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Original Article

Assessment of Natural Radioactivity Levels and Estimation of Radiation Dose by Inhalation Environmental Air Samples from Hanoi

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Abstract: This study investigates radioactivity in the ambient air for a district in Hanoi capital, Vietnam, in the period 2015 - 2018. Aerosol samples are collected by Taifful (Тайфун, Russia) equipment, using ФПП 15-3p filter, to determine the ^{40}K, ^{238}U, and ^{232}Th concentration by gamma spectrometry method and following the STI/DOC 010/295 TRS 295-IAEA-1989 guidelines. While the Radon concentration level is directly determined by the Pylon portable radiation monitors (model AB-5R). Results show that the ^{40}K isotopes, ^{238}U, ^{232}Th, and Radon concentration levels are 40.43 ± 8.88 µBq.m^{-3}, 4.39 ± 0.47 µBq.m^{-3}, 2.01 ± 0.13 µBq.m^{-3}, and 20.63 ± 1.06 Bq.m^{-3} respectively. The total annual effective dose for people of different age groups caused by radioactive isotopes ranges from 0.73 mSv.year^{-1} to 0.84 mSv.year^{-1}. Those levels are lower than the current national standards and regulations of many cities in the world. The study can be used as an initial reference for the recommendation of regulation development for Vietnam in near future.

Keywords: Radioactive, Radiation dose, Ambient air, Vietnam.

1. Introduction

Natural radiation occurs mainly from radionuclides and has different levels in soil, rock, building materials and water. These radioactive nuclei are widely distributed in the Earth's crust, atmosphere and extraterrestrial

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sources arising from cosmic ray bombardment [1, 2]. These natural background radiations can vary significantly depending on geological and environmental factors. Significant portions of background radiation arise from radionuclides such as ^{40}K, ^{238}U, ^{232}Th, Radon and Thoron and their isotopes are present in indoor and outdoor air [1-8].

Humans are frequently exposed to much ionizing radiation from both natural and artificial radioactive sources [1, 7, 9]. Of the total radiation exposure, nearly 85 - 95% are from natural sources and only about 3% are from artificial radioactive sources [1, 3-7]. Natural radiation comes from four main sources: the radioactive nucleus in the human and animal's body, the radiation in the atmosphere, the radiation originating from the Earth and the cosmic radiation [1, 3, 9-12]. Original radiation (derived from the Earth) consists of two natural radioactive groups, mainly Uranium, Thorium and some other radioactive isotopes (^{40}K, ^{50}V, ^{87}Rb, ^{155}I, ^{138}La, ^{147}Sm, ^{176}Lu). Radon in the atmosphere has three important isotopes: ^{220}Rn (also known as Thoron, whose half-life is 55.6 seconds) stays in the ^{232}Th sequence; ^{222}Rn (also known as Radon, has a half-life of 3.82 days) stay in the ^{238}U range, and ^{219}Rn (with a half-life of 3.96 seconds) [1, 3, 9-12]. The most stable of the isotopes is ^{222}Rn, which is universally and henceforth here referred to simply as *"radon"* or *"radon gas"* [6]. Due to the short half-life, ^{220}Rn and ^{219}Rn cannot move far [7, 12]. However, the decay product of ^{222}Rn and ^{220}Rn, ^{212}Pb, has a fairly long half-life (3.82 days and 10.6 hours, respectively) that can travel long distances and attach to secondary aerosols [1]. Radon is a gas, so it has the ability to move away and decay to create products ^{218}Po (half-life of 3.05 minutes), ^{214}Pb (half-life of 26.8 minutes), and ^{214}Bi (half-life of 19.9 minutes) and ^{214}Po (164 µs half-life), then produce long isotopes ^{210}Pb (21.3 years) [10]. Among natural sources of radiation, Radon gives the highest equivalent dose [1]. On average, in natural conditions, the original radiation causing the radiation dose accounts for over 5/6 of the total radiation dose of natural radiation. Radon is a major component of natural radioactive contamination in the air layer near the ground [1-3, 9, 11] while the rest is the projection dose of cosmic radiation. Currently, radioactive substances have many applications for life and economy, however, they also have certain effects on human health. According to the United States Environmental Protection Agency (US EPA) and studies by the World Health Organization (WHO), radon is the second cause of lung cancer, which ranked only after smoking causes [1, 6]. Regarding the viewpoint of protecting health and radiation, many countries have conducted radon surveys nationwide and studied control cases of risk of lung cancer [1, 4-8]. Therefore, Vietnam also needs to raise the issue of research, assessment of radioactive background levels, monitoring the evolution of radioactive concentration due to the impact of nature and society on the whole territory as well as on each locality-specific table. In previous studies in Vietnam, most of the research focused on radioactive concentration in water and soil. In the air, studies focus on radioactive substances such as ^{131}I, ^{134}Cs, and ^{137}Cs [2] or indoor air [12]. There are also some studies in Ho Chi Minh city, which constructed a process to measurement the indoor radon concentration [13], radon distribution and diffusion in soil microenvironment [14, 15]. The study, observation, assessment and warning of environmental pollution by radioactive agents is very necessary and urgent for environmental management, directly organizing and implementing solutions to minimize damage to human health and socio-economic development in each region, including Hanoi. However, research projects on radioactive background in the air environment in Hanoi are limited, these topics also have not been studied in-depth to assess the projection dose of these radioisotopes in the air and evaluate their effects on humans.

Based on this background, this study collected data on the activity of radioactive isotopes ^{40}K, ^{238}U and ^{232}Th and Radon in the ambient air environment site (longitude: 105° 80'89.94" E; latitude: 21° 05' 53.80" N), located at Center for Technology Environmental Treatment (CTET), Tay Ho District, Hanoi, Vietnam over the period from 2015 to 2018. The objective of the study is to assess the current status of radiation background level in the air environment, determine the dose rate for the community in the study area and consider the impact of radioactive nuclei in air environment to human health.

2. Methodology

Aerosol samples were collected by Taifful machine (Тайфун, Russia) with ФПП 15-3p filter. Suction flow rate V_i = 1.000 $m^3.h^{-1}$ with time for monitoring was 4 - 6 consecutive days. Thus, the total volume of air going through each filter was around V_t = 100.000 m^3. Collected samples, filters, were stored in sealed containers and transported to the laboratory for processing and analysis. The radiative concentration of ^{40}K, ^{238}U, and ^{232}Th in those aerosol samples were determined by gamma spectrometry method following the STI/DOC 010/295 TRS 295-IAEA-1989 guidelines [16]. The detector used in the present work is a coaxial P-type HPGe detector model, PGC-1518, manufactured by Canberra (USA) used for low-background gamma spectrometry for environmental radioactivity. Radon concentration level is determined by the Pylon portable radiation monitors (model: AB-5R) manufactured by Pylon Electronics, Canada. The equipment was calibrated at Center for Environmental Radiation Monitoring and Impact Assessment, Institute for Nuclear Science and Technology to ensure the required standards before sampling.

The radioactive isotope concentration (^{40}K, ^{238}U and ^{232}Th and Radon) in the air was analyzed and calculated the inhalation annual effective radiation dose follow the equation (1) [7]:

$$E_i = A_i * B * d_i * [1 - F_0(1 + F_r)] \quad (1)$$

where E_i is the effective dose of radioactive i in the surrounding air ($Bq.m^{-3}$); A_i is the activity of radioactive i in the surrounding air ($Bq.m^{-3}$); B is the inhalation rate ($m^3.year^{-1}$); F_0 is the indoor occupancy factor; F_r which is the ratio of indoor and outdoor air concentrations was assigned a value of 0.3 for all countries [7]; and d_i is the committed dose per unit intake from inhalation or effective dose factor ($\mu Sv.Bq^{-1}$).

The dose factor (d_i) is defined as the dose for the whole body (the effective dose) due to the absorption of one μBq of radioactive material into the body [8]. The annual effective dose (E_i) influenced by respiratory activity was calculated for six age groups, including age groups 3 months, 1, 5, 10, 15 years and adults [6]. The dose factors (d_i), inhalation rate (B) and indoor occupancy factor (F_0) for each age group above are proposed by Eckerman et al. (2012) [6] and summarized in Table 1.

To determine the radiation dose of radon and its decay products, we measured the concentration of Radon in the environment and determine the F-balancing factor between Radon and its decay products. This factor depends on environmental parameters, such as temperature, humidity, ventilation, and is usually in the range of 0.5 - 0.7 [7]. According to a report from UNSCEAR (2000) [7], the value F for indoor and outdoor was assumed to be 0.4 and 0.6 respectively to determine the dose caused by the general public. The annual effective outdoor dose due to radon exposure is calculated using the equation (2) from UNSCEAR (2000) [7]:

$$OAED = C_{Rn} * F * DCF * OF * 8760 \quad (2)$$

where C_{Rn} is the radon concentration in the air ($Bq.m^{-3}$), F is the equilibrium factor of radon and the decay products, DCF is the conversion factor from the radiation dose to radon dose. UNSCEAR (2000) suggested that the DCF factor was assumed to be 9 nSv ($Bq.m^{-3}.h^{-1}$) [7]. For assessing Radon projection doses and its decay products over the long term, the outdoor occupancy factor *(OF)* was set to be 0.2 [7].

Table 1. Dose factor *(d_i)*, inhalation capacity *(B)* and indoor occupancy factor *(F_0)*

Age group / Parameter		3 months	1 year	5 years	10 years	15 years		Adult	
						Male	*Female*	*Male*	*Female*
B		2.8	5.1	8.8	15.2	20.1	15.8	22.2	18.2
F_0		1.00	0.96	0.88	0.88	0.88	0.92	0.92	0.92
d_i	^{40}K	0.024	0.017	0.0075	0.0045	0.0025		0.0021	
	^{238}U	1.9	1.3	0.82	0.73	0.74		0.50	
	^{232}Th	230	220	160	130	120		110	

3. Results and Discussion

3.1. Radioactivity Concentration of ^{40}K, ^{238}U, ^{232}Th and Radon

The activity of isotopes ^{40}K, ^{238}U, and ^{232}Th in the air environment in the sampling site over the period 2015 - 2018 is shown in Figure 1. The values of ^{40}K, ^{238}U, and ^{232}Th's activity observed in CTET were 40.43 ± 8.88 µBq.m^{-3}, 4.39 ± 0.47 µBq.m^{-3}, 2.01 ± 0.13 µBq.m^{-3} respectively. The radioactivity of ^{40}K and ^{238}U in 2018 was higher than in the period 2015 - 2017, while the activity of ^{232}Th in 2018 was higher than in 2015-2016 but lower than in 2017 (Figure 1b). Radioactive activity levels of ^{238}U and ^{232}Th (values in the range of 25% - 75%) are higher than ^{40}K. This is probably due to the ^{238}U and ^{232}Th radioisotopes associated with the decay from natural sources of radon [12].

The variation of Radon concentration in the air environment in CTET observed from 2015 to 2018 is shown in Fig. 2. Radon concentration is about 20.63 ± 1.06 Bq.m^{-3}, where the highest peak was in the measurement session of Oct. 2018 (22.48 Bq·m^{-3}), the lowest Radon concentration was measured in the measurement session of Aug. 2015 (19.23 Bq·m^{-3}). This radon concentration is much lower than the result (46 ± 26 Bq·m^{-3}) found in houses in the area near the Nui Beo coal mine (Quang Ninh, Vietnam) [12].

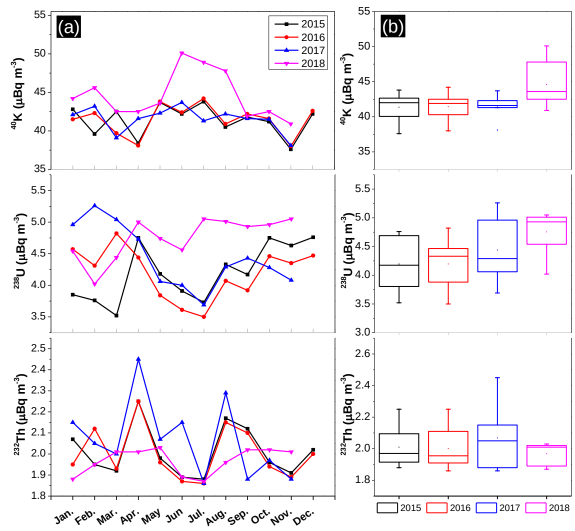

Figure 1. Radioactivity concentration (a) and statistical processing (b) radioisotope activity (^{40}K, ^{238}U and ^{232}Th) in the air in CTET, period 2015 - 2018.

Radon concentration tends to be high in the first months of the year (Feb. - Apr.), then decreases gradually in the middle months of the year (Jun. - Aug.) and increases again in the last months of the year (Oct. - Dec.) (Figure 2a). The average Radon concentration in 2015 and 2016 have similar values, but very low in 2017 and tends to increase slightly in 2018 (Figure 2b). In 2017, although the average value of Radon concentration in the air was low, there were times when the measurement had a high standard deviation. This shows that the instantaneous radiation source has a certain influence on the measurement results. In addition, due to the influence of some natural factors affecting the decay of Radon into radioactive isotopes ^{238}U and ^{232}Th, this activity has a higher volatility than other years as above detect.

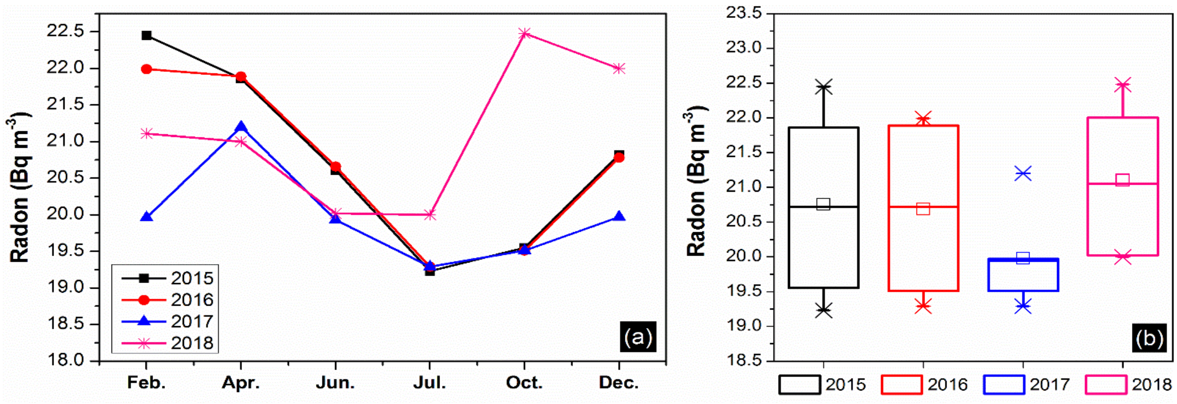

Figure 2. Variation (a) and statistical processing (b) Radon concentration in the air in CTET, period 2015 – 2018.

3.2. Effective Dose of Radioisotope (^{40}K, ^{238}U and ^{232}Th, Radon) in the Air

The annual effective dose of ^{40}K, ^{238}U, and ^{232}Th are calculated by using (eq. 1). Overall, the annual effective dose of ^{40}K highly affects the age group from 1-year-old (0.42 nSv.year^{-1}) to 10 years old (0.39 nSv.year^{-1}) while the effective dose of ^{238}U and ^{232}Th tends to increase for ages 5 - 10 years of age. The total effective dose for 3-month-age children is 144.48 nSv·year^{-1} while for adults reached 528.04 nSv·year^{-1} to 644.09 nSv·year^{-1}. This increase is mainly due to the increase in inhalation capacity that leads to the annual total effective dose increases with age group. At the same time, ^{232}Th has the highest influence on the total annual effective dose for all age groups for both men and women. Although the total effective dose for females after 10 years of age tends to decrease, it continues to increase until age 15 in the case of men (Figure 3a).

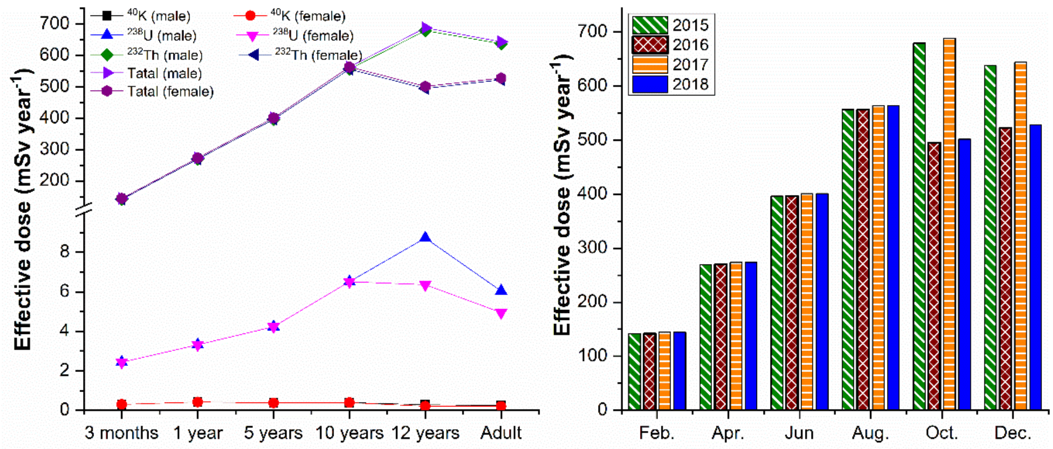

Figure 3. Effective dose of radioactive substances in the air by gender (a); and by year (b) in CTET, period 2015 – 2018.

The annual effective dose for people of different age groups in CTET is caused by radioactive isotopes from 0.2 nSv·year^{-1} to 0.39 nSv·year^{-1} for ^{40}K isotopes; from 2.44 nSv·year^{-1} to 8.73 nSv·year^{-1} for the ^{238}U isotope; from 141.74 nSv·year^{-1} to 679.51 nSv·year^{-1} for the ^{232}Th isotope; 0.2 mSv·year^{-1} for outdoor radon (calculated based on radioactive monitoring data in 2018, in Figure 3b). The results of calculating the dose rate of natural radiation background in outdoor air environment and radon in CTET are presented in Table 2.

In Vietnam, the Ministry of Science and Technology (MOST) has issued a standard (TCVN 6866: 2001) which stipulates that the annual radiation dose to the public is 1 mSv·year^{-1} for 5 consecutive years but no year is greater than 5 mSv·year^{-1}; The equivalent dose for eye lenses should not exceed 15 mSv·year^{-1}, for limbs or skin should not exceed 50 mSv·year^{-1}. These limits include both internal and external irradiation doses, excluding the natural background [17]. At the same time, TCVN 6866: 2001 also stipulates that the occupational radiation dose for all radiation workers must be controlled so that the effective total body dose in a year, averaged over 5 consecutive years, must not exceed 20 mSv; systemic effective dose should not exceed 50 mSv.year^{-1}. The equivalent dose for the eye lens should not exceed 150 mSv.year^{-1} and 500 mSv.year^{-1} for limbs or skin. For workers or students aged 16 to 18 who use radiation sources during research, occupational irradiation must be controlled so that the effective dose in a year should not exceed 6 mSv. The equivalent dose for eye lenses should not exceed 50 mSv·year^{-1}, and limbs or skin should not exceed 150 mSv.year^{-1} [17].

Table 2. Annual effective dose of radioactive isotopes in the air to people in CTET

Age group	3 months	1 years	5 years	10 years	15 years		Adult	
					Male	Female	Male	Female
The inhalation annual effective radiation dose (mSv·year^{-1})	0.35	0.47	0.60	0.76	0.89	0.70	0.84	0.73

Thus, the calculated result shows that the annual effective dose of radioisotopes present in the air environment for people in CTET is lower than the annual effective dose of the world average (1.2 mSv·year^{-1}) [3]. This dose is also much lower than the artificial projection dose that people encounter in everyday life. For example, doses from medical examination and treatment activities such as thoracic tomography, abdominal computed tomography (in health) all produce 7 mSv·time^{-1} [3]; and near the threshold of 1 mSv·year^{-1} according to TCVN 6866: 2001. However, in comparison to Quan (2012) [18], that dose is higher than his data of gamma absorption dose rate in the air in CTET (0.657 mSv.year^{-1}) and the average of Hanoi city (0.66 mSv.year^{-1}) accordingly.

Humans are the highest beings and have complex structures, most closely related to their surroundings than other organisms [9-11]. Therefore, the radiation sensitivity of human is the highest. When inhalation in Radon, Thoron and their decay products, patients often develop tumors in the lungs, causing respiratory diseases [11]. If people do not obey technical regulations, radiation safety and hygiene, when people are affected by a large or consecutive small dose of radiation may lead to radiation sickness. Low doses also reduce the survival time, cause anemia, stimulate the formation of toxic tumors, appear white blood disease, bone marrow failure, skin and mucosal ulcers, and even cause cancer and mutation infused.

4. Conclusions

This study observed and showed activity results of ^{40}K isotopes, ^{238}U, ^{232}Th and Radon concentration in the area of CTET in the period 2015 - 2018, research has corresponding values of 40.43 ± 8.88 µBq.m^{-3}, 4.39 ± 0.47 µBq.m^{-3}, 2.01 ± 0.13 µBq.m^{-3} and 20.63 ± 1.06 µBq.m^{-3} respectively. The total annual effective dose for people of different age groups in CTET caused by radioactive isotopes is from 0.73 mSv.year^{-1} to 0.84 mSv.year^{-1}, lower than those of many cities in the world and current standards and regulations.

Although the total amount of radioactivity and the annual total effective dose of natural radioactive elements in Hanoi are both below the permitted level, it should be paid more attention by the managing authorities because the radiation has a great impact on humans and animals health. Regular monitoring is required to detect and warn about the potential risks caused by radioactive sources. Increasing sources of radioactive pollution lead to risks that may affect human health if incidents occur. Therefore, it is necessary to continue completing the monitoring and warning system, ensuring uniformity and modernity so as to have solutions, and proactively cope with and minimize the impact of radioactive pollution sources on community health.

References

[1] E. Srinivasa, D. Rangaswamy, S. Suresh, K. U. Reddy, J. Sannappa, Measurement of Ambient Gamma Radiation Levels and Radon Concentration in Drinking Water of Koppa and Narasimharajapura Taluks of Chikmagalur district, Karnataka, India, Radiation Protection and Environment, Vol. 41, 2018, pp. 20-25, https://doi.org/10.4103/rpe.RPE_15_18.

[2] N. Q. Long, Y. Truong, P. D. Hien, N. T. Binh, L. Sieu, T. Giap, N. Phan, Atmospheric Radionuclides from the Fukushima Dai-ichi Nuclear Reactor Accident Observed in Vietnam, Journal of Environmental Radioactivity, Vol. 111, 2012, pp. 53-58, https://doi.org/10.1016/j.jenvrad.2011.11.018.

[3] CNSC, Radiation Doses, http://nuclearsafety.gc.ca/eng/resources/radiation/introduction-to-radiation/radiation-doses.cfm/, 2017 (accessed on: April 1st , 2019).

[4] B. Dung, T. Giap, T. Kovács, L. Cuong, N. Quyet, Indoor Radon Concentration Measurements at the Locations of the First Nuclear Power Plants of Vietnam, Romanian Journal of Physics, Vol. 58, 2013, pp. 108-114.

[5] C. H. Han, J. W. Park, Analysis of the Natural Radioactivity Concentrations of the Fine Dust Samples in Jeju Island, Korea and the Annual Effective Radiation Dose By Inhalation, Journal of Radioanalytical and Nuclear Chemistry, Vol. 316, 2018, pp. 1173-1179, https://doi.org/10.1007/s10967-018-5873-6.

[6] K. Eckerman, J. Harrison, H. G. Menzel, C. H. Clement, International Commission on Radiological Protection: Compendium of Dose Coefficients Based on ICRP Publication 60, ICRP Publication 119, Annals of the International Commission on Radiological Protection (ICRP), Vol. 42, 2012, pp. e1-e130, https://doi.org/10.1016/j.icrp.2013.05.003.

[7] UNSCEAR, Sources and Effects of Ionizing Radiation: Sources: United Nations Scientific Committee on the Effects of Atomic Radiation, United Nations Publications, 2000.

[8] J. Valentin, Basic Anatomical and Physiological Data for use in Radiological Protection: Reference Values: ICRP Publication 89, Annals of the International Commission on Radiological Protection, Vol. 32, 2002, pp. 1-277, https://doi.org/10.1016/S0146-6453(03)00002-2.

[9] N. Q. Huy, Safe Ionizing Radiation, Hanoi: Science and Technics Publishing House, 2004 (in Vietnamese).

[10] P. Q. Hung, Radiation Prevention and Nuclear Safety, Hanoi: Vietnam National University Press, 2002 (in Vietnamese).

[11] N. T. K. Ngan, L. Hung, Radioactive Biology, Hanoi: Vietnam National University Press, 2004 (in Vietnamese).

[12] D. D. Nhan, C. P. Fernando, N. T. T. Ha, N. Q. Long, D. D. Thuan, H. Fonseca, Radon (^{222}Rn) Concentration in Indoor Air Near the Coal Mining Area of Nui Beo, North of Vietnam, Journal of Environmental Radioactivity, Vol. 110, 2012, pp. 98-103, https://doi.org/10.1016/j.jenvrad.2012.02.008.

[13] H. T. To, N. T. Nguyen, H. H. Duong, Construction a Process to Measurement the Indoor Radon Concentration, Science and Technology

Development Journal, Vol. 16, 2013, pp. 53-60, https://doi.org/10.32508/stdj.v16i3.1619.

[14] N. P. T. Huynh, V. N. Ba, L. C. Hao, Soil Radon Gas in Some Soil Types in the Rainy Season in Ho Chi Minh City, Vietnam, Journal of Environmental Radioactivity, Vol. 193, 2018, pp. 27-35, https://doi.org/10.1016/j.jenvrad.2018.08.017.

[15] H. N. P. Thu, N. V. Thang, T. T. H. Loan, N. V. Dong, Natural Radioactivity and Radon Emanation Coefficient in the Soil of Ninh Son Region, Vietnam, Applied Geochemistry, Vol. 104, 2019, pp. 176-183, https://doi.org/10.1016/j.apgeochem.2019.03.019.

[16] MOST, Ministry of Science and Technology: QCVN 10: 2013/BKHCN: National Technical Regulation on National Environmental Radiation Monitoring and Warning Network, 2013 (in Vietnamese).

[17] DSMQ, TCVN 6866 : 2001 (2001): Radiation Protection - Dose Limits for Radiation Workers and Public, Directorate for Standards Metrology and Quality, 2008.

[18] N. D. Quan, Research and Apply GIS to Develop Environmental Radioactive Background Map in the Inner City of Hanoi, Master thesis in Faculty of Environmental Sciences, VNU University of Science, 2012, http://repository.vnu.edu.vn/handle/VNU_123/38188 (accessed on: September 15th, 2019) (in Vietnamese).