زانكۆى سەلاحەدين-هەولێر

Salahaddin University-Erbil

College of Education

A Study of Radon Activity Concentration in Soil from Qushtapa region Using RAD7 radon detector

Research Project

Submitted to the Department of Physics in partial fulfillment of the requirements for the degree of BSc. in Physics

By

Zina Sardar Abdulla and Gashbin Amire Abdul-Allah

Supervised by:

Assistant professor Dr. Hiwa Hamad Azeez

April 2024

بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

"وما أوتيتم من العلم إلا قليلا"

صَدَقَ اللهُ العَلِيُّ العَظيمْ

(سورة الاسراء الاية 85)

Dedication

To My

Respectful Parents

Dear Brothers and Sisters

Lovely Nieces and Nephews

Zina Sardar & Gashbin Amire

Acknowledgement

We thank the Deanery of the College of Education – Physics departments for their support during this work. We thank the physics department for their support during this work, particularly Dr. Asaad H. Ismail, the head of the physics department. I am most grateful to my supervisor, Dr. Hiwa Hamad Azeez, for his invaluable guidance, support, and patience during this work. My most gratefulness and respect to my parents.

Abstract

This research provides the measurement of radon ^{222}Rn activity concentrations in soil samples collected from some locations in Qushtapa town south of Erbil city from the Iraqi Kurdistan region using a RAD7 solid-state detector.

The radon activity concentrations have been measured and ranged from (78.70 ± 11.52 Bq.m^{-3}) to (41.70 ± 9.12 Bq.m^{-3}). The obtained values for the outdoor annual effective dose to lunges due to inhalation of radon gas released from soil samples were below the value (1.2 mSv.y^{-1}) recommended by UNSCEAR and WHO.

Finally, it was concluded that the levels of the radon activity concentration in soil samples from the study area are within the internationally acceptable values, which is equal to 100 Bq.m^{-3} (EPA 2010).

Table of Content

Chapter one

1.1 Introduction

In 1900, Dorn discovered the emanation in the uranium series that eventually became the well-known gas ^{222}Rn. From 1900 through 1908, it was demonstrated that ^{222}Rn is a radioactive gas found in tap water, highly condensable at low temperatures with a half-life of approximately 3.7 days, and can be collected on charcoal by adsorption. Although Radon was discovered in 1900, the effects of prolonged exposure had been suspected and noted 300 years earlier among underground miners who developed lung cancer. During the period from 1924 –1932, it was suggested that Radon was the cause of high lung cancer incidence (George, 2008).

We know from medical and environmental studies that Radon can be a health risk, primarily as a cause of lung cancer. Radon comes from the soil, rock, and water around us. Because levels of Radon vary from place to place and houses differ in their vulnerability to Radon, all houses must be measured for Radon (Otton, 1992).

Radon (Rn) is a naturally occurring radioactive noble gas which is generated from the alpha decay of radium (^{226}Ra) in the uranium (^{238}U) decay chain. Since ^{226}Ra and ^{238}U are ubiquitous in natural environments such as soil, rocks, and waterbodies, Radon is widely distributed in the natural world. Because of its unique physical and chemical characteristics, Radon has been adopted as a potential precursor gas for earthquake and volcanic event forecasts (UNSCEAR, 2000).

Historically, anomalous radon concentrations in soil have been observed several times preceding large earthquakes. However, there are still gaps in understanding the use of Radon in soil as an influential precursor for predicting earthquakes and volcanic eruptions worldwide. One of the main reasons is the difficulty in discriminating between anomalies caused by physical processes occurring in the Earth's upper crust and natural variations caused by local meteorological parameters. There are still gaps in understanding the use of Radon in soil as an influential precursor for predicting earthquakes and volcanic eruptions worldwide. One of the main reasons is the difficulty in discriminating between anomalies caused by physical processes occurring in the Earth's upper crust and natural variations caused by local meteorological parameters. Radon concentration in soil is influenced by many meteorological (Mao *et al.*, 2023)

Radon accounts for the third part of the radiation received throughout our lives. The respiratory system is the primary pathway into the human body with ninety per cent. The other ten per cent corresponds to the digestive system (Rizo-Maestre, C. and Chinchon Yepes, S., 2015). Radon is a gas produced by the radioactive decay of the element radium. Radioactive decay is a natural, spontaneous process in which an atom of one element decays or breaks down to form another by losing atomic particles (protons, neutrons, or electrons). When solid radium decays to form radon gas, it loses two protons and two neutrons. The elements that produce radiation are called radioactive. Radon is radioactive because it also decays, losing an alpha particle and forming polonium. Naturally radioactive elements include uranium, thorium, carbon, and potassium, as well as Radon and radium. Uranium is the first element in a long series of decay that produces radium and Radon. Uranium is the parent element, and radium and Radon are called daughters. Radium and Radon also form daughter elements as they decay. (Otton, J.K., 1992)

It is a physical phenomenon where some chemical elements, called radioactive, have a process in their cores that emit radiation with properties that modify and interfere with other mediums or elements (Rizo-Maestre, Chinchón Yepes and others, 2015). The noble gases make a group of chemical elements with similar properties under standard conditions, are monatomic gases, odourless, and colorless with very low chemical reactivity. They are members of the group 18 of the periodic table. The seven gases that include this group are helium (He), neon (Ne), argon (Ar), krypton (Kr), xenon (Xe), Radon (Rn), and Ununoctium (Uuo). Modern theories of atomic structure explain that noble gases only react to certain extreme external conditions. They are chemically stable, inert, and do not interact with other elements (IAEA, 2010).

Radon formation is just as uranium is present in all rocks and soils, and so are radium and radium because they are daughter products formed by the radioactive decay of uranium. Each atom of radium decays by ejecting from its nucleus an alpha particle composed of two neutrons and two protons. Alpha recoil is the most important factor affecting the release of Radon from mineral grains. A radium atom decays to Radon by releasing an alpha particle, containing two neutrons and two protons, from its nucleus. Radon movement: Radon is a gas with much greater mobility than uranium and radium, which are fixed in the solid matter in rocks and soils. Radon can more easily leave the rocks and soils by escaping into fractures and openings in rocks and into the pore spaces between soil grains. The ease and efficiency with which Radon moves in the pore space or fracture affects how much Radon enters a house. If Radon can move quickly in the pore space, then it can travel a great distance before it decays, and it is more likely to collect in high concentrations inside a building. The method and speed of Radon's movement through soils is controlled by the amount of water present in the pore space (the soil moisture content), the percentage of pore space in the soil (the porosity), and the "interconnectedness" of the pore spaces that determines the soil's ability to transmit water and air (the permeability). Radon moves more readily through permeable soils, such as coarse sand and gravel, than through impermeable soils, such as clays. Fractures in any soil or rock allow Radon to move more quickly. Radon in water moves slower than Radon in air. The distance that Radon moves before most of it decays is less than 1 inch in water-saturated rocks or soils, but it is as much as 6 feet through dry rocks or soils. Because water also tends to flow much more slowly through soil pores and rock fractures than does air, Radon travels shorter distances in wet soils than in dry soils before it decays (Otton, 1992).

1.2 Physical and Chemical Properties of Radon

A characteristic common to all natural radioactive series, unlike the artificially produced neptunium series, is the existence of radon isotopes. This element, with an atomic number of 86, as in Fig. (1-1), is a colorless, odorless, tasteless, and radioactive noble gas lacking activity toward other chemical agents. It is the heaviest member of the rare gas group (~100 times heavier than hydrogen gas and ~7.5 times heavier than air). When cooled below its freezing point, Radon exhibits brilliant phosphorescence that becomes yellow at lower temperatures and orange-red at the temperature of the liquid air. The electronic structure of its atom suggests minimal chemical reactivity. However, according to its relatively low first-ionization potential of 10.7 eV, some interactions might be possible (Amgarou, 2003; Lawrence, 2006).

Radon is readily absorbed by charcoal, silica gel, and similar substances. This property separates it from other gases by collecting it on-activated charcoal cooled to the temperature of solid CO_2(-78.2^{o}C). Radon is released from charcoal by heating to 350^{o}C. Anotherproperty of Radon is its solubility in various liquids, such as water or naturalgas, which may transport it over large distances through the soil. In special cases, when they are radon-rich elements, their contribution to the total indoor air concentration might be important. A detailed list of the physical properties of Radonis given in Table (1-1) (Amgarou, 2003; Ganjali *et al.*, 2016).

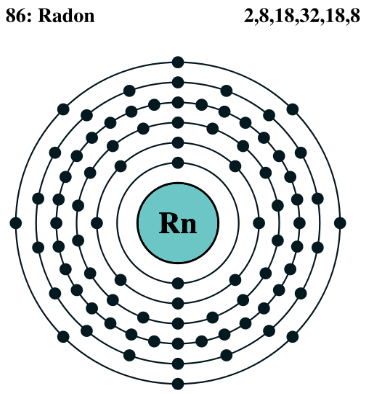

Figure 1.1: An electron shell diagram for radon atom.

Table 1.1 Physical and Chemical Properties of Radon (Azeez, 2010).

Density at 1 atm pressure and 0 ^{o}C	9.73 g L^{-1}
Boiling point at 1 atm pressure	-62 ^{o}C
Density of liquid at normal boiling point	4.4 g cm^{-3}
Diffusion coefficient in air	0.1 cm^{2} s^{-1}
Diffusion coefficient in water	10^{-5} cm^{2} s^{-1}
Viscosity at 1 atm pressure and 20 ^{o}C	0.229 poise
Solubility in water at 1 atm pressure and 20 ^{o}C	230 cm^{3} kg^{-1}
Element category	noble gases
Standard atomic weight	(222) g·mol^{-1}
Electron configuration	$4f^{14}$ $5d^{10}$ $6s^{2}$ $6p^{6}$
Electrons per shell	2, 8, 18, 32, 18, 8
Specific heat capacity	(25 °C) 20.786 J·mol^{-1}·K^{-1}
Crystal structure	face-centred cubic

Chapter two

Materials and Methods

2.1Radon emanation

The effects of moisture content, grain size, temperature, primary elemental composition, and the pH of soils on the radon emanation and diffusion coefficients were evaluated in this study. The emanation and diffusion coefficients are strongly influenced by moisture content and grain size. The radon emanation coefficient increased, and the diffusion coefficient decreased with the decrease in particle size. However, for soils with large particle sizes, the radon emanation and diffusion coefficient remain almost unchanged with variations in grain size. Comparing five different-sized soil particles, the emanation coefficient increased, and the diffusion coefficient decreased with moisture content. The radon emanation coefficient reached a constant value with different moisture contents depending on the range of grain sizes. The saturation emanation coefficient for less than 0.1, 0.1–0.2, 0.2–0.3, 0.3–0.5, and more than 0.5 mm sized soil grain ranges are 0.47, 0.42, 0.35, 0.26 and 0.23, respectively, with saturation moisture contents of 16%, 14%, 10%, 6% and 4%. A drastic increase in radon emanation is found at smaller grain sizes with increasing moisture content. Based on the content of significant elements and the pH of the soils, the multiple regression indicates that the radon emanation coefficient appears to be significantly dependent on iron content and pH. Practical diffusion coefficient values calculated in our study agree with the results calculated by a previous model. Experimental values show that the temperature dependence of the radon diffusion coefficient follows Arrhenius's behaviour (Thu, Van Thang, and others, 2020).

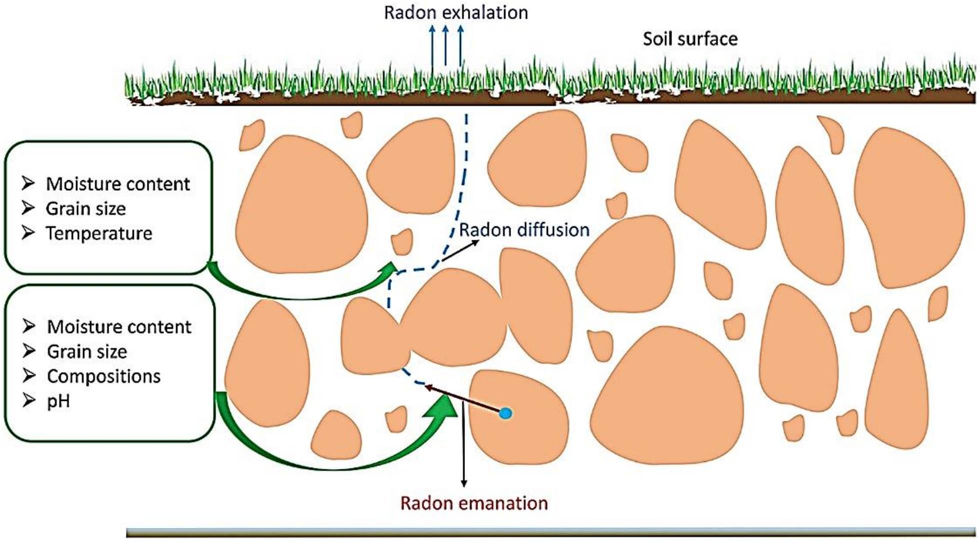

Figure 2.2: soil characteristics on radon emanation and diffusion (Thu, Van Thang and others, 2020)

2.2Radon Effect on Our Health

The factor that causes cancer is unknown; science has not yet proven that certain particles undergo DNA mutation in their cells when subjected to radiation. Radon, as a radioactive chemical element, can cause cancer. The World Health Organization (WHO), along with the International Agency for Research on Cancer (IARC) and the Environmental Protection Agency (EPA), consider the presence of Radon in the environment as the main risk of human lung cancer. Radon affects our health, causing a mutation in the DNA cells that can lead to cancer. For smokers, radium is more detrimental as the particles left behind in the body are more likely to adhere to radium and, therefore, are more difficult to remove. Recommendation 90/193 concerning the population against the dangers of radon exposure within buildings in 1990 recommends an annual level of 400 Bq/m^3 for existing buildings and 100 Bq/m^3 for new buildings (USEPA, 1997; WHO, 2008).

The International Atomic Energy Agency (IAEA) speaks of corrective measures in homes with average levels of Radon between 200 and 600 Bq/m3 per year and above 1000 Bq/m3 in the workplace. The WHO recommends proceeding straightforwardly, beginning at 200 Bq/m3 per year and urgently at 400 Bq/m3 levels (IAEA, 2010; Rizo-Maestre, Chinchón Yepes and others, 2015).

2.3Measurement of Radon

There are different ways to measure Radon, depending on the equipment used and the time required; usually, such devices have a standard rule that the more amount of time, The types of instruments and techniques used in the detection of either the alpha particles emitted by Radon itself or the alpha particles of its decay products are the following:

1. Alpha scintillation detectors include zinc-sulfide phosphors, silver activated, and ZnS(Ag).
2. Alpha track-etch detectors (ATDs) or solid-state nuclear track-etch detectors (SSNTDs) are used to register nuclear tracks of alpha particles in solid-state materials.
3. Alpha radiation spectrometers with silicon diode, either a surface barrier or diffused junction detectors
4. RAD7 Radon detector.

This paper is an overview of instrumentation for measuring environmental Radon in soil gas and ground waters for geophysical, geochemical, and hydrological studies (Papastefanou, 2002).

2.4RAD7 electric radon detector

RAD7 radon detector is a commercial electronic radon detector, generally employed for discrete measurements to assess the radon activity concentration in soil gas or dissolved in water. An electrostatic chamber operated at a nominal voltage of 2,000 – 2,500 V is intended for radon daughters' collection onto the surface of a solid-state silicon detector, which detects and separates alpha particles based on their energies. Only alpha decay from the short-lived ^{218}Po (its half-life is about 3 minutes) can be selected (Sniff mode, according to RAD7 protocols) to rapidly infer ^{222}Rn since the radioactive equilibrium between them is reached in about 15 minutes. Temperature and relative humidity are recorded inside the instrument. A pump guarantees the circulation of the air in the set-up. INGV Radionuclide Laboratory operates two RAD7s used mainly for geochemical surveys.(Galli, G et al.,2019)

Figure 2.3 RAD7 electric radon detector

2.5 Sample preparation

One day, we visited Qushtapa and the surrounding villages to bring samples to measure the radon gas level. We sifted and cleaned the samples and placed them in the oven for 3 hours to dry. Then we brought it to the laboratory, put it in the tube, and waited 1 month for it to combine. After that, we measured the level of radon gas inside using the RAD7 device.

Figure 2.4 Map of the sample's locations.

Chapter Three

3.1 Results and Dissection

Radon activity concentration

Radon concentration in soil gas was measured at fourth locations in Erbile City and surrounding areas using the RAD7 radon monitoring system. In this work, radon concentrations are measured in four locations for the surface soil samples of Qushtapa and are listed in Table 3.1. Also, the histogram schemes of this data are shown in Figure 3.1, in which the result of different zones is declared.

The activity concentration of ^{222}Rn gas in the soil samples was measured to be ranging from (78.70 ± 11.52 Bq.m^{-3}) to (41.70 ± 9.12 Bq.m^{-3}), with the average value (61.60 ± 15.78) Bq.m^{-3}. As shown in Figure 3.1, the highest value of ^{222}Rn activity concentration was found in soil in Qushtapa. The lowest value of ^{222}Rn activity concentration was found in soil in Qultapa. The variation in values of ^{222}Rn activity concentration in soil samples is due to the differences in the content of ^{226}Ra and the geological and geographical conditions in the studied area.

The Annual Effective Dose from the Inhalation of Radon Gas

The annual effective dose to lungs from the inhalation of Radon can be calculated from the following models (UNSCEAR 2000):

$$AED\ (mSv/y) = C_{Rn}\ x\ F\ x\ T\ x\ D$$

Where F is the so-called equilibrium factor, mean values of the equilibrium factor for ^{222}Rn daughters in the indoor and outdoor air are assumed to be 0.4 and 0.6, respectively. T is the number of hours staying in a particular place (indoor or outdoor). The dose conversion coefficient D (the effective dose to the lung where received by adults per unit activities concentration of Radon) was equal to 9x10^{-6} mSv per Bq.m^{-3}. (UNSCEAR, 1993, 2000).

The outdoor annual effective dose due to inhalation of radon gas released from soil samples ranged from (0.26 – 0.50) mSv.y^{-1}, with the average value of (0.39 ± 0.10) mSv.y^{-1}. As shown in Figure 3.2, the obtained values for the outdoor annual effective dose to lunges due to inhalation of radon gas released from soil samples were below the value (1.2 mSv.y^{-1}) recommended by (UNSCEAR, 2000).

Table 3-1 Radon activity concentration (in Bq/m^3) in soil samples and outdoor Annual Effective Dose from the Inhalation of Radon AEDL from Qushtapa town

Code of Samples	Location	Radon Activity Concentration (Bq.m^{-3})	$AED_{outdoor}$ (^{222}Rn) (mSv/y)
S1	Qushtapa	78.7 ± 11.52	0.50 ± 0.04
S2	Qazixana	57.77 ± 11.81	0.36 ± 0.04
S3	Qultapa	41.7 ± 9.11	0.26 ± 0.02
S4	Ber araban	68.23 ± 7.56	0.43 ± 0.03

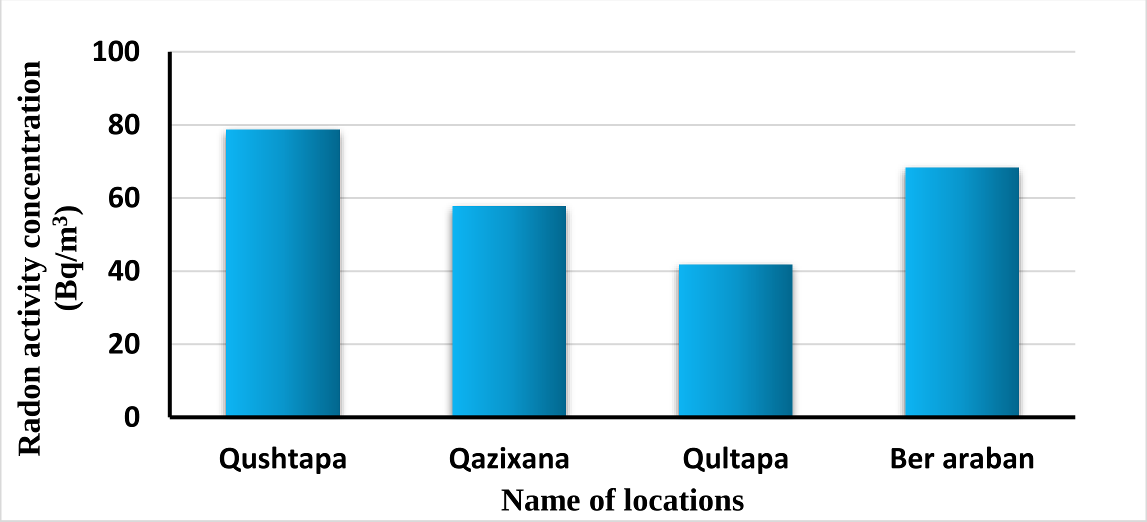

Figure 3.1 Radon activity concentration in soil samples from Qushtapa town.

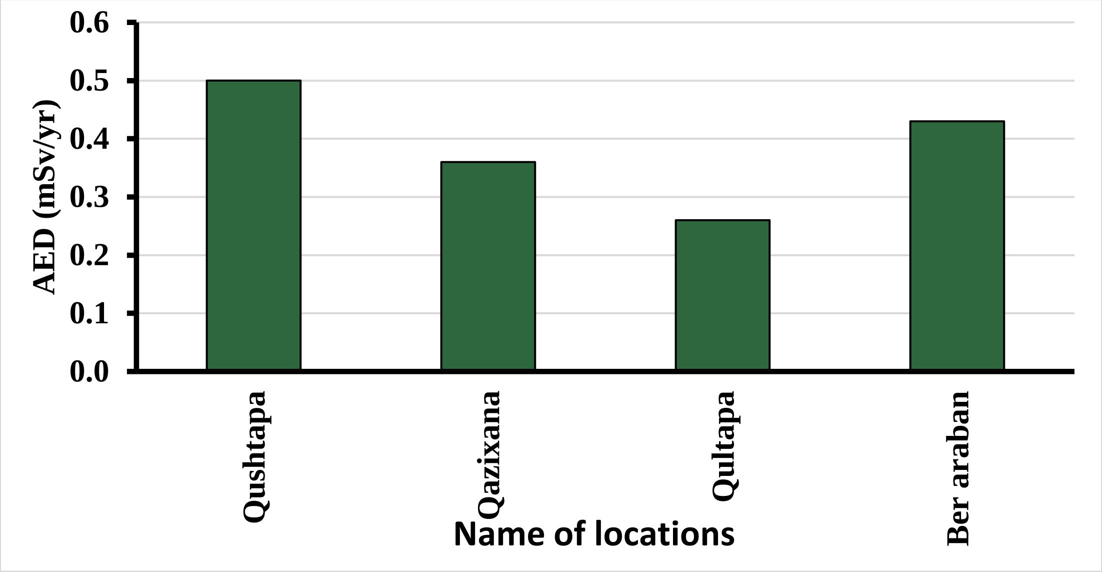

Figure 3.2 Outdoor Annual Effective Dose from the Inhalation of Radon AEDL in soil samples from Qushtapa town.

3.2 Conclusion

The most critical radon isotope from a health viewpoint is ^{222}Rn. Based on the RAD7 radon monitoring detector, radon gas activity concentration in soil samples was collected from Qushtapa in Erbil Governorate from the Iraqi Kurdistan Region. The activity concentration of ^{222}Rn gas in soil samples ranged from (78.70 ± 11.52 Bq.m^{-3}) to (41.70 ± 9.12 Bq.m^{-3}). The results were below the action level recommended by UNSCEAR of 100 Bq.m^{-3}.

The obtained values for the indoor annual effective dose to lunges due to inhalation of radon gas released from soils were lower than the value (1.2 mSv.y^{-1}) recommended by UNSCEAR.

Reference

Amgarou, K. (2003) *Long-term measurements of indoor Radon and its progeny in the presence of Thoron using nuclear track detectors a novel approach*. Universitat Autònoma de Barcelona,.

Azeez, H.H. (2010) *A Study of Radon and Thoron Gases Release from Iraqi-Kurdistan Building Materials Using Passive and Active Methods*. Salahaddin University-Erbil.

Ganjali, M.R. *et al.* (2016) *Lanthanides series determination by various analytical methods*. Elsevier.

George, A.C. (2008) 'World history of radon research and measurement from the early 1900's to today', in *AIP Conference Proceedings*, pp. 20–33.

IAEA (2010) *Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Terrestrial and Freshwater, Technical Reports Series 472, IAEA*. Vienna: International Atomic Energy Agency.

ICRP (1987) *Lung Cancer Risk from Indoor Exposures to Radon Daughters*.

Lawrence, C.E. (2006) *Measurement of 222Rn exhalation rates and 210Pb deposition rates in a tropical environment*. Queensland University of Technology.

Mao, Y. *et al.* (2023) 'The temporal variation of radon concentration at different depths of soil: A case study in Beijing', *Journal of Environmental Radioactivity*, 264, p. 107200. Available at: https://doi.org/https://doi.org/10.1016/j.jenvrad.2023.107200.

Otton, J.K. (1992) *The geology of Radon*. Washington: Government Printing Office.

Papastefanou, C. (2002) 'An overview of instrumentantion for measuring radon in soil gas and groundwaters', *Journal of Environmental Radioactivity*, 63(3), pp. 271–283. Available at: https://doi.org/https://doi.org/10.1016/S0265-931X(02)00034-6.

Rizo-Maestre, C., Chinchón Yepes, S. and others (2015) 'Radon Gas-Hazardous Element for Human Life Really Found in the Environment'.

Thu, H.N.P., Van Thang, N. and others (2020) 'The effects of some soil characteristics on radon emanation and diffusion', *Journal of environmental radioactivity*, 216, p. 106189.

UNSCEAR (1993) *Sources and Effects of Ionising Radiation, United Nations Publications*. New York.

UNSCEAR (2000) *Sources and effects of ionizing radiation, ANNEX B, Exposures from natural radiation sources, United Nations Publications*. New York: Scientific

Committee on the Effects of Atomic Radiation. Available at: https://doi.org/10.1097/00004032-199907000-00007.

USEPA (1997) 'Exposure Factors Handbook', *U.S. Environmental Protection Agency*, I(August 1997), p. 1193. Available at: https://doi.org/EPA/600/P-95/002F a-c,.

WHO (2008) *Guidelines for Drinking-water Quality*. Third, *World Health Organisation*. Third. Geneva, Switzerland: WHO Press. Available at: https://doi.org/10.1016/S1462-0758(00)00006-6.