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DETERMINATION OF RADON CONCENTRATION BY USING CR-39 TRACK DETECTOR IN BINH PHUOC

Bui Ngoc Ha[1], Nguyen Van Hieu[2], Tran Thuy Duong[1,*] and Nguyen Thi Hoai[1]
[1]*School of Engineering Physics, Hanoi University of Science and Technology*
[2]*Binh Phuoc Science and Technology Center*

Abstract. Natural radiation is one of the important environmental quality indicators, receiving special attention from society because of the effects of radiation on the human body. Radon and its decay daughters are considered the leading cause of lung cancer, especially in environments such as caves, underground mines, and homes with poor air convection. This paper presents the results of surveying radon concentrations in the air at several locations in Binh Phuoc province using CR-39 trace detectors. The results indicate that the indoor radon levels are low, with average values in the range of 5–119 Bq/m^3. Indoor radon surveys show that the distribution of radon concentrations in dwellings is approximately log-normal. Our result will be the basis for assessing the level of radioactive hazards in the environment in Binh Phuoc province and will also add to the data set on radon concentration in Vietnam.

Keywords: Radon, Radiation, CR-39 nuclear trace detector, Environmental Physics

1. Introduction

Radon is emitted by radium in geological faults, fissures, rock formations, soil deposits, building materials, and subterranean water sources. The accumulation and exposure to radon primarily occur within residential dwellings, where individuals often allocate a significant portion of their time engaging in activities such as eating, sleeping, resting, or working. The assessment of radon concentrations in residential and environmental settings holds significant importance for several countries globally due to the association between the inhalation of radon gas and its decay products and the development of radiation-induced illnesses [1]. Based on a survey conducted by the International Commission on Radiological Protection (ICRP), it has been determined that radon gas accounts for approximately 50% of the collective natural radiation dosage to which humans are subjected [2]. The introduction of radon gas into the human body, either through inhalation or ingestion, results in the emission of alpha energy. This energy has the potential to induce DNA damage within the cells of vulnerable organs, notably the lungs and stomach, and therefore, contributes to the development of cancer.

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Contact e-mail address: duong.tranthuy@hust.edu.vn

Hence, it has been established that the presence of naturally occurring radon in residential dwellings is recognized as a known carcinogen for the human lungs, ranking as the second most prominent factor contributing to lung cancer, following cigarette smoking [1-3].

Numerous investigations have been carried out globally to assess the levels of radon concentrations in both indoor and outdoor air. The earliest indoor radon gas survey was conducted in Sweden by Hultqvist in 1956. According to this study, the levels of radon gas in residential buildings in Sweden were elevated [2-4]. During the 1990s, the Czech Republic undertook the construction of a digital map depicting the distribution of indoor radon gas concentrations within its territory, with a scale of 1:200,000 [3]. Certain residences in this area exhibited abnormally elevated levels of radon. Indoor radon gas survey procedures have been undertaken in North America and Europe [3]. The International Commission on Radiological Protection (ICRP) has been engaged in the development of measurement techniques since 1994 [2]. Several investigations have been conducted in Vietnam regarding radon gas. Between 1992 and 2002, the Vietnam Geophysical Division and the Association of Geophysicists carried out a comprehensive urban geological exploration program. As part of this initiative, Radon gas concentrations in the air were monitored at 54 metropolitan sites around the country. The findings indicated that the levels of radon gas in residential buildings varied between 5 and 406 Bq/m^3. Out of the total number of dwellings examined, 13 were found to have radon gas concentrations that exceeded the established standard [5]. Several assessments have also been conducted to assess the present state of radon gas concentrations in residential areas and domestic water sources inside Ho Chi Minh City. The findings indicated that the levels of radon in residential dwellings varied between 4 and 23 Bq/m^3 [6]. In general, research on radon indoors in Vietnam is now in its nascent stages.

Binh Phuoc is a region characterized by a wide range of topographical features and geological formations. The minerals found in Binh Phuoc exhibit a notable abundance and diversity in terms of both type and origin. In the province of Binh Phuoc, a total of 91 mines, ore points, and mineralization spots have been discovered, including 20 distinct mineral kinds that may be classified into four major groups: construction materials, metals, non-metals, and raw materials. The distribution of mineral resources is primarily concentrated in the western region, with a smaller one in the central region. It is the source that can release substantial amounts of radon gas. Hence, this research investigated the levels of radon gas in the atmosphere surrounding many mining sites and various dispersed residential regions throughout the province to evaluate the magnitude of Radon's influence on human beings. This article will present the results of the measurement at 124 distinct places within the province of Binh Phuoc.

2. Content

2.1. Research methods

To determine radon concentration, two methods are used: the instantaneous measurement method and the cumulative measurement method [1-3]. Short-term measurement methods, often using an activated charcoal detector or another type of

detector such as an ionization chamber, can provide the first indication of the average long-term radon concentration in the home. However, diurnal and seasonal variations in radon and indoor air circulation need to be taken into account when making short-term radon measurements. To evaluate the annual average radon concentration within a house or other dwellings, long-term measurements are often preferred. Alpha-track detectors, ionization chambers, and activated carbon detectors are the radon measuring tools that are most frequently used [3]. Alpha track detectors are a popular choice for making long-term radon measurements and are typically deployed over one year. They rely on the use of plastic materials to record the traces of alpha particles emitted from radon and its decay products. These traces can be detected later by immersing the plastic materials into a NaOH or KOH solution, sometimes supplemented with ethanol.

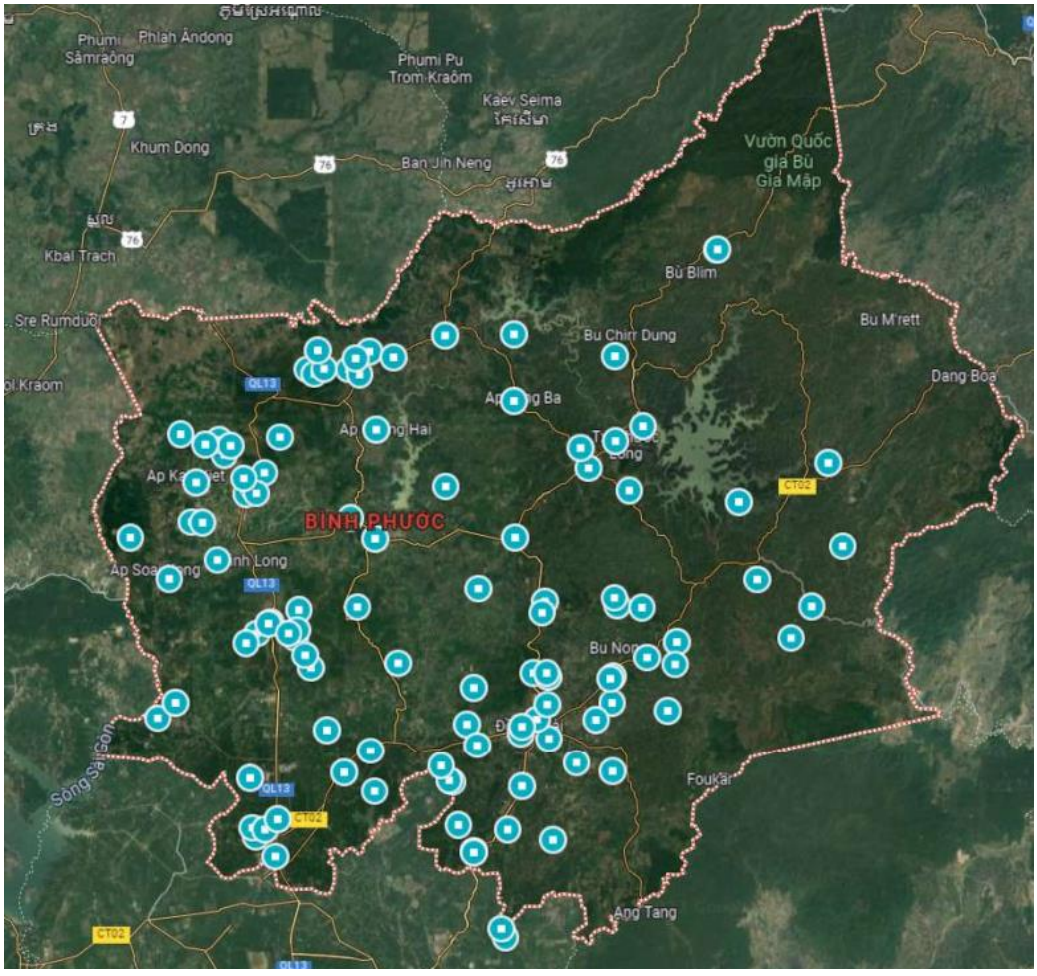

Figure 1. The map of the investigated area with 124 measurement points

In Vietnam, radon concentration is often detected using a RAD7 detector; however, this device only provides immediate radon levels and must be calibrated regularly [5-8]. Developing a method to detect the concentration of radon gas accumulated indoors using a CR-39 trace detector has the potential to be widely used in environmental pollution research, particularly in studies on the health effects of radon gas on people and mapping

indoor radon pollution. This study used the CR-39 alpha trace detector to measure the radon gas concentrations at the selected survey locations. Each detector has dimensions of 1.0 x 1.0 cm^2 and was coated with polyethylene to provide protection against potential moisture. The presence of traces on the detector can be attributed to radon and its daughters, which are alpha radiation emitters. The radon concentration is determined based on these traces.

There are a total of 124 measurement points distributed over residential areas near ore and rock mines in Binh Phuoc province (see Figure 1). The location of the measurement site and the detector installation adhere to the guidelines outlined in TCVN-10759:2016. To ensure the accuracy of measurement and avoid saturation of detectors, the exposure time of the detectors was set for 3 - 4 months. Following the designated duration of exposure, the films or detectors were obtained and subjected to examination to ascertain any potential damage or displacement resulting from external factors. Films that satisfy the prescribed standards will be subjected to laboratory treatments, including trace visualization, trace enumeration, and concentration calculation. The experiments were performed at the VILAS standard laboratory by ISO/IEC 17025:2017 standards. Counting the number of spots formed on the sample surface is performed using an optical microscope. The optimal use of any track detector is largely dependent on the standardization of various etching parameters. They must be experimentally determined under suitable conditions. Indoor radon concentrations were calculated as follows [10]:

$$C_{Rn} = \frac{N_T - N_B}{k.T}$$

where C_{Rn} is the equilibrium radon concentration in Bq/m^3, N_T is the registered whole tracks in T in the CR-39 detector, N_B is the background tracks in detectors used for measurement in T, k is the calibration factor of the CR-39 detector in T.cm^{-2}/kBq·m^{-3}·h, and T is the effective exposure time in hours. The calibration factor is used to convert the net track density to the value of the radon measurement and should be determined in the standard radon chamber before radon measurements. The detection threshold of measurement is about 4 Bq.m^{-3}.h^{-1} for 3 months of exposure.

2.2. Results and discussion

Table 1 displays the results of surveys conducted to assess indoor radon exposure at 124 distinct sites in Binh Phuoc province. The mean concentration of radon in Binh Phuoc was recorded as 42±18 Bq/m^3. The radon concentration at several measurement positions varies between 5±3 and 115±8 Bq/m^3, contingent upon the positioning of the detector. The site exhibiting the greatest concentration of radon is the Ta Thien Stone Mine, situated in Ta Thien Hamlet, Loc Thinh, Loc Ninh. It has been recorded to have a concentration value of 119±12 Bq/m^3. This result can be comprehended as the concentration of radon emanating from rocks being typically higher due to the greater concentration of radioactive isotopes within rocks. Dong Phu district in Binh Phuoc province has the highest mean radon concentration value (53±13 Bq/m^3) due to the strategic placement of detectors near stone quarries or adjacent to mining sites. The districts exhibiting the subsequent highest levels of radon are Loc Ninh (50±15 Bq/m^3),

Dong Xoai (50±17 Bq/m^3), and Bu Dop (48±10 Bq/m^3). Several areas, including residential and commercial buildings, exhibit higher radon concentrations compared to mining sites, where radon monitoring probes are commonly deployed. Two primary factors contribute to this phenomenon. Firstly, inadequate ventilation in residential or commercial buildings leads to an increase in radon gas levels. Secondly, newly constructed structures may be situated in areas where the soil and rocks contain substantial quantities of natural radioactive isotopes, thereby emitting radon gas. Hence, households and organizations must prioritize the act of ventilating their premises and fostering knowledge regarding air convection to reduce the radon gas level within enclosed spaces.

Table 1. Results of measuring radon concentration (Bq/m^3) in some areas of Binh Phuoc province

No.	Sample location (District)	Number of measurement points	Average (Bq/m^3)	Minimum (Bq/m^3)	Maximum (Bq/m^3)
1	Dong Xoai	14	40	33	116
2	Binh Long	7	39	9	85
3	Bu Dang	10	29	9	82
4	Bu Dop	9	48	16	99
5	Bu Gia Map	7	30	30	51
6	Chon Thanh	13	45	16	99
7	Dong Phu	22	53	35	87
8	Hon Quan	6	48	20	114
9	Loc Ninh	20	50	9	119
10	Phuoc Long	8	17	9	37
11	Phu Rieng	8	21	8	48
	Binh Phuoc	*124*	*42*	*5*	*119*

Overall, the distribution of measured radon concentrations is rather uniform, with no significant deviations across different places. Figure 2 is a graphical representation of the frequency distribution of radon concentrations observed at several measurement stations throughout the Binh Phuoc region. The concentration of radon is categorized into numerous intervals of around 10 Bq/m^3. Out of the total of 124 locations, it is seen that 28 locations exhibit the radon concentration within the range of 40-50 Bq/m^3. The subsequent range of radon concentration is 10 - 20 and 30 - 40 Bq/m^3, occurring with a frequency of 19 out of 124 data points.

Upon comparing the obtained data with the established norms, it becomes evident that the mean radon concentration at the surveyed sites in Binh Phuoc province is recorded at 42±18 Bq/m^3. The maximum radon concentration observed among the investigated data points is 119±12 Bq/m^3. All of these results are below the action level

of the yearly average indoor natural radon concentration as stated in TCVN 7889:2008 standard, which is 200 Bq/m^3 [9]. In comparison with the action threshold for indoor radon concentration established by the US Environmental Protection Agency (EPA) at 150 Bq/m^3 [8], the aforementioned concentration is comparatively lower. Hence, the current investigation has not shown any significant indications of acute health hazards posed by radon to those residing in the investigated region.

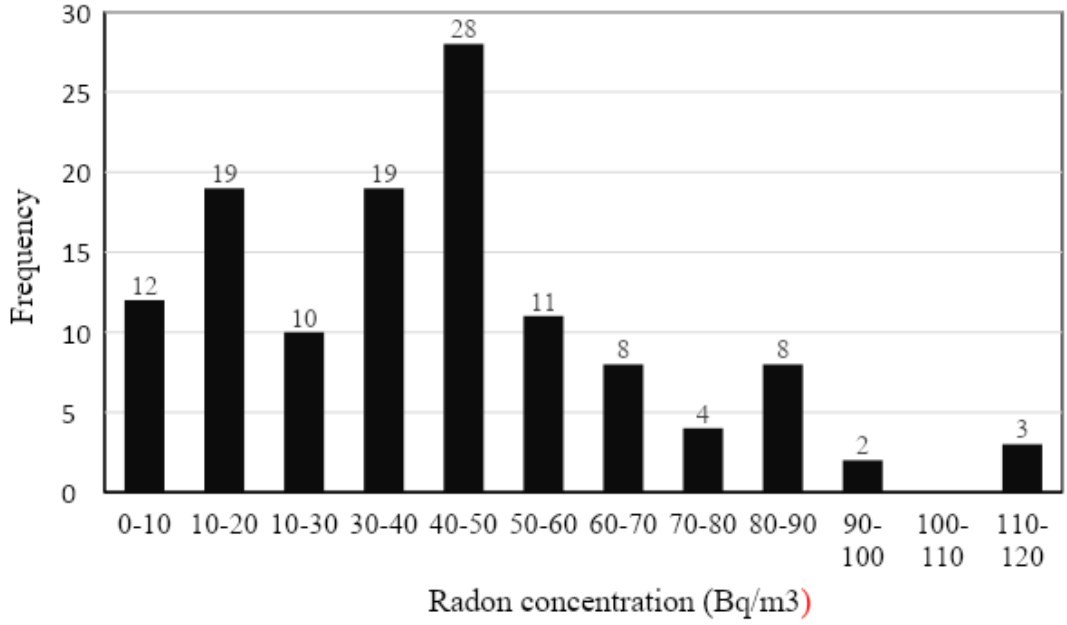

Figure 2. Frequency distribution of radon concentration at several measurement stations in Binh Phuoc

Figure 3 presents a comparative analysis of radon concentration survey findings in various countries. The World Health Organization (WHO) has determined that the mean radon concentration is 64.3 Bq/m^3 [3] based on the results of a survey conducted in 26 countries. This analysis examines the published results of many nations, including the United States (46 Bq/m^3), Canada (28.35 Bq/m^3), Argentina (35 Bq/m^3), France (62 Bq/m^3), Poland (49 Bq/m^3), Saudi Arabia (44 Bq/m^3), and Brazil (81.95 Bq/m^3). Therefore, it is evident that the recorded radon concentration at the surveyed location in Binh Phuoc province (42 Bq/m^3) is comparatively lower than the global average radon concentration. However, it remains greater than certain nations like Argentina, China, Saudi Arabia, and Canada, among others [3]. Nevertheless, it should be noted that all the measuring sites exhibited radon concentrations that were below the action limit as stipulated by the TCVN 7889:2008 standard or the requirements set by the US Environmental Protection Agency (EPA). The findings indicate that there is no evidence of significant immediate health hazards caused by radon exposure among individuals residing in the research region located in Binh Phuoc province.

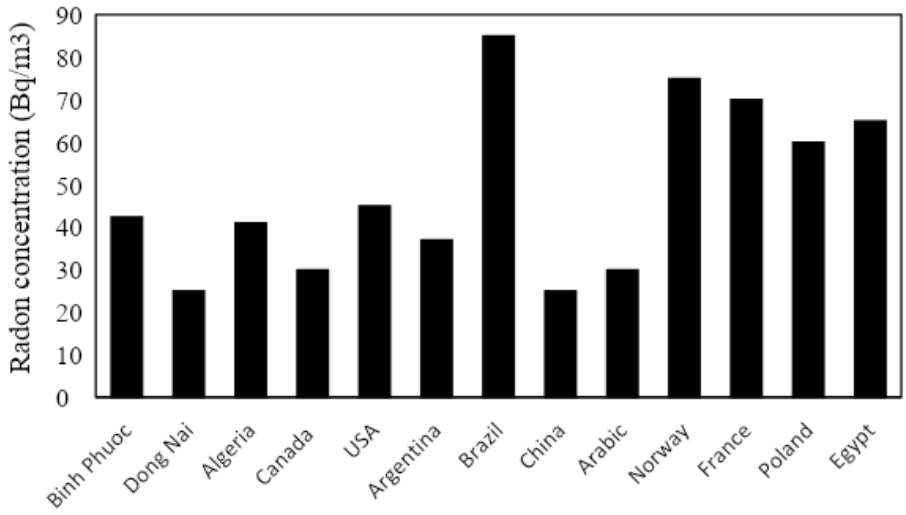

Figure 3. Radon concentration of the survey area compared to countries around the world

3. Conclusions

This study surveyed the indoor radon levels within residential areas, near mining sites, and active stone mines in Binh Phuoc province by using the CR-39 track detectors. The obtained results indicate that the average indoor radon concentration at the measurement sites is 42±18 Bq/m^3, which is comparatively lower than some countries and also lower than the global average value. The radon concentrations at several measurement locations exhibit a range of 5 to 119 Bq/m^3, which is dependent upon the particular location where the detector is placed. All of these values are below the criteria that necessitate action, as outlined by the TCVN 7889:2008 standard. The radiation hazard coefficient associated with radon exposure, which is known to cause lung cancer, is now assessed to be minimal and falls below acceptable limits. As a result, it does not represent a significant danger to the inhabitants and may be considered safe at this time. Nevertheless, it is important to give additional thought to the long-term health effects associated with the inhalation of radon gas. To ensure the safety of housing against natural radiation exposure, it is imperative to implement regular and suitable measures, including the implementation of natural and forced ventilation.

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