

## Measuring Radon Concentration Levels in Fertilizers using CR-39 Detector

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**Keywords:** Radon; CR-39; Fertilizer; Dose rate.

**Abstract.** Radon concentrations in fertilizer samples collected from agricultural areas in Cameron Highlands and Penang, Peninsular Malaysia were studied throughout this paper. The concentrations were measured using a sealed-can technique based on the CR-39 SSNTDs. Results indicate that the concentration of radon in the phosphorus sample was the highest whereas the minimum values were found in CDM (Cow dung manure). The levels of radon concentration were found to lie within the range of  $(634.01 \pm 51.42$  to  $79.25 \pm 23.24)$  Bq m<sup>-3</sup>.

### Introduction

Radon-222 is a colorless, odorless poisonous gas that can lead to lung cancer if being greatly exposed [1]. Epidemiological results from a case controlled extrapolation of the radon gas being exposed underground attributed to a considerable amount of lung cancers to the working miners [2]. In the US population, lung cancer is believed to be responsible for 31% and 25% of all cancer deaths in males and females respectively [3]. Radon-222 is the most significant natural isotope of the radioactive element. It is a decay product of <sup>238</sup>U and has a half life of 3.82 days [4]. <sup>238</sup>U has a strong association with phosphate ore, which is the major raw material for the production of phosphate fertilizers. It was reported that <sup>238</sup>U is elevated in phosphate ores of a sedimentary origin. The latter contains also an amount of natural radioactivity of <sup>232</sup>Th and <sup>40</sup>K due to a geological reason [5]. The fertilizers derived from the phosphate rocks further contain naturally occurring radioactive nuclides, which are members of the thorium and uranium decay series. These radioactive nuclides will find their way into the crop through the uptake of these fertilizers and might pose radiological hazards to human health through the consumption of agricultural produce [6]. The average of the worldwide annual effective dose from the natural sources of radiation in areas of normal background is reported to be 2.4 mSv. An amount of 1.275 mSv is estimated to be contributed by radon [7].

In Malaysia, mineral fertilizers account for more than 90 percent of the fertilizers used by all types of farming systems. The main fertilizers are urea, ammonium sulphate, calcium ammonium nitrate, phosphate rock, super phosphates, ammonium phosphate, potassium chloride, potassium sulphate and NPK, NP and PK compound fertilizers. Furthermore, the government promotes the use of organic fertilizers in Malaysia for two main reasons. First, organic agriculture is important for the sustainable use and management of natural resources. Second, in the NAP3 (Third National Agricultural Policy), the organic agriculture is identified as a niche market opportunity for fruits and vegetables [8].

The aim of this paper is to measure the radon concentration in the fertilizers found in Malaysia using a nuclear track detector (CR-39) to assess the exposure risk for the persons working in the fields where a lot of fertilizers are being used to increase the crop yields in terms of occupational exposure.

## Collection and Preparation of Samples

Fertilizer samples were collected from Cameron Highlands and Penang, Malaysia. These samples were oven-dried at 110 °C for 24 h to remove moisture. Then, the fertilizer samples were grinded and sieved through a 2 mm nylon mesh to ensure homogeneity. Each 20 g of these fertilizer samples was transferred to separate plastic cans (5.5 cm diameter × 10 cm height) and was then sealed. Each sample was equipped with a CR-39 plastic track detector (1.5 cm × 1.5 cm), produced by the Track Analysis Systems Ltd., Napier House, Meadow Grove, Bristol, UK. The detector was fixed at the top inside of the cans lid prior to closing, as shown in figure 1. It was further found that radon and its daughters reached an equilibrium concentration after three weeks. Thus, the equilibrium activity of emergent radon could be obtained based on the geometry of the can and on the exposure time. After 90 days of exposure, the detectors from all the cans were retrieved. The CR-39 detectors were etched at several conditions. The optimum condition for the etching of the CR-39 detectors was 6.25% N - NaOH at 70 °C with an accuracy of  $\pm 0.1^\circ\text{C}$  and an etching time of 6 h. After etching, the detectors were washed in distilled water and were then dipped for a few seconds in 3% acetic acid solution. Afterward, the detector was washed again and allowed to dry in air. The numbers of tracks in 40 fields were scanned for each detector using an optical microscope with 400× objective lens to determine the track density per  $\text{cm}^2$  [9, 10]. The CR-39 detector records the tracks of alpha particles emitted by the radon gas, which was produced through the alpha decay of radium. The CR-39 detector records the tracks of alpha particles emitted by radon gas. The track density ( $\rho$ ) ( $\text{track m}^{-2}$ ) is related to the radon activity concentration  $C_{\text{Rn}}$  ( $\text{Bq m}^{-3}$ ) and the exposure time  $T$  (h), based on the formula given by [11]. In this formula, where  $k$  is the calibration factor of CR-39 and has a value of 0.024 ( $\text{tr. Cm}^{-2}$  per  $\text{Bq. m}^{-3}.\text{d}$ ) [12].

$$\rho = k \times C_{\text{Rn}} \times T \quad (1)$$

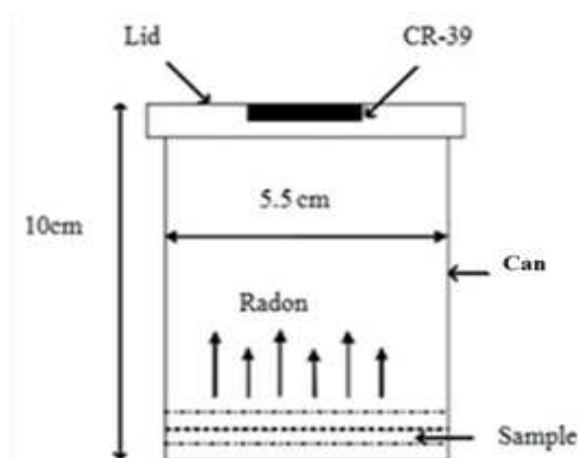


Fig. 1. Experimental set-up for the measurement of radon exhalation and radium content

## Result and Discussion

Table 1 shows the values of radon concentration in different fertilizers that were collected from Cameron highlands and Penang. In the phosphorus sample, the concentration was  $(634.01 \pm 51.42) \text{ Bq m}^{-3}$ . That is, a high concentration of radon found in the phosphorus fertilizers, which were used in the agricultural area. The minimum value was found in ammonium sulphate; its value is  $(79.25 \pm 23.24) \text{ Bq m}^{-3}$ . The average radon concentrations were found to be  $(277.84 \pm 29.41) \text{ Bq m}^{-3}$ . The study further revealed that the average concentration obtained in this study is lower than the reported average of radon concentration in Hungary, which was ranged between  $(200 \pm 14 \text{ to } 1139 \pm 38) \text{ Bq m}^{-3}$  [13]. The highest concentration recorded in this study was lower than the concentration in Egypt which was  $(7160 \text{ to } 8765) \text{ Bq m}^{-3}$  [13].

The concentration in organic fertilizers was lower than the concentration in NPK, TSP, RF and SSP

Table 2, Statistical data was calculated by using SPSS programme for radioactivity concentrations of  $^{222}\text{Rn}$  and annual effective dose fertilizers samples. These results were indicated the radon concentration is higher that the results are reported in UNSCEAR [14], whilst theses results lower than the concentration is mentioned in ICRP [15].

## Conclusion

The fertilizers used in Cameron highlands and Penang were measured for the radon concentration content. The results show that the radon in phosphorus was higher than in other types of fertilizers. Futhermore, the concentration in organic fertilizers was lower than the concentration in Chemical fertilizers.

The phosphorus fertilizer samples were found to have radon concentration of  $(634.01 \pm 51.42) \text{ Bq m}^{-3}$ , which represents a high radon content used in the agricultur area. The minimum values were found in ammonium sulphate,  $(79.25 \pm 23.24) \text{ Bq m}^{-3}$ . Considerably, these values were greater than the ones obtained by UNSCEAR [14] as well as these results were below the recommended action level by ICRP [15].

Table 1. Radon concentration level (  $\text{Bq/m}^3$  ) in fertilizer samples

| Samples                                  | $^{222}\text{Rn}$  |
|------------------------------------------|--------------------|
| NPK                                      | $225.37 \pm 45.16$ |
| Urea                                     | $94.12 \pm 14.59$  |
| Muriate Potash                           | $148.59 \pm 37.00$ |
| Phosphorus (34% $\text{P}_2\text{O}_5$ ) | $634.01 \pm 51.42$ |
| Ammonium Sulphate (21%N)                 | $79.25 \pm 23.24$  |
| Potassium ( $\text{K}_2\text{O}$ 60%)    | $118.87 \pm 16.18$ |
| Ammonium Sulphate Nitrate                | $108.97 \pm 17.18$ |
| Triple Supper Phosphate (TSP)            | $386.35 \pm 31.08$ |
| Rock Phosphate                           | $416.07 \pm 46.89$ |
| Single Superphosphate (SSP)              | $455.69 \pm 66.71$ |
| Organic                                  | $172.81 \pm 30.29$ |

Table 2. Statistical data (SPSS output) for radioactivity concentrations of  $^{222}\text{Rn}$  and annual effective dose fertilizers samples

| Statistical       | Range  | Minimum | Maximum | Mean   | Std. Error | Std. Deviation | Skewness        |
|-------------------|--------|---------|---------|--------|------------|----------------|-----------------|
| $^{222}\text{Rn}$ | 594.39 | 59.43   | 653.82  | 277.84 | 29.41      | 158.39         | $1.33 \pm 0.43$ |

## Acknowledgements

This study was supported by the School of Physics, Universiti Sains Malaysia. Financial support was provided by the School of Physics, Universiti Sains Malaysia 1001/PFIZIK 846086.

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