Review of Radon and Its Progeny Measurement Technology in Environmental Gamma Measurement

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Abstract. The contribution of radon and its progeny to environmental gamma dose should not be ignored. In recent years, a large number of scholars all over the world have studied the migration behavior of radon and its progeny in the environment, and analyzed their impact on environmental gamma dose. Especially in uranium (thorium) bearing mining areas and other special areas, the influence of radon and its progeny is more prominent, which poses an important challenge to radiation monitoring. This paper summarizes the analysis and processing technology of radon and its progeny in environmental gamma monitoring, and puts forward the research trend and development direction of radon and its progeny analysis technology.

1. Introduction
Radon is a natural and relatively short-lived radioactive inert gas and is produced in the radioactive decay of radium, especially ²²²Rn in ²²⁶Ra decay (²³⁵U decay chain), ²²⁰Rn in ²²⁴Ra decay (²³²Th decay chain), and ²¹⁹Rn in ²²⁴Ra decay (²³⁵U decay chain). The half-life of ²²⁰Rn is T²²⁰ = 55.6 s, and the half-life of ²¹⁹Rn is T²¹⁹ = 3.96 s [1], which is obviously shorter than ²²²Rn. The current reports focus on the results that the concentrations of ²²⁰Rn, ²¹⁹Rn and their progenies in the air can be ignored compared with the concentrations of ²²²Rn and their progenies [2]. ²²²Rn has the most prominent contribution to the background of natural radiation [3].

²²²Rn precipitates from the surface and diffuses in the atmosphere, which is characterized by generation, emission and migration [4]. The surface radon exhalation rate is also affected by various environmental and meteorological parameters, as well as geochemical and geophysical parameters [5-7]. The air concentration of ²²²Rn not only affects the daily monitoring of environmental gamma dose, but also has a great impact on the alarm accuracy of radioactive emergency monitoring of nuclear facilities, which increases the difficulty of nuclear emergency screening [8].

First of all, this paper summarizes the influence factors of indoor radon concentration and atmospheric radon concentration. Secondly, this paper summarizes the measurement and analysis methods of radon and its progeny, and analyzes the application status of mainstream technologies from the perspective of monitoring. Then, this paper summarizes the detection data processing technology of radon and its progeny, and analyzes the advantages of various processing model algorithms. Finally, the future development direction of radon and its progeny analysis technology is put forward.
2. Influencing Factors of Radon Concentration

$^{222}$Rn is produced in the rock layer and will leak through openings and cracks in the ground according to the porosity and permeability of the material [9]. Therefore, the geological and lithologic structure of the geographical area is an important factor for gas monitoring [10-12]. The radon exhalation rate is also affected by environmental, meteorological, geochemical and geophysical parameters [5-7].

2.1. Influencing Factors of Indoor Radon Concentration

The radon concentration in buildings mainly comes from soil, building materials and water. The radon concentration in the bottom room is higher than that in the high-rise apartment building [13]. In a group of literature [14-17], it shows that researchers are very concerned about the influence of building floor level on indoor radon concentration distribution. At the same time, many researchers are committed to these specific studies [18-21]. The main source of radon in high-rise buildings is building materials, and the general deviation of measured data can be observed. There are great differences in building materials between urban and rural areas (other remote areas). Scholars have studied and analyzed the relationship between the differences of building materials and indoor radon concentration [22-25].

2.2. Influencing Factors of Atmospheric Radon Concentration

Radon concentration in the atmosphere is controlled by the following factors: (i) The content of radon precursors (related to uranium and thorium series) in the ground / rock; (ii) Ground / rock properties such as mineral composition, porosity, permeability, humidity; (iii) Type of soil cover [26-30]. Other factors that affect radon concentration are atmospheric stability and wind speed, atmospheric pressure and temperature, and precipitation [31, 32]. In addition, the atmospheric concentration will change with the change of atmospheric stability and precipitation (snow or rain), and the precipitation will concentrate the surface gamma radiation aerosol [33, 34].

3. Measurement Technology of Radon and its Progeny

In order to improve the accuracy of environmental gamma radiation monitoring and master the composition of environmental gamma dose, scholars are committed to the study of precise measurement of radon and its progeny. In the process of monitoring, the radioactive measurement of radon may be affected by thorium [35]. The measurement of radon and thorium was studied in reference [36] by using the passive RADUET radon-thorium identification monitor [37]. Reference [38] proposed that LaBr$_3$ detector and NaI(Tl) detector constitute a real-time environmental radioactivity monitoring system. The system can work at a certain height in the air, and judge whether the radioactivity comes from the ground radioactive waste or the original radioactivity in the air. In the Fukushima area, monitors were unable to work long hours in contaminated areas. In order to distinguish natural radionuclides and cosmic rays, six large-scale NaI(Tl) detectors were installed in the manned helicopter and three LaBr$_3$ detectors were installed in the unmanned helicopter radiation monitoring system in reference [39]. Based on the system, researchers developed a method for analyzing and comparing high altitude radioactivity in Fukushima nuclear accident area. At the same time, in order to accurately estimate the deposition of artificial radionuclides and exclude the influence of gamma rays from natural nuclides (especially radon progenies $^{214}$Pb and $^{214}$Bi), reference [40] proposed using the relationship between the counting rates of six NaI(Tl) detectors and one LaBr$_3$ detector to eliminate the influence of radon progeny in the air.

4. Radon and its Progeny Data Analysis Technology

In order to analyze the influence factors of environmental gamma dose, especially the influence of radon progeny on environmental gamma dose rate, many researchers have carried out a lot of research work on the later data analysis. Based on the classic Gauss Markov linear regression model, the reference [41] adopts NASVD algorithm, which can effectively deduct the background and accurately analyze the gamma spectrum. In order to distinguish false alarms and true alarms of radioactive
contamination, an optimized data analysis model was designed based on the automatic radiation monitoring system in nuclear facilities [42]. The regional monitoring researchers of Fukushima nuclear accident area in Japan obtained the effective attenuation factor in the air by comparing the flight altitude counting rate with the actual flight point measurement air dose rate, and effectively calibrated the radiation intensity of the radioactive area by using the difference of the effective attenuation factor between the actual absolute altitude and the standard altitude [39]. In reference [43], a 3D Eγ-Eγ-Eγ cube background correction method is designed based on the mathematical principle and a large number of measured data. The effectiveness of the method is proved by experiments, and it is proposed that the method can be applied to the analysis of any mass of gamma spectrum data.

5. Conclusions
The measurement technology of radon and its progeny is very important in the environmental gamma measurement. The key is to consider the external influence factors and the detailed analysis of radon and its progeny. In this paper, the influencing factors of radon and its progeny, the application status of detection devices and data analysis, and the achievements and technologies of research institutions are summarized. In the future, the measurement technology of radon and its progeny needs further research. First of all, there are many external factors. Considering a single factor or a few factors will affect the measurement accuracy. In the future, we should comprehensively consider the influence of multiple factors to improve the measurement accuracy. Secondly, the research and application of detector hardware needs a lot of work, which is the basis of improving the detection accuracy. Finally, we need to study the data analysis model and algorithm.

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