ENVIRONMENTAL RADIOACTIVITY STUDIES WITHIN THE VIETNAM ATOMIC ENERGY INSTITUTE DURING THE TIME PERIOD 1980 – 2010

Dang Duc Nhan[1], Pham Duy Hien[1], Ngo Quang Huy[1], Vuong Thu Bac[2], Nguyen Thanh Binh[3], Phan Sơn Hai[3], Nguyen Quang Long[2], Nguyen Trong Ngo[3], Nguyen Hao Quang[1], Nguyen Trong Trang[1], Tran Ngoc Toan[1] and Trương Y[3]

[1]Viet Nam Atomic Energy Institute, 59 Ly Thuong Kiet, Ha Noi, Vietnam
[2]Institute for Nuclear Sciences and Technology, 179 Hoang Quoc Viet, Cau Giay, Ha Noi,Vietnam
[3]Nuclear Research Institute, Da Lat, No.1 Nguyen Tu Luc St., Da Lat, Lam Dong,Vietnam

Project information:

- **Code:**
- **Managerial Level: Ministry**
- **Allocated Fund: 480,000,000 VND**
- **Implementation time: 24 months (Jan 2010 - Dec 2011)**
- **Contact Email: dangducnhan50@gmail.com**
- **Paper published in related to the project:**

1. Ngo Quang Huy, **2010**. The influence of dead layer thickness increase on efficiency decrease for a coaxial HPGe p-type detector. *Nucl Inst and Methods in Phys Res*, (A 621): 390-394.
2. Dang Duc Nhan, Dinh Thi Bich Lieu, Vo Thi Anh, Ha Lan Anh va Nguyen Thi Thai, 2010. Concentration of tritium in the precipitation and water from the Red River (North Viet Nam) during the period of time 2001-2010. Available on the http://www.iaea.org/water.
3. *Dang Duc Nhan, Nguyen Van Lam, Ha Chu Ha Long, Dao Dinh Thuan, Dang Anh Minh, and Vo Thi Anh, 2011. Hydrological characteristics of karstic groundwater in the Northeast Viet Nam as studied by isotopic techniques.* J. Environ. Earth Sci. DOI 10.1007/s12665-011-0943-x. Published on line 30 Nov 2011.
4. Ngo Quang Huy, **2011**. Dead layer thickness effect for gamma spectra measured in an HPGe p- type detector. *Nucl Inst and Methods in Phys Res*, A 641: 101-104.
5. Dercon G., L.Mabit, G. Hancock, M.L. Nguyen, P. Dornhofer, O.O.S. Bacchi, M. Benmansour, C. Bernard, W. Froehlich, V.N. Golosov, S. Haciyakupoglu, P.S. Hai, A. Klik, Y. Li, D.A. Lobb, Y. Onda, N. Popa, M. Rafiq, J.C. Ritchie, P. Schuller, A. Shakhashiro, P. Wallbrink, D.E. Walling, F. Zapata, X. Zhang, **2012**, "Fallout radionuclide-based techniques for assessing the impact of soil conservation measures on erosion control and soil quality: an overview of the main lessons learnt under an FAO/IAEA Coordinated Research Project", *Journal of Environmental Radioactivity, 107:* 78-85.
6. Ngo Quang Huy, Do Quang Binh and Vo Xuan An, **2012**. A study for improving detection efficiency of an HPGe detector based gamma spectrometer using Monte Carlo simulation and genetic algorithms. *Appl Radiat and Isot*, 70: 2695-2702.
7. N.Q. Long, Y Truong, P.D. Hien, N.T. Binh, L.N. Sieu, T.V. Giap, N.T. Phan, **2012**. Atmospheric radionuclides from the Fukushima Dai-ichi nuclear reactor accident observed in Vietnam. *Journal of Environmental Radioactivity 111: 53-58.*
8. N.Q. Huy, P.D. Hien, T.V. Luyen, D.V. Hoang, H.T. Hiep, N.H. Quang, N.Q. Long, D.D. Nhan, N.T. Binh, P.S. Hai and N.T. Ngo, **2012**. Natural radioactivity and external dose assessment of surface soils in vietnam. *Journal of Radiation Protection Dosimetry, 15(3): 522-531.*
9. Ngo Quang Huy, Pham Duy Hien, Tran Van Luyen, Dao Van Hoang, Huynh Thuong Hiep, Nguyen Hao Quang, Nguyen Quang Long, Dang Duc Nhan, Nguyen Thanh Binh, Phan Son Hai, and Nguyen Trong Ngo, **2012**. Natural radioactivity and external dose assessment of surface soils in Vietnam. *Radiat. Prot. Dosim., 151: 522-531.*
10. Dang Duc Nhan, Carvalho P. Fernando, Nguyen Thi Thu Ha, Nguyen Quang Long, Dao Dinh Thuan, and Heloisa Fonseca, **2012**. Radon (^{222}Rn) concentration in indoor air near the coal mining area of Nui Beo, North of Viet Nam. *J. Environ. Radioact*., 110: 98-103.
11. Ngo Quang Huy, Do Quang Binh, Vo Xuan An, Truong Thi Hong Loan and Nguyen Thanh Can, 2013. Self-absorption correction in determining the ^{238}U activity of soil samples *via* 63.3 keV gamma ray using MCNP5 code. *Appl Radiat and Isot*, 71: 11-20.

12. Dang Duc Nhan, Carvalho F.P., Oliveira J. M, N. Q. Long, D. D. Thuan, and Malta M., 2013. Coal mining and radioactivity in the coastal area of Ha Long Bay, North Viet Nam. 2nd Intl. Conf. on "Environ. Poll., Restn, and Manag.". SEATAC Asia Pacific, Loyola University Chicago, and Ha Noi Univ. of Nat. Sci., Ha Noi, Mar 4-8, 2013.
13. Dang Duc Nhan, Doan Van Canh, Pham Quy Nhan, Nguyen Thi Thanh Thuy, Dinh Thi Bich Lieu, Vo Thi Anh, and Dang Anh Minh, 2013. Mobilization of arsenic in groundwater in the Southern Ha Noi City (Viet Nam) as studied by isotopic and related techniques. *J. Environ. Prot.*, 4: 68-74.

ABSTRACT: This report summarizes results of the monitoring activities for natural and anthropogenic radioactivity in the environment such as in surface soil, in surface and groundwater, in the atmosphere and food of Viet Nam that have been conducted by the staff of the Vietnam Atomic Energy Institute (VAEI) since the first day of its foundation. Among natural radionuclide, uranium/radium, thorium, potassium-40 in surface soils and ^{222}Rn in the atmosphere are of particular interest for estimating the annual effective dose resulted from gamma radiation and inhalation to the public. The total annual effective dose (outdoor and indoor dose) from gamma radiation of natural radioactivity (U, Th, ^{40}K) in surface soil to the public of all the 63 provinces over Viet Nam was estimated as high as 0.54 mSv that is in 10% higher than those reported in the UN SCEAR-2000. The annual effective dose due to inhalation with the air containing ^{222}Rn to the habitant in the Ha Noi city was found to be as high as 1.13 mSv that is in the range of the dose reported for the Asian region.

The anthropogenic radionuclides under the monitoring are ^{90}Sr, ^{137}Cs, and $^{239+240}$Pu originated from nuclear weapon tests during the 1950-1960. Concentration of the anthropogenic radionuclide in surface soil gives an idea about the fall-out inventory of the radio-isotopes from the nuclear explosion in the past. This information would be necessary for the Environmental Impact Assessment for the Nuclear Power Construction Project in Viet Nam.

The results of environmental radioactivity monitoring activities of the VAEI has been composed in twelve scientific papers published in numerous International Scientific Journals like J. Environ. Radioact. and Radiat. Prot. Dosim. Two books entitled:"Radioactivity in the Environment" and "Radioactivity Measurement Applied in the Environmental Researches" has been drafted and submitted to the Publishing House "Science and Technique" for printing out soon.

I. INTRODUCTION

Since the first days of its foundation (1976), the Viet Nam Atomic Energy Commission, and it is Viet Nam Atomic Energy Institute (VAEI), at present, has been much interested in the researches of radioactivity in the environment. However, due to the limitation of the infrastructure conditions, most researches that time were focused on the development of methods and procedures applied for monitoring the environmental radioactivity, so there was not much results to publish in International Scientific Journals. Environmental radioactivity investigation of the VAEI was intensively developed after the accident of the Chernobyl nuclear power plant in 1986. The main directions in the research were: i) determine radioactivity in construction materials [1]; ii) determine ^{222}Rn concentration in indoor air [2]; iii) determine concentration of gross alpha and beta in the black sand along the marine coast of the country [3].

Investigation of ^{137}Cs inventory in surface and undisturbed soil throughout terrestrial Viet Nam was conducted in 1998 [4, 5]. The concentration of ^{90}Sr and $^{239+240}$Pu in cultivated soils was determined in the 2000 [6]. The ^{137}Cs monitoring campaign conducted in the 1998-2000 [4] gave additional data of natural radioactivity of ^{238}U/^{226}Ra, ^{232}Th, ^{40}K in the surface soils samples. These data allows to estimate the annual effective dose to the public of Viet Nam due to the gamma radiation from surface soils [7].

Radioactivity in construction materials is continuously monitored by the staff of the Nuclear Research Institute in Da Lat (NRI) [8]. The NRI and the Institute for Nuclear Sciences and Technologies (INST) are the two stations of the National Monitoring Network of the Ministry of Natural Resources and Environment setting up for monitoring radioactivity in the environment throughout the country. Data on the concentration of ^{7}Be, ^{238}U, ^{232}Th, ^{40}K, ^{226}Ra, ^{137}Cs in wet, dry deposition, in soils, in the air and some biological indicators like pine leaves are collected periodically by each quarter in the year. Radioactivity in the marine environment is studied by Nguyen Trong Ngo (NRI) and his co-laborators [9]. Consecutive collection of data on the tritium concentration in the precipitation and in water from the Red River in the Ha Noi city has been

conducted by the group leading by Dang Duc Nhan since 2002 [10]. The concentration of radioactivities in food was determined by Nguyen Quang Long and his co-laborators from the INST [11]. Investigation of the ^{210}Po accumulation in sea food from the Ha Long Bay area was also studied [12]. It should be noted that the contribution of ^{210}Po into the annual committed dose is as high as 70%.

This report summarizes the results of the environmental radioactivity monitoring activities recently conducted by the staff of the VAEI.

II. FACILITIES AND PROCEDURES APPLIED FOR THE ENVIRONMENTAL RADIOACTIVITY MONITORING

II.1. Sampling and sample treatment in the field

Soil samples were taken using a metallic corer from the surface to a depth not deeper than 30 cm. In each sampling site, soil sample was collected in three points that formed an equilateral triangle with a length of each side of 0.5 m. These three soil cores were mixed in one the have representative sample for each location [4]. Sediment samples were taken by the same method, but the sediment cores were frozen at -24 ^{o}C for transportation and easy to slice in the laboratory.

Food was bought directly from the local market or super markets in big cities. The food commodities were selected based on the diet of Vietnamese. These are rice, different vegetables (edible part only), pig and beef meat, fishes, seafood (oyster, clam, shrimp, squid etc.). The samples were kept in a freezer until the analysis.

Construction materials including brick, domestic and imported tiles, cement, sand, gravel and marble were bought from markets in the Ha Noi, Hue, Da Nang, Nha Trang, Da Lat and Ho Chi Minh cities, each by around 2 kg.

Rainwater and water from the Red River in Ha Noi were collected on monthly basic at the same site (21^{o}02'44"N, 105^{o}47'55"E for precipitation and 21^{o}01'50"N, 105^{o}51'42"E for the river's water) from 2002 till now.

II.2. Sample treatment in the laboratory for radioactivity quantification

In the laboratory soil sample were air dried then sieved through a metallic sieve to remove gravel, roots etc. Afterwards, the samples were dried at 105 ^{o}C till unchanged weight. The dried samples were packed in plastic bags until measurement conducted. Sediment cores were first slice with a thickness of 1 cm, air dried, sieved to remove any plant residues and then dried at 105 ^{o}C till unchanged weight. The edible part from biota samples were collected only. These samples were cryogenic dried following grinding to 1 mm particle size. To analyze ^{210}Po in the biota samples, it was necessary to treat samples with HNO_3(d1,65 g cm^{-3}) +H_2O_2 at a temperature not exceeded 100^{o}C till clear solution was obtained. The ^{210}Po isotope was separated from other contaminant by cation exchange method using Dowex AG1-X8 resin. Polonium-210 in the eluate was electrochemically deposited on the surface of well polished silver disk (ϕ24 mm) in HCl 0.1 M solution as a source for the alpha spectrometric analysis.

Strontium-90 in soil samples was radiochemically separated followed a procedure described in the paper of [6]. Its was reportedly that the radiochemical separation yield of the strontium isotope was as high as 70%. Nuclides $^{239+240}$Pu in soils samples were separated by solvent extraction using tri-octylamine (TOA) in xylene with a ratio of 1:10 by volume. Isotope ^{242}Pu was used as an internal standard in the $^{239+240}$Pu quantification.

Water samples before the tritium measurement were distilled to remove all the dissolved minerals. The electric conductivity of the distilled samples must be <10 mS cm^{-1}. Tritium in the samples was enriched using electrochemical method [13, 14].

Concentration of ^{222}Rn in indoor air in Ha Noi was measured using nuclear solid trace detector polycarbonate (Iupilon) accommodated in Urban diffusion cups [15] but in the Ha Long

Bay area detector type LR-115 was used and they were hang barely. The duration of detectors exposure in the air was 3 months. The detectors after harvesting were etched with NaOH 2M at 60^oC for 2 hours. The trace numbers developed in the detectors were registered by counting under a optical microscope. This number was then converted into the unit of Bq m^{-3} air using a calibration factor set up by the laboratory [2, 16].

The natural radionuclides of ^{238}U, ^{226}Ra, ^{232}Th in soil samples were quantified by two methods. The first is to seal the samples to get secular equilibrium between $^{238}U/^{226}Ra$ and ^{214}Bi and ^{214}Pb as well as between ^{232}Th and ^{218}Ac. The radioactivity of ^{214}Bi and ^{214}Pb was quantified based on the gamma lines of 351.9 keV và 609.3 keV and this value was attributed to the radioactivity of $^{238}U/^{226}Ra$. Similarly, the radioactivity of ^{218}Ac and ^{208}Tl was quantified based on the gamma lines of 911.1 keV and 583.2 keV attributed to the ^{232}Th nuclide [17]. A gamma spectrometer equipped with HPGeD (Canberra) was used.

The second method to quantify the radioactivity of uranium and thorium was radiochemical separation of U and Th and then co-precipitate it with LaF_3 to get sources for alpha spectroscopic analysis [18].

Radioactivity of ^{40}K and ^{137}Cs was measured directly on a Canberra gamma spectrometer based on the gamma lines 1 460 keV and 661 keV, respectively [5]. The features of gamma spectrometers used in three Institutes, namely NRI (Da Lat), INST (Ha Noi) and Center for Nuclear Techniques (CNT, HCM city) to analyze gamma emitters in soil and food samples are presented in Table 1.

Table 1: Technical features of HPGeD used to quantify gamma emitters in the three Institutes of VAEI.

Technical features	INST	NRI	NTC
Detector type	GMX40P4-76	GX-3019	GX-3019
Relative efficiency	40%	30%	30%
Counting efficiency at 661 keV	2.1%	1.9%	1.9%
FWHM at 661 kev, keV	1.8	1.4	1.4

Sealing method seems to be more simple compared to the radiochemical separation method and its was successfully applied to analyze more than 500 soil samples collected within the Project:" Investigation into the contamination by anthropogenic radionuclides originated from the nuclear activities and nuclear power plant accident in the territory of Viet Nam". The accuracy of the method was proven as high as within 5-15%.

Radioactivity of ^{90}Sr was quantified either directly based on the Cherenkov effect on a HP liquid scintillation counter (TriCarb 3770 TR) or indirectly through ^{90}Y that was accumulated from the ^{90}Sr decay. The equilibrium between ^{90}Sr and ^{90}Y was 18 days. A gross beta counter was used for this analysis [6]. The accuracy of the method was better than 20%.

Radioactivity of $^{239+240}Pu$ was determined using a HP Canberra alpha spectrometer equipped with PIPS (Passive Implanted Planar Silicon) with active surface area of 350 mm^2, 450 mm^2 and 1200 mm^2 and the resolution of 25-35 keV, the minimum detectable limit is 0.004 Bq kg^{-1} dry soil. Counting time was from 80 000 to 400 000 seconds. The radioactivity of ^{210}Po was quantified on the same alpha spectrometer. The accuracy of plutonium and polonium was better than 25-30% and 10%, respectively.

Tritium content in water samples was measured on a HP liquid scintillation counter TriCarb 3770 TR with low level of tritium (LLT) cocktail. The minimum detectable limit of the procedure was 0.45 TU and the repeatability was 0.2 TU [10].

Quality control program for the analytical results was implemented through analysis Certified Reference Materials, e.g. IAEA Soil-6 for gamma emitters and IAEA Soil4/2000 for ^{90}Sr. Besides, the laboratories regularly participate in Intercomparison Exercises, e.g. TRI-2000, TRI-2004 for ^{3}H in water sample and other Proficiency Tests organized by IAEA within the Framework of RAS Programs.

III. MAIN RESULTS OBTAINED

III.1. The ^{137}Cs inventory in the terrestrial territory of Viet Nam

Fig. 1 presents the distribution of ^{137}Cs inventory (Bq m^{-2}) over the terrestrial territory of Viet Nam. This result was derived from analysis of 528 soil samples collected from undisturbed sites over all the 63 provinces and cities of Viet Nam. The map was constructed based on the MAPINFO v.9.0 program. It was revealed that the ^{137}Cs inventory is latitude and rainfall dependent. The farer to the North and the heavier rainfall the higher ^{137}Cs concentration in soil was observed. A model described the dependence between ^{137}Cs inventory and latitude and rainfall was derived as follows:

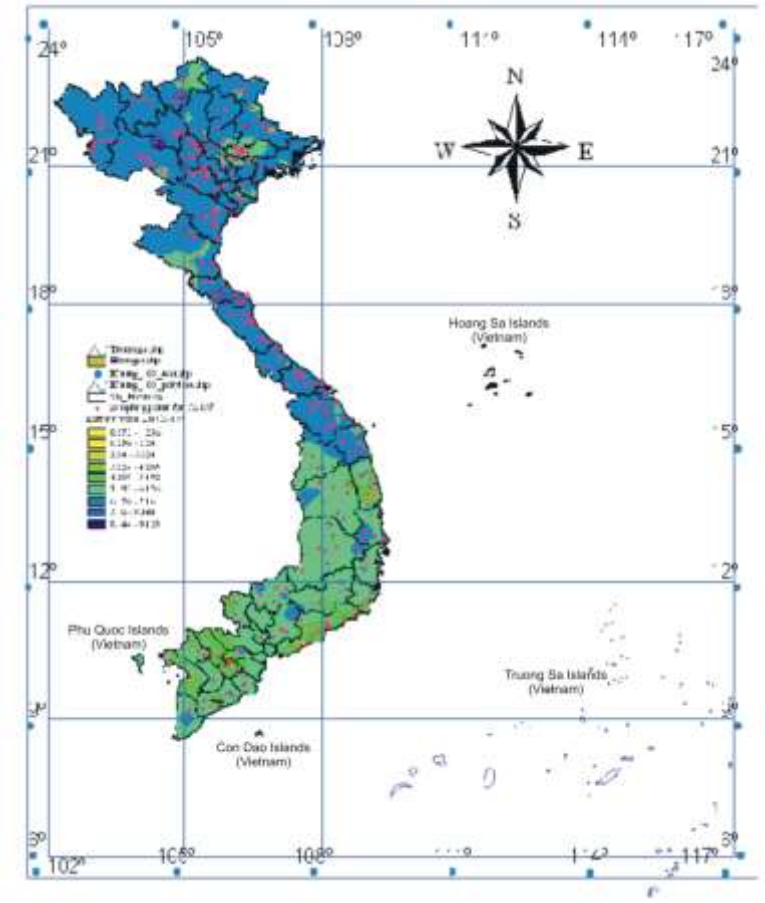

Figure 1: Map showing sampling sites for soil to determine the ^{137}Cs inventory over the terrestrial territory of Viet Nam. The map shows also the distribution of the ^{137}Cs inventory. The inventory increases from yellow to blue colour [5].

$$Ln(I) = (3.53 \pm 0.09) + (0.092 \pm 0.004)L + (0.62 \pm 0.03)AR + \varepsilon \quad (1)$$

where Ln is natural logarithm, I is the ^{137}Cs inventory, L is latitude (^{o}N), AR is annual rainfall (mm) and ε is residue that not be explained by the model. It is not uncertainty of the measurements. This could be due to erosion or sedimentation that caused loss or build-up of the radio-isotope [5].

III.2. The ^{90}Sr and $^{239+240}$Pu inventory in the terrestrial territory of Viet Nam

The ^{90}Sr and $^{239+240}$Pu inventory was studied for cultivated soils along with ^{137}Cs. The purpose of this study was to elucidate whether the inventories of the three nuclides have a relationship between each other. The idea is come from the point of view that ^{137}Cs, ^{90}Sr and $^{239+240}$Pu have the same origin, they are fission products of nuclear reactors, and the results of the study could give more details about the fall-out of radionuclides from the Chernobyl nuclear power plant accident in 1986 [6].

Based on the results obtained, Nguyen Hao Quang and his co-workers concluded that the inventory of ^{137}Cs, ^{90}Sr and $^{239+240}$Pu was independent upon the soil properties like pH, texture, CEC et. as well as independent upon the soil depth (0-10 cm, 10-20 cm, 20-30 cm). Despites the

absolute inventories of ^{137}Cs and $^{239+240}Pu$ much varies from site to site, however the ratio [$^{239+240}Pu$] to [^{137}Cs] was not varied much and ranged within 0.0225±0.001 (n = 20).

Unlike plutonium, strontium behaved in the soil environment more mobile. The ratio of [^{137}Cs]/[^{90}Sr] in cultivated soils varied in a wide range, from 2 to 28 with a medium of 9.3 and standard deviation of 2.2. This ratio showed higher than that expected from the fissible yield of the two radio-isotopes in a nuclear reactor of 1.6 [19]. An explanation for too high ratio between [^{137}Cs] and [^{90}Sr] in soils could be the fact that in the soil environment strontium is more mobile compared to caesium and it was more readily to wash out. One of conclusion of Hao Quang's work was that to determine exact amount of radioactive strontium deposited in the soil one should apply radiochemical separation of ^{90}Sr first, then measure its activity using beta activity counting method.

III.3. Radioactivity of ^{226}Ra, ^{232}Th and ^{40}K in soils

Results of the measurement for ^{226}Ra, ^{232}Th and ^{40}K in 528 soil samples collected over the territory of Viet Nam was conducted along with those for ^{137}Cs [4, 7]. It was revealed that the range of average activity of the three nuclides in the surface soils was (± SD):

^{226}Ra: 42.77 ± 18.15 (Bq kg^{-1}), range: 15.02-121.58 Bq kg^{-1}

^{232}Th: 59.84 ± 19.81 (Bq kg^{-1}), range: 16.07-129.16 Bq kg^{-1}

^{40}K: 411.93 ± 230.69 (Bq kg^{-1}), range: 10.47-1085.39 Bq kg^{-1}

Based on the activities of the three nuclides in the surface soils, Ngo Quang Huy and his co-workers [7] has estimated the outdoor absorption dose rate (OADR) from gamma radiation as high as 71.72 ± 24.72 nGy h^{-1} and the OADR corrected for the population weighted (PW OADR) to be 66.70 nGy h^{-1}. The authors of this paper [7] have also estimated the external annual public dose of gamma radiation from the surface soil and it is 0.54 mSv y^{-1}, in which 0.458 mS y^{-1} is the indoor dose rate and 0.082 mS y^{-1} is outdoor dose rate. These figures are around 10% higher than the annual dose rate for the public that was reporteded in the [19] as of 0.41 mSv y^{-1} and 0.07 mSv y^{-1}, respectively.

Recently, Nguyen Quang Long and his co-workers has conducted a survey for the ^{226}Ra, ^{232}Th and ^{40}K in soils from the Ha Noi city area [20]. However, the results of this investigation were transferred to the Dept of Science and Technology of Ha Noi for the use to construct a map of spatial distribution of the three radio-nuclides within the city. The results were not processed yet to estimate the public annual gamma dose rate to the population on the city.

III.4. Concentration of ^{222}Rn in indoor air in the Ha Noi and Ha Long Bay areas

Concentration of ^{222}Rn in indoor air in the Ha Noi area was determined by Nguyen Hao Quang and his co-workers during 1994-1995 [1]. The survey was conducted in two types of houses, one was constructed by bricks and another by precast concrete. The results showed that the ^{222}Rn concentration in indoor air for both types of houses was in the same range and be (35 ± 15) Bq m^{-3} in the dry and (30 ± 10) Bq m^{-3} in the rainy seasons. Additionally, its was revealed that the ^{222}Rn concentration in door air at the ground floor was not significantly (p = 0.05) different from those at higher floor, e.g. at the fifth floor. These results was explained by the living behaviours of the city's population, they prefer to open the doors to get fresh air and this led to the homogeneity of the ^{222}Rn concentration in the air throughout the buildings.

With the use of the Urban diffusion cup for the monitoring campaign one can estimate the annual effective dose to public caused by the inhalation of air containing ^{222}Rn, because as it was shown by Urban [15] that from the total alpha activity derived from the numbers of tracks in the detector only 7% could be thoron. So, based on the ^{222}Rn concentration in indoor air derived from the paper of Nguyen Hao Quang and his co-worker [20] with using appropriate coefficients to convert the activity unit into dose unit [18] one can estimate the annual effective dose from ^{222}Rn in indoor air to the public in the Ha Noi area as high as 1.10 mSv y^{-1}. This figure is in the range of the public dose reporteded in [18] or the public dose in India of 1.14 mSv y^{-1} [21, 22].

III.5. Radioactivity in construction materials

Radioactivity of ^{226}Ra, ^{232}Th và ^{40}K in 11 different kinds of construction materials available on the markets throughout Viet Nam was determined [8]. The materials include brick, import and domestic tiles, import and domestic granite, marbles, cement, sand, gravel, gypsum. Based on the average radioactivities of the three nuclides in the materials, the authors of the works have estimated the effective dose rate from gamma radiation to public. The figure ranged from 0.01 to 1.26 mSv y^{-1}. The highest dose rate comes from the import granite and the lowest dose rate come from domestic marble.

III.6. Radioactivity in food

Data of the radioactity in food were derived from several investigation campaigns conducting at both NRI and INST [11, 23]. Table 2 summarizes the concentration of ^{238}U, ^{232}Th, ^{40}K và ^{137}Cs in food that is the main diet of Vietnamese.

Table 2: Concentration of ^{238}U, ^{232}Th, ^{40}K và ^{137}Cs in main kinds of Vietnamese food.

TT	Food	Concentration, Bq kg^{-1} (ww)			
		^{238}U	^{232}Th	^{40}K	^{137}Cs
01	Rice*	0.137±0.027	0.034±0.007	21.4±1.1	0.094±0.028
		0.002÷0.380	0.002÷0.060	13.0÷35.9	0.002÷0.148
02	Other cereals*	0.123±0.024	0.027±0.005	38.3±1.9	0.240±0.072
		0.040÷0.320	0.020÷0.050	15.8÷153.5	0.002÷0.240
03	Sweet potato	0.099±0.020	0.038±0.008	57.7±2.9	<0.002
		0.002÷0.110	0.011÷0.110	33.9÷80.0	<0.002
04	Vegetables (leaves, flower, fruits)	0.143±0.029	0.130±0.26	76.4±3.8	0.004±0.001
		0.002÷0.373	0.012÷0.429	35.5÷109.5	0.002÷0.004
05	Vegetable (tuber, grain)	0.099±0.020	0.116±0.023	76.0±3.7	0.024±0.007
		0.002÷0.294	0.002÷0.928	32.4÷170.0	0.002÷0.070
06	Fruit	0.122±0.024	0.074±0.015	92.3±4.6	<0.002
		0.002÷0.227	0.002÷0.246	35.7÷142.8	<0.002
07	Meat	0.156±0.031	0.064±0.13	71.9±3.4	0.046±0.014
		0.002÷0.577	0.002÷0.210	41.7÷110.7	0.002÷0.081
08	Milk*	3.11±0.775	0.310±0.062	365.5±18.3	0.943±0.283
		2.300÷4.500	0.002÷0.310	250.9÷496.0	0.002÷1.074
09	Fish	0.368±0.073	0.773±0.170	67.4±3.4	0.063±0.018
		0.002÷0.729	0.002÷3.220	33.2÷94.1	0.002÷0.127
10	Seafood	0.233±0.046	0.239±0.048	39.4±2.0	0.009±0.003
		0.002÷0.559	0.015÷0.702	11.7÷80.5	0.002÷0.015

*) For rice and other cereals and milk the unit is Bq kg^{-1} (dw)

In Table 2 the data given for each commodity comprises the average value of activity of each nuclide with its standard deviation (first row) and its range (second row).

Nguyen Quang Long and his group [11] has surveyed for the concentration of ^{238}U, ^{232}Th, ^{40}K và ^{137}Cs in 130 kinds of Vietnamese food, among other there were 43 samples of rice. The results of this survey showed the average and range of concentration of the 4 nuclides as follows:

^{40}K:	(255.3 ± 226.0) Bq kg^{-1};	(10.4 ÷ 856.6) Bq kg^{-1},
$^{232}Th(^{228}Ac)$:	(1.3 ± 1.6) Bq kg^{-1},	(0.3 ÷ 9.0) Bq kg^{-1},
$^{238}U(^{214}Bi)$:	(1.1 ± 0.7) Bq kg^{-1},	(0.3 ÷ 3.1) Bq kg^{-1},
^{137}Cs:	(0.19 ± 0.07) Bq kg^{-1},	(0.09 ÷ 0.30) Bq kg-1
Gross gamma activity:	(369.6 ± 329.8) Bq kg^{-1},	(25.7 ÷ 2029.1) Bq kg^{-1},
Gross beta activity:	(110.9 ± 124.4) Bq.kg^{-1},	(2.1 ÷ 519.3) Bq kg^{-1},
Gross alpha activity:	(31.9 ± 60.8) Bq kg^{-1},	(LOD÷306,7) Bq kg^{-1},

LOD of the radioactivity measurement facilities is 0.01 Bq kg^{-1}.

III.7. Tritium concentration in the precipitation and water from the Red River in Ha Noi

Monitoring for tritium concentration in precipitation and water from the Red River has been initiated since 2002. This activity mostly deals with hydrogeological studies in Viet Nam and now this monitoring station is one of the members of the Global Network for Isotopes in Precipitation (GNIP) of IAEA. Precipitation and river's water were collected consecutively on the monthly basis and results of the monitoring campaign are shown in Fig.2 and Fig.3.

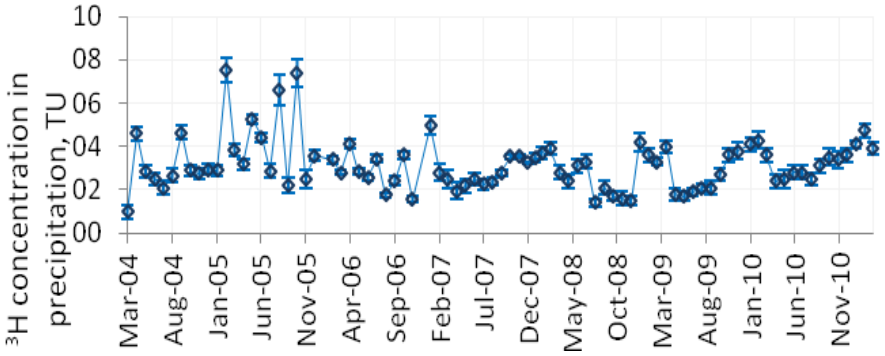

Figure 2: Tritium concentration in precipitation at the Ha No area (sampling site: at a roof of the INST premises). TU= tirtium unit, 1TU = 0.118 Bq L^{-1}[10].

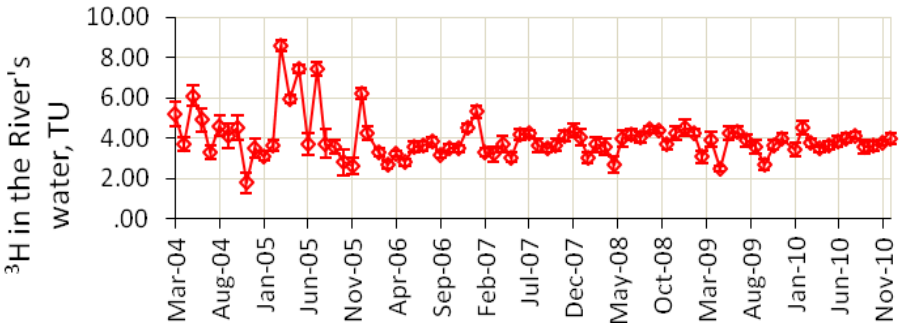

Figure 3: Tritium concentration in water from the Red River (in Ha Noi) (sampling site:). Samples were taken at a depth of 0.5 m and 50 m apart from the river bank [10].

The tritium concentration in water from the Red River in both dry and rainy seasons appears to be significant higher than that in the precipitation ($p = 10^{-6}$). This is due to the fact that the river is originated from the Himalayas where tritium in snow is still high, e.g. hot water from springs flowing from Himalayas to Nepal contains very high concentration of tritium, up to 68 TU [24] Ranjit, 2010). The results of the tritium monitoring activity in Ha Noi and other parts of the country are very useful for the evaluation of resident time of groundwater. This kind of hydrogeological study is important in respect of the elucidation for the vulnerability of groundwater to anthropogenic contamination (see e.g. [25, 26]).

III.8. Study of the impact of the Fukushima nuclear power plant accident to Viet Nam

Air pollution is consecutively monitored since many years ago by the staff of the INST in Ha Noi and the staff of the NRI in Da Lat and HCM city. During this monitoring activity it was observed that two weeks after the Fukushima nuclear power plant accident occurred, radio-isotopes of ^{134}Cs, ^{137}Cs and ^{131}I was detected in the air at the three air pollution stations in Viet Nam. Fig.4 shows the change of ^{134}Cs, ^{137}Cs and ^{131}I activity in air at the three monitoring stations [27].

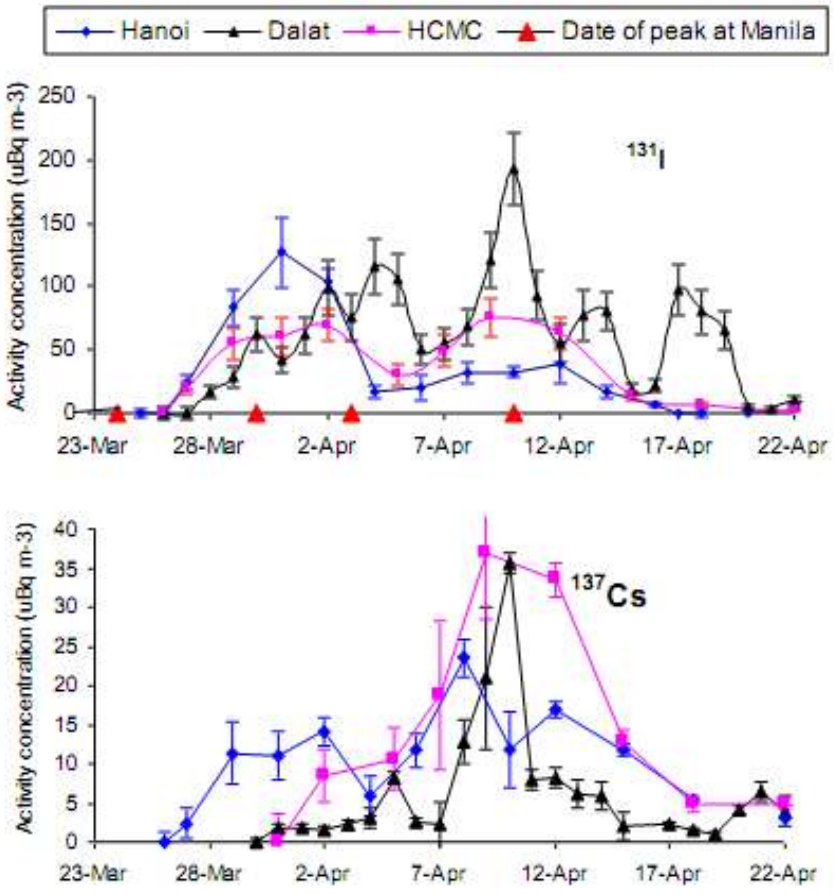

Figure 4: Radioactivity of ^{131}I (above) and ^{137}Cs (below) in the air at three air monitoring stations in Ha Noi, Da Lat and HCM city. The days observed maximum activity of the isotopes in the Manila station of the CTBTO is marked by red triangles in the abscissa [28].

The ^{134}Cs/^{137}Cs ratio was 0.86 ± 0.12; 0.93 ± 0.14 and 0.76 ± 0.14 at Đa Lat, HCM and Ha Noi, respectively. These results are consistent with those reported by the CTBTO that in Manila the ratio was 0.80± 0.17, in Ulaanbaatar it was 0.78 ± 0.20 and in Kuala Lampur it was 0.99 ± 0.09.

IV. CONCLUSIONS AND SUGGESTIONS

Environmental radioactivity studies have been one of most fruitful activities of the VAEI since the first days of its foundation in 1976. The studies cover all the environment and are conducted systematically, however, many results are still in raw data not processed yet to publish. On the other hand, ultimate results of radioactivity monitoring should be addressed to the impact assessment of the radioactive environment to public of the country. This requires to derive the annual effective dose to the public. It is particular important this time when nuclear power plants are going to construct in Viet Nam.

It is advised to conduct investigation on other dose components, namely medical dose, cosmic dose, occupational dose, dose caused by radon inhalation, committed dose in order to estimate the annual effective to public before the nuclear plants start to construct and put into operation.

REFERENCES

[1] Nguyễn Hào Quang, Trần Thanh Minh, Nguyễn Quang Long, Ngô Tiến Phần, Trần Tuyết Mai, Trương Quang Chinh, Đặng Thanh Lương, Phan Tường Vân, Nguyễn Phương Dung, Phạm Quang Điện. Đánh giá tính trạng phóng xạ trong vật liệu xây dựng ở Hà Nội. Tuyển tập báo cáo khoa học. Hội nghị Vật lý và kỹ thuật hạt nhân lần thứ nhất. Hội Vật lý và Viện Năng lượng nguyên tử Việt Nam, tr.303-307, 1996a, Hà Nội, 1996.

[2] Nguyễn Hào Quang, Ngô Tiến Phần, Nguyễn Quang Long, Trần Tuyết Mai, Trương Quang Chinh, 1996b. Xây dựng thiết bị chuẩn nồng độ radon trong không khí. Tuyển tập báo cáo khoa học. Hội nghị Vật lý và kỹ thuật hạt nhân lần thứ nhất. Hội Vật lý và Viện Năng lượng nguyên tử Việt Nam, Hà Nội, tr.340-345, 1996,.

[3] Bùi Văn Hưng, Trần Thanh Minh, Nguyễn Quang Long, Trần Tuyết Mai và Phạm Quang Điện. Điều tra mức phóng xạ tại các mỏ khai thác sa khoáng ven biển miền Trung. Tuyển tập báo cáo khoa học. Hội nghị Vật lý và kỹ thuật hạt nhân lần thứ nhất. Hội Vật lý và Viện Năng lượng nguyên tử Việt Nam, Hà Nội, tr.293-301, 1996.

[4] Huỳnh Thượng Hiệp, Phạm Duy Hiển, Nguyễn Hào Quang, Nguyễn Quang Long, Vương Thu Bắc, Nguyễn Thanh Bình, Nguyễn Trọng Ngọ, Phan Sơn Hải, Ngô Quang Huy, 1999. Điều tra sự nhiễm bẩn phóng xạ nhân tạo do các hoạt động hạt nhân và sự cố hạt nhân trên thế giới gây ra trên lãnh thổ Việt Nam. Báo cáo dự án điều tra cơ bản năm 1997-1999. Hà Nội, 1999.

[5] Pham Duy Hien, Huynh Thuong Hiep, Nguyen Hao Quang, Ngo Quang Huy, Nguyen Thanh Binh, Phan Son Hai, Nguyen Quang Long, Vuong Thu Bac. Derivation of ^{137}Cs deposition density from measurements of ^{137}Cs inventories in undisturbed soils. J. Environ. Radioact., 62: 295-303. 2002.

[6] Nguyen Hào Quang, Nguyen Quang Long, Dinh Bich Lieu, Tran Tuyet Mai, Nguyen Thi Ha, Dang Duc Nhan, and Pham Duy Hien. $^{239+240}$Pu, ^{90}Sr and ^{137}Cs inventories in surface soil of Viet Nam. J. Environ. Radioact., 75: 329-337, 2004.

[7] Ngo Quang Huy, Pham Duy Hien, Tran Van Luyen, Dao Van Hoang, Huynh Thuong Hiep, Nguyen Hao Quang, Nguyen Quang Long, Dang Duc Nhan, Nguyen Thanh Binh, Phan Son Hai, and Nguyen Trong Ngo. Natural radioactivity and external dose assessment of surface soils in Vietnam. Radiat. Prot. Dosim., 151: 522-531, 2012.

[8] Lê Như Siêu, Nguyễn Thanh Bình, Trương Ý, Nguyễn Trọng Ngọ, Nguyễn Thị Linh, Nguyễn Văn Phúc, Nguyễn Đình Tùng, Nguyễn Kim Thành, Trần Đình Khoa, Nguyễn Thị Mùi. Hoạt độ phóng xạ tự nhiên trong các loại vật liệu xây dựng chủ yếu ở Việt Nam. Báo cáo tổng kết đề tài cấp bộ mã số DT.07/07-09/NLNT, Đà Lạt, 2010.

[9] Nguyen Trong Ngo, Nguyen Thanh Binh, Nguyen Van Phuc, Le Nhu Sieu, Truong Y, Mai Thi Huong, Nguyen Thi Linh, Nguyen Mong Sinh, Phan Son Hai, Le Ngoc Chung, Dang Duc Nhan, Nguyen Quang Long, Nguyen Hao Quang và Tran Tuyet Mai. Radionuclides concentration in marine nvironmental samples along the coast of Viet Nam. Jurnal Sains Nuklear Malaysia, 21/2: 12-20, 2009.

[10] Dang Duc Nhan, Dinh Thi Bich Lieu, Vo Thi Anh, Ha Lan Anh va Nguyen Thi Thai, 2010. Concentration of tritium in the precipitation and water from the Red River (North Viet Nam) during the period of time 2001-2010. Available on the http://www.iaea.org/water

[11] Nguyễn Quang Long, Trần Tuyết Mai, Dương Văn Thắng, Đoàn Thị Hậu, Hà lan Anh, 2009. Điều tra độ phóng xạ trong một số mặt hàng lương thực, thực phẩm xuất nhập khẩu chủ yếu nhằm tiến tới xây dựng cơ sở dữ liệu về độ phóng xạ trong lương thực, thực phẩm Việt Nam. Báo cáo tổng kết đề tài cấp bộ, mã số: 11/09/NLNT; năm 2006-2007.

[12] Dang Duc Nhan, Carvalho F.P., Oliveira J. M, N. Q. Long, D. D. Thuan, and Malta M., 2013. Coal mining and radioactivity in the coastal area of Ha Long Bay, North Viet Nam. 2nd Intl. Conf. on "Environ. Poll., Restn, and Manag.". SEATAC Asia Pacific, Loyola University Chicago, and Ha Noi Univ. of Nat. Sci., Ha Noi, Mar 4-8, 2013.

[13] Villa, M. and Manjon, G. Low-level measurements of tritium in water. Applied Radiation and Isotopes. 61/2-3, 319-323, 2004.

[14] Plastino, W., Chereji, I., Cuna, S., Kaihola, L., de Felice, P., Lupsa, N., Balas, G., Mirel, V., Berdea, P., Baciu, C., Tritium in water electrolytic enrichment and liquid scintillation counting. Radiat. Meas. 42/1, 68-73, 2007.

[15] Urban M., Piesch E, Low level environmental radon dosimetry with a passive track etch detector device. Radiat. Prot. Dosim., 1(2): 97-109, 1981.

[16] Dang Duc Nhan, Carvalho P. Fernando, Nguyen Thi Thu Ha, Nguyen Quang Long, Dao Dinh Thuan, and Heloisa Fonseca. Radon (^{222}Rn) concentration in indoor air near the coal mining area of Nui Beo, North of Viet Nam. J. Environ. Radioact., 110: 98-103, 2012.

[17] Ngo Quang Huy and Tran Van Luyen. Study on external exposure dose from terrestrial radioactivity in southern Viet Nam. Radiat. Prot. Dosim. 118/3: 331-336, 2006.

[18] Ngo Quang Huy, Trinh Thi Bich, and Nguyen Van Suc. Determination of uranium and thorium isotopes in soil samples by co-precipitation. J. Radioanal. Nucl. Chem., 269/1: 129-133, 2006.

[19] UN SCEAR. Report of the United Nations Scientific Committee on the effects of atomic radiation to the General Assembly. Annex B: Exposures from natural radiation sources. United Nations, New York, 2000.

[20] Nguyễn Quang Long, Trần Tuyết Mai, Dương Văn Thắng, Doàn Thị Hậu. Báo cáo kết quả quan trắc hàm lượng ^{226}Ra, ^{232}Th và ^{40}K trong đất khu vực Hà Nội. Đề tài cấp thành phố Hà Nội, 2004.

[21] Sathish L. A., Nagaraja K., and Ramachandran T. V., Indoor ^{222}Rn and ^{220}Rn concentrations and doses in Bangalore, India. Radiat. Prot. Dosim., 151/2: 344-353, 2012.

[22] Khan H. A., Qureshi I. E, Tufail M., Passive dosimetry of radon and its daughters using solid state nuclear track detectors (SSNTDs). Radiat. Prot. Dosim., 46: 149-170,1993.

[23] Nguyễn Trọng Ngọ, Nguyễn Thanh Bình, Nguyễn Giằng, 2005. Thống kê, điều tra phóng xạ và các nguyên tố độc hại trong một số loại lương thực thực phẩm chủ yếu của Việt Nam". Báo cáo tổng kết đề tài cấp Bộ năm 2004-2005. Viện NC HN Đà Lạt, 5-2005.

[24] Ranjit, M., 2010. Preliminary evaluation of geothermal reservoir in central Nepal using geochemical data. Proc. World Geothermal Congress 2010. Bali, Indonesia, 2010.

[25] Norrman J., Sparrenbom C. J., Berg M., Dang Duc Nhan, Pham Quy Nhan, Emma Sigvardsson, David Baric, Johanna Moreskog, Peter Harms-Ringdahl, Nguyen Van Hoan, Håkan Rosqvist, Gunnar Jacks. Arsenic mobilisation in a new well-field along the Red River, Nam Du, Hanoi. *Appl. Geochem., 23:3127-3142*,2008.

[26] Dang Duc Nhan, Nguyen Van Lam, Ha Chu Ha Long, Dao Dinh Thuan, Dang Anh Minh, Vo Thi Anh, 2011. Hydrological characteristics of karstic groundwater in the Northeast Viet Nam as studied by isotopic techniques. *J. Environ. Earth Sci.* DOI 10.1007/s12665-011-0943-x. Published on line 30 November 2011.

[27] Nguyen Quang Long, Truong Y, Pham Duy Hien, Nguyen Thanh Binh, Le Nhu Sieu, Trinh Van Giap, Ngo Tien Phan, Atrmospheric radionuclides from the Fukushima Dai-ichi nuclear reactor accident observed in Viet Nam. J. Environ. Radioact., 111: 53-58, 2012.