Overview of Radon Background Correction Technology for Airborne Gamma Spectrometry

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Abstract. In radiometric measurements, the radiation characteristics of radon and its daughters will increase the detection background value and affect the detection results. Research institutes in various regions of the world have studied the effects of radon and its daughters, and have done a lot of work according to the special climate, geological conditions and characteristics of radioactive events in their regions. In the view of the influence of radon background in airborne gamma-ray spectrometry measurement, this paper summarizes the research results of radon background correction in gamma-ray spectrometry measurement from three aspects in the world scope: environmental radiation monitoring, radiation monitoring instruments and nuclear emergency monitoring. In the aspect of environmental radiation monitoring, the research unit mainly considers the climatic factors such as rainfall, temperature and humidity, atmospheric and hydrological changes and seasonal changes, geological factors such as altitude, mineral types, and measurement means such as alpha measurement and inverse derivation gamma measurement. In terms of radiation monitoring instruments, radon and its daughters are mainly considered to reduce the impact and improve the measurement accuracy. In the aspect of nuclear emergency monitoring, the main consideration is how to improve the accuracy of measurement and avoid false alarm. On this basis, the research trend and development direction of radon background correction in airborne gamma-ray spectrometry are put forward.

1. Introduction

Background correction, stripping correction and height correction must be carried out in airborne gamma-ray spectrometry. Radon background has great influence on the measurement process. Researchers in various countries are devoted into radon correction. At present, researchers in China use 3 methods to correct radon background in aeronaautical measurement\textsuperscript{[1-6]}. The first method is the upper method\textsuperscript{[7]}. The IAEA-323 technical document recommends that the attached detector be placed above the main detector to measure radon in atmosphere. The second method is energy spectrum ratio
method[8]. The method recommend to use the relative height of uranium series photoelectric peak to evaluate the contribution of airborne radon to the observed energy spectrum. The third method is the full spectrum[9], which is proposed by Dickson et al. (1981). For a specific aerial survey height, the energy spectrum fitting method is used to calculate the atmospheric radon background.

With the continuous development of science and technology, radiation detection equipment and monitoring technology are changing rapidly. Researchers around the world are gradually studying the radon background correction method for the measurement of gamma spectrum from different aspects. In this paper, the advanced radon background correction technology in the world is investigated in combination with research needs. The radon background correction techniques for gamma-ray spectrometry are reviewed from three aspects: environmental radiation monitoring, radiation monitoring instruments and nuclear emergency monitoring. The research trend and development direction of radon background correction for airborne gamma-ray spectrometry are presented.

2. Environmental radiation monitoring

2.1. Rainfall influence

Many researchers have done a lot of practical measurement and analysis of the rainfall effects on radon and its daughter activities. The impact of radon progeny $^{210}$Pb and $^{214}$Bi on environmental gamma measurement after rainfall is very important[10]. The influence of radon accumulation in stable boundary layer on environmental gamma measurement is secondary[11, 12]. Thirdly, hydrological movement at sites with high radon fluxes may represent a source of false alarms about radioactive contamination[12].

The environmental gamma dose during rainfall is temporarily lower than the background value, sometimes due to water accumulation in the surface soil, which is part of the natural radioactivity in the soil gamma shielding and preventing radon emission[13-16]. The concentration of radon progeny in precipitation is a very complex function (distribution in the low altitude atmosphere)[17, 18]. Corresponding increases in near-surface environmental gamma doses appear to be inconsistent with rainfall rates, duration of rainfall events, precipitation, or other meteorological parameters[19-21]. However, it is often reported that there is an inverse relationship between its concentration and rainfall rate[20-22].

The National Institute of Physics and Nuclear Engineering of Romania tested a simple model for predicting Rainfall-Related enhancement of environmental gamma doses based on rainfall observations of events of comparative duration and intensity[10]. The Health Bureau of Ottawa, Canada, and the Radiation Protection Agency use rebound trajectory analysis, environmental gamma doses and rainwater data to obtain estimates of relative radon emission rates far from actual detection points[11]. Environmental Geology Research Institute of Italy use automatic NaI or CsI total gamma spectroscopy systems for monitoring radioactive contamination, hydrometeors forming at the ESHs in sites with a high radon flux could represent a relevant source of false alarms of radioactive contamination[12].

2.2. Geological factors

$^{222}$Rn, which is almost chemically inert, is released from soil and rock into the atmosphere for diffusion and convective transport, unaffected by atmospheric removal, and is therefore depleted primarily by radioactive decay[23, 24]. The atmospheric abundance of $^{222}$Rn is closely related to its emission rate, usually 0.2 to 1.5 atoms cm$^{-2}$ s$^{-1}$[25]. It is affected by soil type, grain size, water content, porosity and permeability in turn[26-28]. Because of the complexity of geology, the effect of radon is very different[29]. In particular, pay attention to some special mining areas, such as the thorium mine area[30]. The basic release and transport mechanism between radon and thorium is the same[31]. According to the UNSCEAR report, thorium (including daughters) usually contributes 0.1 mSv, 10% or less of the radon dose[32, 33]. In addition, the marine contribution should be also paid attention to [34].
Atmospheric $^{214}\text{Bi}$ measurements were carried out at University of Ferrara in Italy to assess the feasibility of its abundance and vertical distribution. In this context, direct measurement of radon is carried out to verify its mode [23]. Ground gamma radiation from the Netherlands National Radiation Monitoring Network and soil radionuclides are compared in detail by the Institute of Energy and Sustainability at the University of Groningen in Nijmegen, the Institute of Earth Energy and the Groningen Isotope Research Centre. It enables the development of reliable and accurate radon flux maps in countries with little or no information on radon flux values[28]. Radon potential maps of the Oslo region have been produced by the Avalonian Geophysical College in the United Kingdom, using geological experiments, combined with indoor radon measurements and airborne gamma spectrometer measurements. Their work shows that the map provides the best indication of radon hazard in the whole area[29]. Researchers in India conducted field measurements of radon and thorium emission from thorium development zones in the coastal areas of Kerala to compare radon and thorium emission rates. The spatial variability of the thorium emanation rate on the beach was measured in situ. In addition, the gamma radiation was investigated in detail, the outdoor gamma dose was calculated, and the correlation between the two parameters was found[30].

3. Radiation monitoring instrument
Radon is produced by the decay of radium, which is part of the original decay chain of thorium and uranium, and exists in many structural materials used in detectors[35]. The radioactive daughter isotope of $^{222}\text{Rn}$ is one of the most dangerous pollutants in small signal detection. Since the half-life of $^{222}\text{Rn}$ is relatively long. It is uniformly distributed in the target, and its attenuation can simulate signal events. This background source will become the main source of large-scale experiments in the future.

A new anti-radon system based on high-purity germanium detectors has been developed by the underground laboratory of Camfranco and the low-activity Laboratory of the University of Zaragoza in Spain to provide ultra-low background and copper electroforming technical services to obtain high-purity copper parts[36]. This is a method worth learning to prevent radon.

Cryogenic distillation technology is also an important way to reduce radon's influence on liquid xenon detectors. The literature[37-39] shows that researchers have done a lot of research on cryogenic distillation technology, effectively reducing the impact of radon. In addition, cryogenic distillation is already successfully applied in the separation of xenon from $^{85}\text{Kr}$, which is another important internal background source in liquid xenon experiments[40, 41].

4. Nuclear emergency monitoring
A large number of beta and gamma emitters, such as $^{90}\text{Sr}$ and $^{137}\text{Cs}$, appeared during the nuclear accident. There are a large number of beta and gamma emitters, accompanied by alpha particle emitters like plutonium isotopes (38Pu, 249Pu and 240Pu)[42-44]. In order to detect plutonium isotopes in high-beta and gamma background fields, the IAEA, the Graduate School of Medicine of Nagoya University and the Institute of Engineering of Hokkaido University require alpha particle detectors with low beta and gamma ray sensitivity and good energy resolution to distinguish plutonium isotopes from Radon and its daughters. Taking the contaminated area of Fukushima Nuclear Power Station as the research area, they developed a new type of detector (gadolinium gallium garnet (GAGG) scintillator combined with silicon photomultiplier tube (SiPM)), which is of great practical significance for detecting places with high beta and gamma background (such as plutonium pollution in the contaminated area of Fukushima)[45].

In order to improve the early warning capability of the Czech Republic radiation monitoring network, the Czech National Conservation Institute upgraded the large-capacity aerosol sampler by placing the NaI (TI) detector directly above the aerosol filter, and subtracted the background effect caused by radon decay products accurately based on principal component regression (PCR)[46].

In addition, many other researchers are committed to studying the impact of radon reduction in nuclear emergency monitoring.
5. Conclusions
Radon is a very important element in nature. Radon and its progeny can not be ignored. In this paper, the effects of radon on environment, detection means and application of radiation monitoring are reviewed. The results and technical of research institutes around the world are summarized. In the future, radon correction will develop more and more. First of all, there are many factors affecting climate, not only rainwater, air flow, temperature and humidity, but also artificial climate changes can be studied in depth to create conditions for experiments. Secondly, the complexity of geological conditions will bring new topics to radon correction research. Finally, in-depth study from particle physics detection is an important way to reduce the influences of radon and its progeny.

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