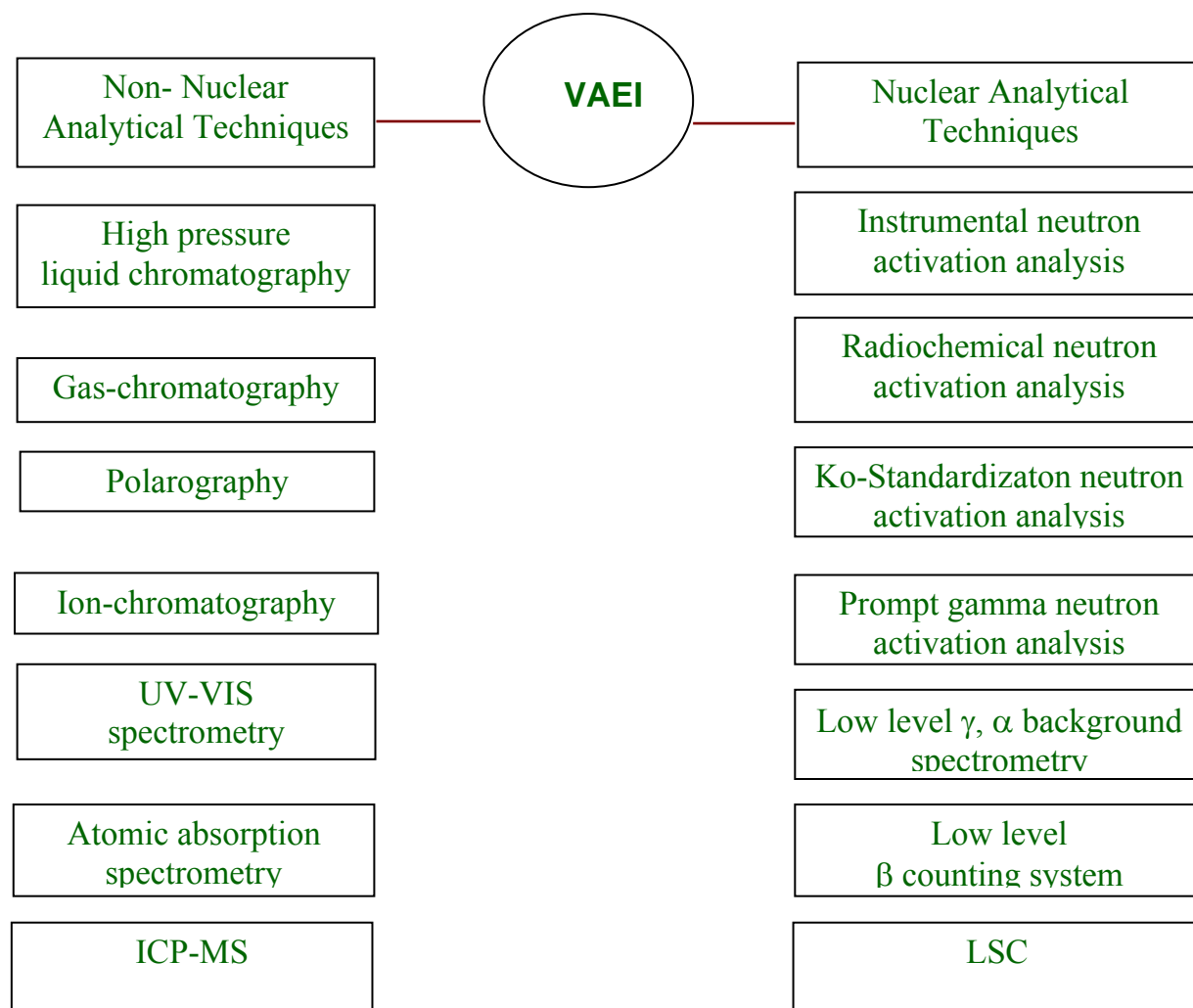


Fig. 13. The used measurement approaches of VAEI.

#### 4. CONCLUSION AND RECOMMENDATION

Further co-operation aspects proposed from RCA Marine Environment program:

4.1. Collaborative research to establish an integrated program of Marine environmental radiation/ radioactivity monitoring network (points, matrices, target pollutants and frequencies).

4.2. Collaborative research to establish the standard sampling and sample preparation protocols, and standardize the analytical procedures and methods in order to obtain the comparative data, which allow evaluating the changes of marine environmental quality in the whole region.

4.3. Collaborative research and analysis of some selective samples in pollution source identification, for example, the determination separately Pu-239 and Pu-240 in marine sediment by ICP-MS.

4.4. Support sediment sampling equipment

4.5. Development of documented total quality management system guidelines for monitoring the impacts of nuclear activities in the Marine environment.

4.6. Proficiency test round/RCA Intercomparison exercise (more supplementation of standard solutions and reference materials with the same traceability).

4.7. To facilitate mechanism by which a participating member can ask another to perform referee analysis of samples.

4.8. Expansion, improvement and maintenance of the Regional radioactivity database:

- Each participating country carries out measurements and sends the results in the form of standard datasheet to the Lead Country.
- The Lead Country compiles the data into the Regional database and distributes it to all the participating countries and other relevant agencies.
- The database is updated at an appropriated interval.

4.9. To promote the use of radiotracer techniques to determine transfer factor, bioaccumulation factors and transport of pollutants.

4.10. To promote the use of advanced statistical and modeling techniques in Marine environment monitoring and dose assessment from ingestion pathway of seafood.