A New-Type Detector for Atmospheric Radon Measurement
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Abstract: The proposed new portable and absolute atmospheric radon detector is designed to collect newly born radon daughters on the surface of a small metal disc. The technology is described as follows. At the first step, the existed radon daughters in atmosphere are scavenged at entrance by means of electric power. Then, new radon daughters are artificially loaded with negative charge in the decay chamber, followed by collection of such decay products with a small metal disc positively charged at the exit of the chamber. Finally, radon daughters carried on the small metal plate are measured by an alpha-counter with a ZnS(Ag) crystal. This instrument works with a sampling pump. The calibration of the instrument had been made at Asia Regional Coordination Laboratory for International Radon Metrology Programme in Hengyang, China. The calibration factors of radon are 1.66 Bq·m⁻³/cpm for sampling duration of 30 minutes and countering duration 60 minutes; 2.76 Bq·m⁻³/cpm for sampling duration 30 minutes and countering duration 30 minutes; 3.12 Bq·m⁻³/cpm for sampling duration 10 minutes and countering duration 60 minutes; 5.43 Bq·m⁻³/cpm for sampling duration 10 minutes and countering duration 30 minutes and 6.88 Bq·m⁻³/cpm for sampling duration 30 minutes and countering duration 10 minutes. This new detector as an atmospheric radon measurement has been advanced-loaded with negative electric charge can measure the short-lived radon decaying products. It was applied to measure several dwellings of Fuzhou city. The remarkable aspect of this method is its simplicity, not only in the sample collection equipment used, but also in the measurement instruments, as well as fast count gathering.

Keywords: radon; radon daughters; instrument; atmosphere

1. Introduction
Radon is the most important source of natural radiation. Its radiological importance resides not in the radon itself, but in its short-lived progeny [1,2], because when they are inhaled, they deposit and irradiate the respiratory tract.

The detection of radon is very important in environmental dosimetry studies. Recent years, there is an increasing scientific and regulatory interest concerning the indoor radon problem [3] and the instruments detecting radon and its progeny. This is due to the establishment that the radiation from radon and its progeny produces a risk of lung cancer by inhalation of air with high radon and radon progeny’s concentration over a long period of time. More then 50% of the total dose from natural sources is attributed to the inhaled radon and its progeny [4].

The measurement of the total radon progeny activity in atmosphere has been the traditional procedure used to control the levels of exposure due to the inhalation of these nuclides [5,6,7,8,9]. The instruments for the measurement of radon and its daughter products are mostly based on the detection of alpha particles, the energy of which ranged from 5.5 to 7.7 Mev (²²²Rn 5.5 Mev, ²¹⁸Po 6.0 Mev, ²¹⁴Po 7.7 Mev) (see Fig. 1). The instruments and methods used depend on whether radon or its progeny products are measured.
According to the time of measurements, there are two types of measurements: ( ) instantaneous; ( ) integrating. According to the condition of measurements, there are two types of measurements: ( ) continuous; ( ) separate. The radon sampling collectors can be subdivided into active collectors that require electric power to collect a sample, passive collectors that do not require electric power (maybe dry battery operated) and filter collector (charged electrostatic or not). Among the criteria used in the design of the instruments for measuring radon are field measurements applicability, portability, convenience, reliability and cost [10,11,12].

There are two filters at the two ends of chamber of double filter radon instruments. They make large air resistance for collecting air way so the strong power pump must be used in this kind of instrument, there is a negative pressure in the decaying chamber so that it leak air, and the chamber that the new progeny decay is big so that the double filter radon instruments are heavy [9]. In order to solve these problems, a small electric clearing and electric collecting system are used in this instrument.

2. Experimental
The main parts of the new portable and absolute air radon detector are shown in Fig. 2. The air flow

FIG. 2. The main parts of the new portable and absolute atmospheric radon detector
(1) Collecting old radon progenies; (2) Eliminating old progenies; (3) The space of radon decay; (4) Collecting new radon progenies; (5) Small electrical fan; (6) Entrance of atmosphere; (7) Exit of atmosphere.
system is pumped by a small electric fan with power of 6v. When air enter into the instrument from the entrance, the collecting machine which charged the positive electric collects the old progenies in atmosphere in order to calculate the density of old radon progenies in atmosphere. Then the air gets into the mc-cleaning system to eliminate old radon progenies in air. The air that the old radon progenies are cleaned up is put into the decaying chamber, with a size of 18L and radon decay to new radon progenies. The new radon progeny is collected by a small metal plate, which is charged with positive electricity. Finally, the detector can automatically calculate the radon density.

2.1. Experimental determination of the collection efficiency \( E_c \)

To calculate the collection efficiency \( E_c \), the methodology firstly described is followed. Air flow from the decaying chamber are taken by means of collecting device holders \( I_1 \) and \( I_2 \) that contain two metal plate of 0.79 \( \text{(cm}^2 \text{)} \). The air flowrate is adjusted to 10 \( \text{L} \cdot \text{min}^{-1} \). The sampling duration is 30 min. Then the activities of both plates are measured in two alpha-counters of known efficiency, and the collection efficiency is calculated experimentally with formula (1).

\[
E_c = \frac{I_1 - I_2}{I_1} \times 100\%
\]  

(1)

where \( I_1 \) is the counts on the first metal plate and \( I_2 \) is the counts on the next one.

In Table 1 the several values of the experimental efficiency \( E_c \) for the various measurement are shown.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>( n_1 ) (Counts / cpm)</td>
<td>179</td>
<td>182</td>
<td>184</td>
<td>168</td>
<td>201</td>
<td>193</td>
</tr>
<tr>
<td>( n_2 ) (Counts / cpm)</td>
<td>128</td>
<td>124</td>
<td>130</td>
<td>121</td>
<td>146</td>
<td>131</td>
</tr>
<tr>
<td>( E_c ) (%)</td>
<td>28.5</td>
<td>31.9</td>
<td>29.3</td>
<td>28.0</td>
<td>27.4</td>
<td>32.1</td>
</tr>
</tbody>
</table>

The data in table 1 show that the average collecting efficiency \( E_c \) is 29.5%. Because the \( E_c \) is low, the sampling duration and the measuring duration are long. The adapted working mode is that sampling duration and measuring duration are 30 min individually (see table 2).

2.2. Detector calibration

The detector was calibrated with a large type of standard chamber at Asia Regional Coordination Laboratory for International Radon Metrology Programme in Hengyang, China. The working mode with that sampling duration is 10 min. and measuring duration is 10 min. is adopted. When a parameter was changed, at least five readings were read, and then the average value was calculated. The relation between the radon concentration and the reading of detector can be modeled with many methods, and the results also are different. However, the linear equation model with zero intercept was adopted. The calculating formula of radon concentration in common atmospheric environment was following:
\[ C = K \times I \]  \hspace{1cm} (2)

Where

- \( C \) is radon concentration (Bq·m\(^{-3}\));
- \( I \) is the reading of detector (cpm);
- \( K \) is calibrating factor of radon concentration in common environment.

The data of calibration are shown in Table 2. The total related uncertainty of radon concentration, which was provided by this Laboratory in Hengyang, was 8.7%.

### Table 2. The calibrating factor in various working modes

<table>
<thead>
<tr>
<th>Working mode ((t_1 + t_2))</th>
<th>Calibrating factor ((K)) (\text{(Bq·m}^{-3}/\text{cpm)})</th>
<th>Working mode ((t_1 + t_2))</th>
<th>Calibrating factor ((K)) (\text{(Bq·m}^{-3}/\text{cpm)})</th>
</tr>
</thead>
<tbody>
<tr>
<td>10+10</td>
<td>14.5</td>
<td>10+60</td>
<td>3.12</td>
</tr>
<tr>
<td>30+10</td>
<td>6.88</td>
<td>30+30</td>
<td>2.76</td>
</tr>
<tr>
<td>10+30</td>
<td>5.43</td>
<td>30+60</td>
<td>1.66</td>
</tr>
</tbody>
</table>

\(t_1\): sampling duration (minute); \(t_2\): countering duration (minute).

### 2.3. Detector comparison

This detector was compared with balloon double membrane radon instrument in Hengyang. The compared result was shown in table 3. The data in table 2 indicate that error of the measuring results with two instruments that were compared with concentration in standard radon chamber is less than \(\pm 10\%\), so the results are reliable.

### Table 3. The comparison with balloon double membrane radon instrument which is in use

<table>
<thead>
<tr>
<th>No.</th>
<th>Balloon double membrane radon instrument ((K=0.398\text{Bq}·\text{m}^{-3}/\text{cpm}))</th>
<th>Concentration in radon chamber (\text{(Bq}·\text{m}^{-3}))</th>
<th>Error (%)</th>
<th>This new radon detector ((K=14.5\text{Bq}·\text{m}^{-3}/\text{cpm}))</th>
<th>Concentration (\text{(Bq}·\text{m}^{-3}))</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>326</td>
<td>310</td>
<td>5.2</td>
<td>293</td>
<td>-5.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1495</td>
<td>1570</td>
<td>-4.8</td>
<td>1610</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1542</td>
<td>1620</td>
<td>-4.8</td>
<td>1653</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>456</td>
<td>450</td>
<td>1.3</td>
<td>438</td>
<td>-2.7</td>
<td></td>
</tr>
</tbody>
</table>

### 3. Advantage of this detector

The greatest advantage of this detector we designed for measuring Rn is that filters are not used at the entrance and exit between the decaying chamber, but only used a small metal plate charged with positive electricity individually at both sides. This gives detailed information on Rn concentration.

Therefore, these disadvantages encountered in measuring Rn concentration such as heavy weight, strong pump, leaking air and load noise can be overcome by means of the electrical collection and electrical clearance.

Another great advantage is fast response to change in the Rn level in the air. When a detector draws in
air with Rn and makes measurements, the $^{222}\text{Rn}$ decays within the decaying chamber and there is buildup of $^{222}\text{Rn}$ progeny. $^{214}\text{Po}$, the relatively long-lived $^{222}\text{Rn}$ progeny (see Fig. 1), takes many hours to decay away. Therefore, this detector is capable of focusing at $^{218}\text{Po}$ alone and discarding information on $^{214}\text{Po}$.

Due to use a small power electrical fan, the air can be pumped up by the electrical power with A.C. and D.C. So it works expediently indoor and outdoor.

4. Results
After this detector was calibrated in Hengyang, it was used to measure radon concentration in 15 office rooms, 23 dwellings and 20 outdoor points. The measuring results were shown in table 4. The data in table 4 indicate that outdoor radon concentration is the lowest, the radon concentration in the rooms closed window is larger than that in the room opened window. They are concordance with general rule. Because there are air conditioners in office rooms, their measuring results are larger than that in resident rooms.

<table>
<thead>
<tr>
<th>Outdoor concentration (Bq·m$^{-3}$)</th>
<th>Radon concentration in office room (Bq·m$^{-3}$)</th>
<th>Radon concentration in resident room (Bq·m$^{-3}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed window</td>
<td>Open window</td>
<td>Closed window</td>
</tr>
<tr>
<td>11-47</td>
<td>52-218</td>
<td>41-63</td>
</tr>
<tr>
<td>52-218</td>
<td>41-63</td>
<td>22-94</td>
</tr>
</tbody>
</table>

5. Conclusions
A portable radon detector has been implemented based on the positive electricity collection with a small metal plate. The remarkable aspect of this instrument is its simplicity, not only in the equipment used to collect the samples, but also in the instrument used for measurement. Moreover, the counting protocols are simple and fast.

Because the unattached fraction implies a greater risk than the same amount of activity attached to aerosols, an important improvement in collecting samples with positive electricity is obtained, carrying out measurement by forcing the unattached radon and its progeny with negative during the sampling.

Acknowledgements
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Reference


