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Chapter 1

Introductory Chapter: Radon Phenomenon

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http://dx.doi.org/10.5772/intechopen.70170

Live beings on earth have always been exposed to radiation from nature and more recently from artificial sources of radiation. The main components of radiation from nature are cosmic rays, terrestrial gamma ray, ingestion, and inhalation of natural radionuclides. On normal occasions, terrestrial sources are responsible for most of human exposure to natural radiation. These are, above all, radionuclides that are members of the three natural radioactive series: uranium-radium (^{238}U), uranium-actinium (^{235}U), and thorium series (^{232}Th). Usually, the radionuclides on the beginning of these three radioactive chains are called primordial or primary natural radionuclides. All members of these series are genetically linked and are the result of the successive decay of the first member of the series, which explains the law of radioactive decay. Natural radioactivity is the occurrence of atomic core decomposition that exists in nature, without external influences, at which alpha particles (helium nucleus), beta particles (electrons and positron), and cosmic rays (photons) are emitted.

Researches of natural radioactivity include a wide range of science disciplines, starting with physics as a fundamental science, which explains the phenomenology of radioactive disintegration and measurements of activity of radioactive elements, and geological disciplines such as geochemistry, radionuclide prospecting, and physical chemistry, which explains the mobilization and spreading of radionuclides in nature. In the environment, radionuclides of natural origin, at most locations, are mainly present in low concentrations. However, these radionuclides through various geochemical processes can be significantly concentrated regionally or locally, leading to even their mineralization and/or forming mineral deposits, such as in the case for isotopes U and Th [1, 2]. The radium follows the secondary uranium concentration but often forms separate aureole dispersion due to certain differences in geochemical characteristics. Radium, as a dissolvable cation, is migrative under conditions where the uranium is immobile and in the water or land can be to a greater or lesser degree separated from uranium and locally separately concentrated.

Natural radionuclides of terrestrial origin enter into the environment in various ways and from different sources: natural, geochemical (mineral deposits of phosphate, lead and zinc and other raw materials, various rocks), and anthropogenic sources (mining and processing,

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production and use of mineral fertilizer, radioactive waste dumps, ash emissions, ash and slag dumps from thermal power plants). Three natural radionuclides that are representing the greatest environmental risks, uranium, radium, and radon, appear in different parts of the environment: in soil, underground, surface waters, and air, either together or separated [3]. These natural terrestrial radionuclides are the most common and most important sources of ionizing radiation in the environment, among which the radon isotope ^{222}Rn occupies a central place, both in terms of total irradiation of the population and in terms of local high-radiation doses. Ionizing radiation is one of the most dangerous health risks in the environment.

Radon is a subject of intensive research around the world. Problems related to this radioactive gas are very complex and are representing wide field for scientific research. Radon is of special health importance for humans, and this is a motive, among other things, why there is a permanent interest in it. The study of the biological effects of radon on man is a very demanding scientific task. The human body is a very complex system with many organs of different chemical properties, functions, and radiosensitivity, so the reliable estimation of exposure risk, the development of adequate protection from radon, requires a multidisciplinary approach to these problems.

Radon as an inert gas, almost without forming any compounds in nature, is a global natural phenomenon. Radon isotopes, ^{222}Rn, ^{220}Rn, and ^{219}Rn, with a half-life of 3.825 days, 55.6 s, and 3.96 s, respectively, are the central members of each natural radioactive chain. Their immediate predecessors are radium isotopes, whose atoms disintegrate into radon via alpha decay. The isotope ^{219}Rn is insignificant due to the small amount of ^{235}U, while the isotope ^{220}Rn is of less importance due to its short half life. Because of the longest life time and isotope abundance, the highest importance of natural radon isotopes is ^{222}Rn, and the term radon refers to this isotope. In its decay chain, the radon ^{222}Rn gas is transformed into a stable lead ^{206}Pb through the short-living descendants of disintegration, emitting five alpha particles of energy up to 7.7 MeV, a beta radiation of up to 2.8 MeV, and a photon of gamma radiation of energy up to 2.4 MeV.

Humans are constantly exposed to radiation from many sources from nature and in the last 100 years from artificial sources. Over 80% of global exposure is from natural sources, and about 20% comes from artificial sources—mostly from radiation used in medicine. Natural radioactive sources contribute with 2.4 mSv to an average annual effective dose, and it varies from about 1 to more than 10 mSv, depending on where people live. The average annual effective dose of ^{220}Rn inhalation and its progeny is 70 μSv and by ^{222}Rn inhalation and its progeny is about 1.2 mSv [4]. For this reason, the problem of the radon level in the environment is treated with special care.

The high mortality rate of miners in central Europe was noted in the sixteenth century, but only at the end of the nineteenth century, it was concluded that the lung cancer was the cause of this phenomenon. The measurements of radon activity concentrations in the Schneeberg mines and Jachymov mines (ranging from 70 to 120 kBq/m^3), in the 1930s and 1940s, showed that the lung cancer of miners in these mines was caused by high radioactive radon gas levels. Finally, after almost 500 years, the mysterious deaths in these mines, called "Bergsucht" or "mountain sickness," have been puzzled out. Measurements of radon activity concentrations in the mines of leading industrial countries in the world were followed. These measurements confirmed the radon damage to the human health, and the risk awareness of lung cancer among miners was slowly but persistently matured. This had finally encouraged the motivation for a professional attitude toward radioactive radon gas, providing new and more effective protection guidelines for underground mines, especially uranium mines.

Based on the significant experience gained through numerous researches of radon in uranium mines, as in other mines, radon and radon progeny have been identified as causes of lung cancer [5–8]. Epidemiological studies on levels of radon activity in underground mines have become the main basis for estimating quantitative risk for lung cancer associated with exposure to radon and radon decay products. Surprisingly, the space where a man lives up to 70% of his time in life was not a priority in the initial stages of radon concentration research. Measurements of radon activity concentrations in indoor enclosures were made for the first time in 225 houses in Sweden, whose results were officially published in 1956. The initiative for these studies, given by Rolf Sievert, was proved to be justified because in a number of houses that were made of porous concrete with increased content of ^{226}Ra; the radon concentration was noticeably higher than in the other houses. These researches did not attract the attention of the international experts, because they were considered to have local significance and therefore were forgotten.

The return of interest for the research for this radioactive gas was only 20 years later, again in Sweden, due to energy saving during oil crisis. The Swedish government's commission points out that the radon problem is a common problem and that it exists outside of Sweden. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) quickly reacted, and in the 1982 report [5], for the first time, the radon contribution to the average radiation exposure in natural conditions was taken into account. Similarly, in 1983, International Commission on Radiological Protection (ICRP), in its publication ICRP-39, the Principles for Limiting Exposure of the Public to Natural Sources of Radiation, issued the first recommendations for this specific natural radionuclide [9].

Researches in Sweden gave motive for systematic measurements of radon concentration in residential and workplaces around the world. Numerous studies have shown that the concentration of radon activity in homes depends on a large number of factors, such as design and type of home, local geology, soil permeability, building material and building ventilation, etc. All of these factors are variable, even in a small area, and therefore, radon concentrations can be significantly different even between neighboring dwellings and houses. Concentrations of indoor radon in buildings, homes, schools, and offices at investigated locations in the world range from 10 to 10,000 Bq/m^3 [10]. Fortunately, the number of objects with such high concentrations of radon is very small. Certain mentioned factors give a dominant contribution to the concentration levels of the indoor radon activity.

The health effect that radon has on the population has ultimately become the primary cause for the interest of the scientific audience for radon. In addition, with scientific and expert research on the radon problem, numerous possibilities of the physicochemical property application of this radioactive gas have been revealed. This is primarily related to the prospect of uranium and then for geothermal investigations, earthquake prediction, and volcanic eruptions.

Measuring the concentration of radon activity in groundwater can identify different cracks as well as geothermal sources that lie deep beneath the earth's surface. The presence of geological cracks enables radon to increasingly exhalates from the soil through transport processes, which are related to the deep bursts of earth [11].

A significant role in the total population irradiation has the content of radon in drinking water but also water used for other purposes. This primarily applies to water used in swimming pools, as well as baths and tubs for inhalation in recreational and medical centers. Radon from water contributes to the total inhalation risk associated with indoor air radon. The most extensive research on radon water risk is presented in the report of the US Scientific Committee on Risk Assessment of Radon in Drinking Water. Underground water often travels through rocks that contain radium, which in the process of disintegration releases radon into water [12]. The radiation dose for radon that enters the body with drinking water depends on its concentration activity in the water, metabolism, and radon kinetics in the body. Radon dissolves in water, body, and blood. Radiation emitted by radon and its products of radioactive decay displays sensitive stomach cells as well as other organs after it is being absorbed into the bloodstream. It is easily absorbed from the gastrointestinal tract and distributed among the tissues, partly due to a large coefficient of emanation and partly due to its relative solubility in blood and tissue.

Many studies have crystallized evidence that cell exposure to high radiation, such as alpha particles, can trigger a series of molecular and cellular events, DNA breaks, inaccurate repairs, apoptosis, gene mutations, chromosome changes, and genetic instability, to culminate in the end in the development of lung cancer and cancers of the other branches [13–17]. Radon was identified as a public health problem [18]. The complexity of observing radon dosimetry on biotics systems is also related to the fact that radon and its short- and long-lived products are alpha, beta, and gamma emitters. These various forms of ionizing radiation, with various energies and physical-chemical tendencies, give the whole range of biological effects on the way of transporting radon through tissues of the organisms.

On the other hand, treatment with radon is one of the oldest therapies used by humans, and it is in use today [19]. Radon treatment involves inhalation from natural sources (ore mine) or bathing in the water that contains radon, while there is less use of radon-rich drinking water [20, 21]. The first results of radon-rich water activity were observed in patients with acute and chronic rheumatism, motor regeneration, posttraumatic and postsurgical conditions, and other diseases of the organism [20, 22]. Particularly, positive radon activity was observed in the cardiovascular system, certain radon levels lead to cardiac contractions, and arterial pressure drops. These are special "hormesis" [23].

According to US Environmental Protection Agency (EPA) estimates, radon is the cause of the number one lung cancer among nonsmokers and the second leading cause of lung cancer after smoking. Although radon is one of the most widely investigated human carcinogens, which is proved the most in epidemiological researches on lung cancer in underground miners, the effect of small doses has not yet been sufficiently resolved. By developing new dosimetry models and new measuring systems that are adjusted to realistic measuring conditions, knowledge of the biological effects of radon and its degradation products will be complemented.

One of the missions of the book *Radon* is to keep the radon problem always in the sphere of human interest.

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References

[1] Faure G. Principles of isotope geology. 2nd ed. New York: Wiley, ©1986

[2] Fritz P, Fontes JC, editors. Handbook of environmental isotope geochemistry. Vol. 1. Elsevier; Amsterdam,1980

[3] Gržetić I, Jelenković R. Prirodni radioaktivni elementi, geološko porijeklo i oblici pojavljivanja i migracije. Monografija: Jonizujuća zračenja iz prirode, JDZZ, Beograd; 1995. pp. 1-39

[4] UNSCEAR. Report to the General Assembly, with Scientific Annexes, Sources and Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation. New York: United Nations; 1993

[5] UNSCEAR. Report to the General Assembly, with Scientific Annexes, Sources and Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation. New York: United Nations; 1982

[6] ICRP. Protection Against Radon-222 at Home and at Work. ICRP Publication 65. 1993

[7] ICRP. Human Respiratory Tract Model for Radiological Protection. ICRP Publication 66. 1994

[8] UNSCEAR. Sources and Effects of Ionising Radiation. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation; 2000

[9] ICRP. Principles for Limiting Exposure of the Public to Natural Sources of Radiation. ICRP Publication 39. 1984

[10] WHO, Radon and Health, June 2016

[11] Fleischer RL. Radon: Overview of properties, origin and transport. In: Durrani SA, Ilic R, editors. Measurements by Etched Track Detectors. Singapore: World Scientific; 1997. pp. 3-18

[12] National Research Council. Risk Assessment of Radon in Drinking Water. 1999

[13] International Atomic Energy Agency (IAEA). Radiation Biology: A Handbook for Teachers and Students. 2010

[14] Kronenberg A. Mutation inductions in human lymphoid cells by energetic heavy ions. Advances in Space Research. 1994;**14**(10):339-346

[15] Anderson R, Marsden SJ, Wright EG, Goodhead DT, Griffin CS. Complex chromosome aberrations in peripheral blood lymphocytes as a potential biomarker of exposure to high-LET alpha particles. International Journal of Radiation Biology. 2000;**76**:31-40

[16] Maffei F, Angelini S, Cantelli FG, Lodi V, Mattioli S, Hrelia P. Micronuclei frequencies in hospital workers occupationally exposed to low levels of ionizing radiation: Influence of smoking status and other factors. Mutagenesis. 2008;**17**:405-409

[17] WHO Handbook on Indoor Radon: A Public Health Perspective. World Health Organization; 2009

[18] Environmental Protection Agency (EPA). A Citizen's Guide to Radon: The Guide to Protecting Yourself and Your Family From Radon U.S. 2005

[19] Falkenbach A, Wolter N. Radonthermalstollen-kur zur Behandlung des Morbius Bechterew, Research in Complementary Medicine. 1997;277-283

[20] Parker D. Letter to Sponsors of the Free Enterprise Radon Health Mine, Boulder, MT, regarding trip to Moscow, Austria, West Germany, and France. 1987

[21] Becker K. One century of radon therapy, International Journal of Low Radiation, 2004;**1**:334-357

[22] Cohen B. Test of the linear-no-threshold theory of radiation carcinogenesis for inhaled radon decay products. Health Physics. 1995;**68**:157-174

[23] Macklis R, Beresford B. Radiation hormesis. Journal of Nuclear Medicine. 1991;**32**:350-359

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