Indigenous development of online radon and thoron monitors for applications in Uranium mining and Thorium processing facilities

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Abstract

Using the conventional ZnS(Ag) detector, two different continuous radon monitors and an online thoron monitor have been developed, for application in underground U mine and thorium processing plant respectively. Special features of these monitors include low cost, high sensitivity and non-interference of humidity and trace gases. The capability of the radon monitor in networked radon monitoring in U mines, has been demonstrated. The thoron monitor is designed for stack monitoring of thoron release, in a thorium processing facility. Being highly sensitive, these monitors can also be used for environmental studies such as emission measurement from soil, building materials, thorium powders and monazite sands in High Background Radiation Areas. These indigenous monitors have the potential to serve as import substitutes for the Indian radon/thoron research programmes.

Introduction

The measurement of radon in air, is primarily based on the detection of alphas from radon and its decay products. Measurement could either be passive time-integrated or active measurement through grab or continuous sampling radon (Lucas, 1957; Abbady et.al., 2004). Time-integrated measurement of radon is mainly limited to dosimetric applications, where as-continuous measurement yields insight into spatio-temporal correlations, build-up in confined spaces, hourly variations induced by pressure and temperature variations, atmospheric transport, extreme excursions, duration of specific highs and lows etc. While increased computational capabilities on environmental modeling have given rise to greater needs for real time data, the corresponding developments in networking and data transmissions have made it possible, to achieve large scale simultaneous measurements. Such facilities are being increasingly developed as part of systems for earthquake predictions, in uranium mining, for environmental monitoring and geophysical research. Apart from these general applications, monitoring radon concentrations in Uranium mining and thorium processing facilities is important in evolving effective strategies to reduce radiation doses to occupational workers. With this in view, automatic online radon and thoron monitors have been developed as detailed in the following sections.

Description of systems

Online Radon Monitor

Using an innovative algorithm developed for correlating the total counts with the radon concentration, two versions of radon monitor have been developed. The portable version called SRM (Scintillation Radon Monitor), utilizes
a ZnS:Ag based scintillation cell for measurement of alpha from radon and its decay products. The other version named ECAS (Electrostatic Collection and Alpha Scintillation) is developed using an electrostatic chamber for collecting the charged decay products of radon on the ZnS:Ag surface. The details are as follows:

**Portable Radon Monitor - SRM**

The schematic of the microprocessor based SRM and its photograph are shown in Fig. 1a and Fig. 1b respectively. Radon is sampled into the scintillation cell (150 cc) through a "progeny filter" and "thoron discriminator" eliminating radon progenies and thoron gas respectively. The thoron discriminator based on "diffusion-time delay" does not allow the short lived thoron 220Rn (half life 55.6 sec) to pass through. The alpha scintillations from radon and its decay products formed inside the cell, are continuously counted for a user-programmable counting period by the PMT and the associated counting electronics. The alpha counts obtained are processed as per the developed algorithm, to display the concentration of radon. Considering the limitations on the range of the alpha particles (~6 cm), the dimensions of the scintillation cell were optimized to achieve high sensitivity (1.2 cph/Bqm⁻³) with lower detector volume (150 cc). This configuration is very useful for measurement of mass exhalation and surface exhalation of radon from various naturally occurring radioactive materials.

**High Sensitivity Radon Monitor - ECAS**

The low range of the alpha particles (~6 cm), makes it difficult to enhance the sensitivity of the SRM monitor, by just increasing the volume of the scintillation cell. Hence, an electrostatic collection technique for charged decay products of radon, on the ZnS:Ag scintillator has been used. The schematic and the photograph of ECAS are shown in Fig. 2a and Fig. 2b respectively. As in SRM, the sampling of radon into the detector volume (1000 cc) is carried out by diffusion, through "progeny filter" and "thoron discriminator" in succession. The electric field for various detector geometries and dimensions were modeled using commercial software and the optimal field with this simple-to-fabricate cathode and anode design was obtained. Accordingly, an electrical potential
of ~2 KV is applied to an aluminized mylar (12 μm thickness) covering the ZnS:Ag scintillator coated on the cathode, which is a solid perpex cylindrical block with a hemispherical head. The alpha scintillations produced by $^{222}$Rn, $^{218}$Po and $^{214}$Po are detected by the PMT and the associated counting electronics. The alpha counts obtained are processed by a microprocessor unit, to display the concentration of radon.

**Online Thoron Monitor**

The indigenously developed, microprocessor-based thoron monitor consists of two Lucas Scintillation Cells (LSCs) which are coupled to a separate photomultiplier tube with associated pulse preamplifier and scalar. Its schematic diagram and photograph are shown in Fig. 3a and Fig. 3b respectively. The LSC is a 2' dia and 3' height cell, made of S.S. 316 material with two inbuilt levels of radon-thoron progeny pre-filters for reducing background contamination. The flow to either of the LSCs is switched by the microprocessor at the intervals specified through programmable parameters. During each interval, while one cell counts the background, the other cell measures counts due to both thoron and the background activity. The unit automatically calculates and logs the thoron concentration data in the memory.

**Performance evaluation**

Various tests were carried out under controlled conditions in a chamber, to evaluate the performance of the monitors. The first set of experiments was carried out, to compare the measurements of online radon monitors against the commercially available system AlphaGUARD. A fair agreement was seen between ECAS, SRM and AlphaGUARD as shown in Fig. 4. Similarly, measurements with the indigenous thoron gas monitor were compared with that obtained using the commercial unit RAD-7 (Fig. 5). Since the background is high at higher thoron concentrations, the thoron monitor is tested upto
2 MBq/m³. For both the monitors, the variations were within 3%.

Measurement of radon emission from soil and building materials

We have demonstrated the use of ECAS for measuring the rate of radon emission from soil, using the “accumulator” technique. The soil is covered with the accumulator and the radon build up in it is monitored, using ECAS connected in a closed loop with an external pump. The buildup data is fitted to an appropriate model, to extract the radon emission rate from soil. For the experiment conducted in an open ground (Fig. 6), the accumulator technique (Sahoo and Mayya (2010)) gave

Applications of radon monitor

Features such as uninterrupted online operation, high sensitivity and free from humidity / trace gas interference, open up diverse applications in radon and thoron studies. These include calibration of passive detector systems, indoor/outdoor radon monitoring, network-based online radon monitoring in workplaces such as underground uranium mines, radon emission studies from soil/water/...
the radon emission rate as 80 Bq m$^{-2}$ h$^{-1}$, close to the value obtained using RAD-7. Since building materials are the second most important source of radon, ECAS was also used, to measure radon emission from cement samples (Fig. 7) according to the measurement procedure (Sahoo et al. (2007)). The emission rate was found to be 7.2 mBq kg$^{-1}$ h$^{-1}$.

**Networking in Uranium mines at Turamdih - field trial**

The networking capability with fast response of ECAS is useful for monitoring uranium mines and tailings pond, to give real-time spatial profiles of radon. In this context, few online monitors were installed inside the uranium mines (Fig. 8) at locations where the concentration of radon is expected to be high. Results of the measurements are shown in Fig. 9.

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**References**