ENVIRONMENTAL THORON AND RELATED ISSUES

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Contents

Summary

Exposure to radon has been identified as the second leading cause of lung cancer after tobacco smoking. Thoron (radon-220) is an isotope of radon. This chapter focuses on indoor exposure to thoron. However, environmental thoron is part of the issues of environmental radon. The chapter starts, therefore, with discussion on characteristics of thoron in comparison to other isotopes of radon, followed by radiation doses to the lung and associated health effect.

An overview is given for thoron levels in the environment and its contribution to the total exposure to indoor radon (radon-222) and thoron (radon-220). Because exposure to thoron is a health hazard, the chapter discusses the reasons for the increased attention to thoron issues, and the effective and practical control of indoor exposure to thoron. While reducing indoor radon and thoron as low as practically achievable, we should always remember the fact that choosing to not smoke is the most effective way to reduce the risk of developing lung cancer.

1. Introduction

Radon is a naturally occurring radioactive gas generated by the decay of uranium and thorium bearing minerals in rocks and soils. Radon and its short-lived decay products in the atmosphere are the most important contributors to human exposure from natural sources (UNSCEAR 2000, 2009). Radon escapes from the ground into the air. In the open air, the amount of radon gas is very small and does not pose a health risk. However, soil gas containing radon can enter enclosed spaces whenever it finds an opening or a path. In enclosed spaces like residential homes, schools, office buildings and especially underground mines, radon can sometimes accumulate to relatively high levels and become a health hazard.

Long-term exposure to indoor radon has been associated with an increased risk of developing lung cancer, even at concentrations commonly found indoors. Exposure to radon has been identified as the second leading cause of lung cancer after tobacco smoking (WHO 2009). Recent studies on indoor radon exposure and lung cancer incidence in Asia, Europe and North America provided strong evidence that radon causes a substantial number of lung cancers in the general population. Current estimates of the proportion of lung cancers attributable to indoor radon range from 3 to 14% (WHO 2009). Because of the significant health effect, issues associated with indoor radon exposure are the focus of this chapter.

Radon-222 and radon-220 are the most common isotopes of radon, with the term “radon” typically used when referring to radon-222 and “thoron” to radon-220. Because thoron is an isotope of radon, environmental thoron is part of the issue of environmental radon. Although this chapter focuses on indoor exposure to thoron, all thoron related issues need to be considered within the framework of radon exposure.

Therefore, this chapter is organized into five sections starting with Section 1 - Isotopes of Radon and Radioactive Decays where characteristics of thoron are compared to other isotopes of radon. Radiation doses to the lung and associated health effects are discussed in Section 2. Section 3 provides an overview of thoron levels in the environment, and its contribution to the total exposure from indoor radon and thoron. Measurement issues to quantify thoron levels are discussed in Section 4, where thoron interference with radon measurement is addressed.

Because exposure to radon and thoron is a health hazard, control of indoor exposure to radon has been an international action for many years. In the last section (Section 5), we will discuss the reasons for the increased attention to thoron issues, and the effective and practical control of indoor exposure to thoron.

2. Isotopes of Radon and Radioactive Decays

The element of radon has an atomic number of 86. In the periodic table of elements, radon is in the group of noble gases. At normal room temperatures, radon is a colorless, odorless and tasteless gas. Although radon is chemically inert and electrically uncharged, it is radioactive. This means that radon atoms in the air can spontaneously decay, or change to other atoms. The resulting atoms are called radon decay products or radon progeny.

There are three radioactive isotopes of radon naturally and commonly occurring in the environment; they are radon-222, radon-220, and radon-219. Radon-222 (^{222}Rn), commonly called radon (symbol Rn), has a half-life of 3.82 days and is derived from the natural radioactive series headed by uranium-238 (^{238}U). Its immediate parent in the uranium-238 decay chain is radium-226 (^{226}Ra). Radon-220 (^{220}Rn), commonly referred to as thoron (symbol Tn), has a half-life of 55.6 seconds and is derived from the natural radioactive series headed by thorium-232 (^{232}Th). Radium-224 (^{224}Ra) is thoron’s immediate parent in the decay chain. Radon-219 (^{219}Rn), sometimes called actinon (symbol An), has a half-life of 4.0 seconds and is derived from the natural radioactive series headed by uranium-235 (^{235}U).

In a typical sample of natural uranium, almost all the mass (99.27%) consists of atoms of uranium-238, and less than 1% (0.72%) of the mass consists of atoms of uranium-235. Because of the very small natural abundance of uranium-235 and very short half-life of radon-219, this isotope of radon has very limited environmental impact and is not discussed further. In the subsequent text, only radon (referring to ^{222}Rn) and thoron (referring to ^{220}Rn) are considered because of their significance in the environment and associated health concerns.

Radioactive decay occurs when an unstable isotope transforms to a more stable isotope, generally by emitting a subatomic particle such as an alpha or beta particle. An alpha particle (symbol α) is identical to a helium nucleus having two protons and two neutrons. It is a relatively heavy, high-energy particle, with a positive charge of +2 from its two protons. When an atomic nucleus emits an alpha particle, it transforms or decays into an atom with a mass number 4 less and atomic number 2 less. For example, $^{222}_{86}\mathrm{Rn}$ decays to $^{218}_{84}\mathrm{Po}$ and $^{220}_{86}\mathrm{Rn}$ decays to $^{216}_{84}\mathrm{Po}$ by emitting an alpha particle.

Beta decay is another type of radioactive decay. Beta particles (symbol β^-) are equivalent to electrons. The difference is that beta particles are ejected from the nucleus of radioactive atoms and electrons originate outside of the nucleus. When an atomic nucleus emits a beta particle, it decays into an atom with the same mass number but atomic number increased by 1.

For example, $^{214}_{82}\mathrm{Pb}$ transforms to $^{214}_{83}\mathrm{Bi}$ and $^{212}_{82}\mathrm{Pb}$ transforms to $^{212}_{83}\mathrm{Bi}$ through beta decay. Gamma radiation is not a mode of radioactive decay. It is a mechanism by which excess energy is emitted from certain radionuclides as highly energetic electromagnetic radiation emitted from the nucleus of the atom. In the natural decay series, some isotopes are significant gamma emitters.

The decay schemes for radon and thoron are given in Figures 1 and 2, respectively. They illustrate the major decay modes for radon and thoron. In the decay schemes, isotopes significantly emitting gamma rays are indicated with an asterisk. As radon decays, it produces decay products, sometimes called radon decay products, radon daughters or radon progeny.

Similarly, as thoron decays, it produces thoron progeny. Both radon and thoron decay and emit alpha particles. Their progeny decay further and emit alpha particles, beta particles and gamma rays. Detailed radioactive properties are given in Table 1 for the radon decay series and Table 2 for the thoron decay series (Peterson et al. 2007). These radiation characteristics will be discussed further in Section 3 on radiation doses and associated health effects.

Radon and thoron have quite different half-lives. The half-life is the time it takes for half of the radioactive isotopes in a sample to decay. In the case of radon and thoron, the sample is a given volume of indoor air. While radon has a half-life of 3.82 days, the half-life of thoron is much shorter, only 55.6 seconds. As they are gases, radon and thoron can be carried away from their place of origin by the movement of air. With a half-life of 3.82 days, radon can be found almost everywhere in indoor air. Since thoron has a much shorter half-life, once it is formed in soil, rock or building material, the distance it can travel before undergoing radioactive decay is much shorter than the distance radon can travel in the same medium. Therefore, thoron in the environment behaves quite differently than radon. These characteristics affect the measurement of radon and thoron which will be discussed in Section 4.

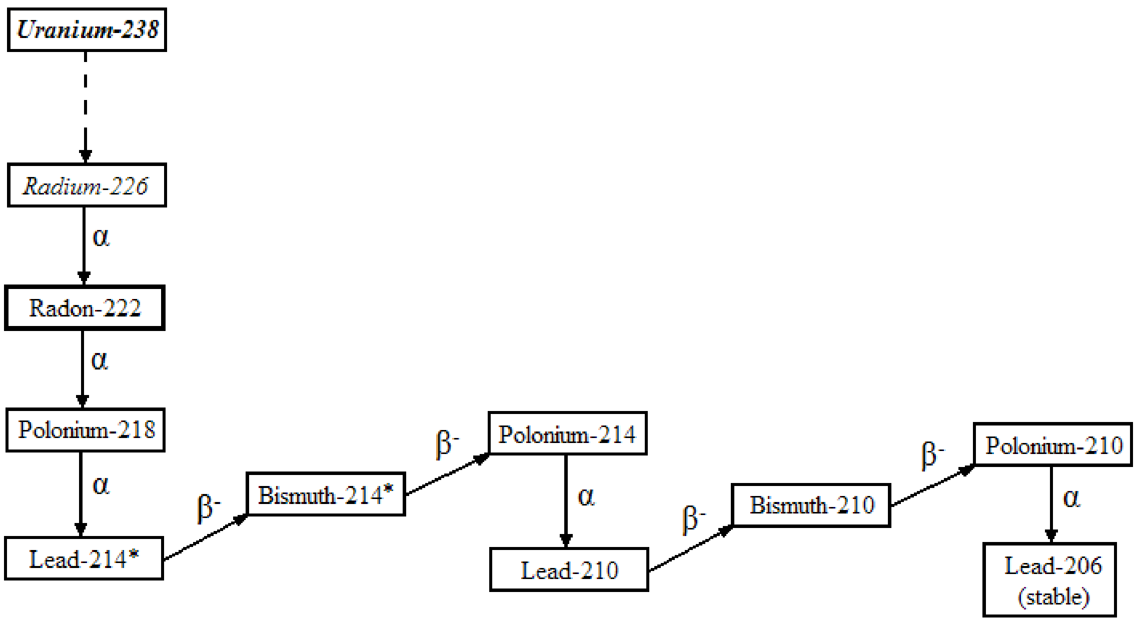

Figure 1. Radon decay series (part of the natural decay series: Uranium-238)

nuclide	**Half-life**	**Decay mode**	**Energy released**	**Product of decay**
Radon-222	3.82 days	α	5.59 MeV	Polonium-218
Polonium-218	3.10 minutes	α	6.11 MeV	Lead-214
Lead-214	26.8 minutes	β^-	1.02 MeV	Bismuth-214
Bismuth-214	19.9 minutes	β^-	3.27 MeV	Polonium-214
Polonium-214	164 microseconds	α	7.83 MeV	Lead-210
Lead-210	22.3 years	β^-	63.5 keV	Bismuth-210
Bismuth-210	5.01 days	β^-	1.16 MeV	Polonium-210
Polonium-210	138 days	α	5.41 MeV	Lead-206 (stable)

Table 1. Radioactive properties of nuclides from the radon decay series (based on data given by http : / / ie . lbl . gov / education / isotopes . h tm, LBNL 2000).
Note: in the beta decay model, the listed energy is the average beta energy released.

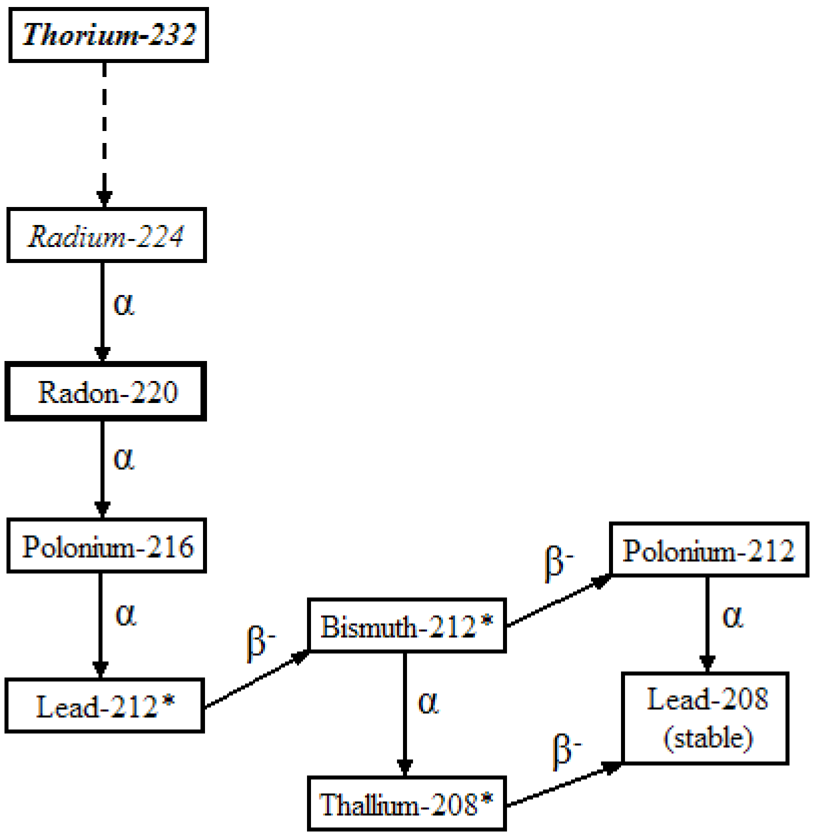

Figure 2. Thoron decay series (part of the natural decay series: Thorium-232).

nuclide	**Half-life**	**Decay mode**	**Energy released**	**Product of decay**
Radon-220	55.6 seconds	α	6.40 MeV	Polonium-216
Polonium-216	145 milliseconds	α	6.91 MeV	Lead-212
Lead-212	10.6 hours	β^-	0.574 MeV	Bismuth-212
Bismuth-212	60.6 minutes	β^- (64%) α (36%)	2.25 MeV 6.21 MeV	Polonium-212 Thallium-208
Polonium-212	299 nanoseconds	α	8.95 MeV	Lead-208 (stable)
Thallium-208	3.05 minutes	β^-	5.00 MeV	Lead-208 (stable)

Table 2. Radioactive properties of nuclides from the thoron decay series (based on data given by http : / / ie . lbl . gov / education / isotopes . htm, LBNL 2000).
Note: in the beta decay model, the listed energy is the average beta energy released.

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Biographical Sketch

Jing Chen holds a Ph.D. in Physics from the University of Wuerzburg, Germany. She is a senior scientist with expertise in radiation protection and dosimetry, and currently heads the Radiological Impact Section at Health Canada. Dr. Chen has been involved in international efforts to minimize risks of radon, and served as an expert from Health Canada on the International Radon Project organized by the World Health Organization. She is one of the key players in the Canadian National Radon Program, and has authored/coauthored more than 38 publications on issues of environmental radon and thoron in peer-reviewed scientific journals. Her previous research experience includes work at Bubble Technology Industries Inc., Chalk River, Canada, Los Alamos National Laboratory, Los Alamos, USA, GSF-National Research Center for Environment and Health, Neuherberg, Germany, University of Wuerzburg, Wuerzburg, Germany, University of Nuernberg and Erlangen, Erlangen, Germany, and the Chinese Academy of Medical Sciences, Tianjin, China.