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Preliminary Development of Thoron Exposure System in the Philippines

Kazuki Iwaoka*
Hirosaki University, Japan
National Institutes for Quantum and Radiological Sciences and Technology, Japan
Health Physics Research Section, Atomic Research Division
Philippine Nuclear Research Institute
Department of Science and Technology (PNRI-DOST)
Republic of the Philippines

Lorna Jean H. Palad
Eliza B. Enriquez
Fe M. dela Cruz
Christopher O. Mendoza
Juanario U. Olivares
Ryan Joseph Aniago
Christian L. dela Sada
Health Physics Research Section, Atomic Research Division
Philippine Nuclear Research Institute
Department of Science and Technology (PNRI-DOST)
Republic of the Philippines

Masahiro Hosoda
Shinji Tokonami
Hirosaki University, Japan

ABSTRACT

The influence of ^{220}Rn (thoron) which is a gaseous radioisotope like ^{222}Rn (radon) has been the focus of attention of recent studies concerning the protection of the general public from natural radiation. Hence, it is necessary to investigate the possibility of exposure to thoron in the Philippines. Passive detectors, which do not need external power, are often used for measurements for thoron concentration in the environment. However, it is necessary to check if the passive detectors can appropriately work by being exposed to thoron at several thoron concentrations before conducting the investigation. In this study, a thoron exposure system was developed in the Philippines to validate the passive detectors for thoron measurement and to test its performance. The thoron exposure system in this study can control the thoron concentration at the range of 5.9×10^4 to 1.5×10^5 Bq m^{-3}. The thoron exposure system will be utilized to validate the passive detectors for the investigation of thoron exposure in the Philippines in the future.

Keywords: Thoron, radiation measurement, quality assurance, natural radionuclides

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**Corresponding Author*

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INTRODUCTION

It is well known that more than half of public exposure from natural radiation is due to ^{222}Rn(radon) and ^{220}Rn(thoron). Radon is generated by the alpha decay of ^{226}Ra, which is derived from radioactive decays of ^{238}U as an initial parent nuclide. Thoron is generated by the alpha decay of ^{224}Ra, which is derived from radioactive decays of ^{232}Th as an initial parent nuclide. The half-life of radon (3.82 days) is longer than that of thoron (55.6 seconds). It is also believed that radon inhalation increases the risk of lung cancer and is regarded as the second risk factor (WHO 2009). In the current International Commission on Radiological Protection (ICRP) Publication 126, an annual average radon activity concentration of 300 Bq m^{-3} is recommended as the reference level in workplaces and all other buildings (ICRP 2014). In the Philippines, a national survey for indoor radon concentration has been performed in order to investigate the risk of exposure of the general public to radon. Until now, indoor radon concentration above the ICRP reference levels has not been reported (Dela Cruz et al. 2012). On the other hand, the influence of thoron on human health impacts has been the subject of recent studies (Hosoda et al. 2014). Although thoron and radon are exhaled from natural substances, such as soil, rock, and building material, and cause internal exposure, it has been regarded that the influence of thoron is too small compared to that of radon. However, it was found that thoron exposure is equal to or exceeds radon exposure, and is thus not negligible for dose estimation in some areas in Asia, such as India and China (Kudo et al. 2015; Omori et al. 2016). Therefore, it is necessary to investigate the possibility of thoron exposure in the Philippines.

Passive detectors, which do not need external power, are often used for measurements of thoron concentration as well as radon concentration in the environment. To test whether the detectors can appropriately work before conducting the actual investigation, thoron exposure facilities are needed. Although there are thoron exposure facilities in other countries, such as the Hirosaki University in Japan (Pornnumpa et al. 2016; Pornnumpa et al. 2017; Janik 2017), there are no similar facilities in the Philippines. Hence, there are no means for any domestic research organization in the Philippines to validate the devices for thoron measurement. In this study, a thoron exposure system was developed in the Philippines to easily validate the devices for thoron measurement in the country. The performance of the system was tested.

MATERIALS AND METHODS

The thoron exposure system was developed at the Philippine Nuclear Research Institute of the Department of Science and Technology with reference to literature (Pornnumpa et al. 2016; Pornnumpa et al. 2017). A schematic diagram of the system is shown in Figure 1. The system consists of three units: thoron generator unit; exposure unit; and monitoring unit. Air in the room goes to the thoron generator unit using an air-pump with a flow rate of 1L min^{-1}, which then goes to the thoron exposure unit. Air in the thoron exposure unit goes outside the monitoring unit with a flow rate of 1L min^{-1}. In the thoron generator unit, the amount of thoron exhaled from the thoron source depends on the humidity of the flowing air (Pornnumpa et al. 2016; Pornnumpa et al. 2017). Therefore, air that has stable humidity goes to the thoron source through a humidifier. A sectional view of the humidifier is shown in Figure 2. Dry air from the dryer goes to two pathways (airA and airB). The airA bubbles water to generate the humidity. The airB just passes through without any significant event. airA and airB join together eventually to go through the thoron source. The stable humidity can be maintained by controlling the flow rates of airA and airB using the regulators. The amount of thoron generated (i.e., thoron concentration in the thoron exposure chamber) can be controlled by changing the humidity of the flowing air or amount of thoron source. In the exposure unit, thoron gas in the thoron exposure chamber can be homogeneously mixed by a circulator inside the exposure chamber. Dimensions of the thoron exposure chamber are as follows: 20 cm in length; 30 cm in width; and 20 cm in height. Thoron gas in the thoron exposure chamber goes to the monitoring unit. In the monitoring unit, continuous measurements of thoron concentration in the thoron exposure chamber can be performed. The humidity and temperature in the thoron exposure chamber can be continuously monitored using an environment monitor.

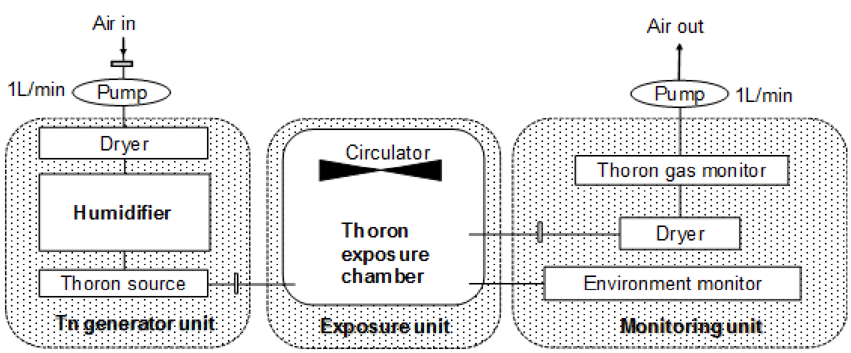

Figure 1. A schematic diagram of the thoron exposure system.

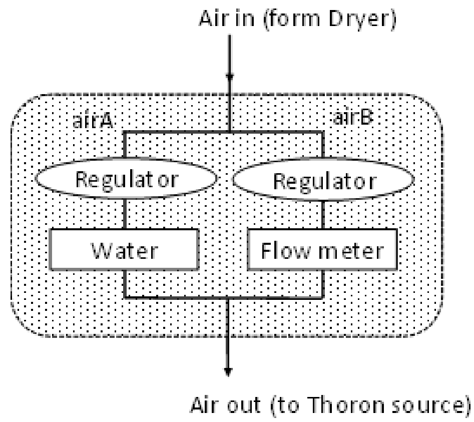

Figure 2. A sectional view of the humidifier in the thoron exposure system.

The performance of the thoron exposure system developed in this study was tested as follows. Humidity for the thoron source and thoron exposure chamber was maintained at 71-85%, which is within the range of typical relative humidity (RH) in Manila (PAGASA 2017), by controlling the humidity in the thoron generator unit. Temperature for the thoron exposure chamber was set at approximately room temperature. A recorder (TR-73U, T&D Corporation) was used for monitoring RH and temperature. A tube filled with a gas mantle, which has high activity for thoron and very low activity for radon, was used as thoron source (i.e., tube source). Thoron gas generation was performed on three situations (first: utilization of one tube source; second: utilization of two tube sources; third: utilization of three tube sources). Humidities of the thoron exposure chamber and tube sources were stabilized in advance before thoron gas started to flow through the thoron exposure chamber. A detector with electrostatic collection (RAD7, DURRIDGE Company Inc.) was used for thoron gas monitoring. The RAD7 can collect radon and thoron decay products on a silicon ion-implanted semiconductor using a high electric eld, and alpha particles released from the products can be measured with energy discrimination (Burnett et al. 2001). Because the RAD7 is affected by humidity, the dryer was installed before the RAD7. Monitoring by the RAD7 was performed for 8 hours at 30-minute intervals at a flow rate of 1L min^{-1}. Before thoron gas in the thoron exposure chamber reaches the RAD7, thoron concentration decreases because of its short half-life. Therefore, the indicated values of thoron concentration in the RAD7 were corrected to the actual values of thoron concentration in the thoron exposure chamber using the following equations:

$$F_t = 1/\{e^{(-\lambda \times V/R)}\} \quad (1)$$

$$C = C_r \times F_t \times F_d \times F_c \quad (2)$$

where F_t is the correction factor for decay compensation during the gas' flow from the thoron exposure chamber to the RAD7's dryer (-); λ is the decay constant of thoron (s^{-1}); V is the volume of tubes from the thoron exposure chamber to the RAD7's dryer (cm^3); R is the flow rate($cm^3\ s^{-1}$); C is the thoron concentration in the thoron exposure chamber; C_r is the indicated value of thoron concentration in RAD7; F_d is the correction factor for decay compensation during the gas' flow from the RAD7's dryer to the RAD7 (-); and F_c is the correction factor for responsivity of RAD7(-). V was set at 10.8 cm^3. R was set at 1.0 L min^{-1} (17 $cm^3 s^{-1}$). F_d was assumed to be 2 on the basis of the RAD7's manual. F_c was set as 1.0 as on the basis of the references (Pornnumpa et al. 2016; Pornnumpa et al. 2017).

RESULTS AND DISCUSSION

The values of thoron concentration, RH, and temperature in the thoron exposure chamber with two tube sources are shown in Figure 3 as a representative for the three situations of the tube source. The thoron concentration in the thoron exposure chamber was stably maintained within a constant temperature and humidity range. The values of thoron concentration in three situations of the tube source are shown in Figure 4 and Table 1. The thoron concentration, based on the average of 16 measurements, was maintained at 5.9 × 10^4 Bq m^{-3} (Relative standard deviation (RSD): 1.6 %) for one tube source, 1.1 × 10^5 Bq m^{-3} (RSD: 1.7 %) for two tube

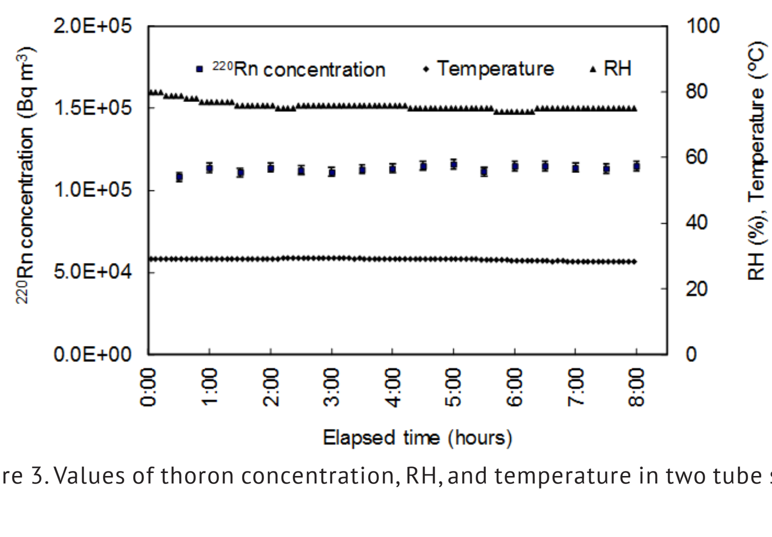

Figure 3. Values of thoron concentration, RH, and temperature in two tube source.

sources, and 1.5 × 10^5 Bq m^{-3} (RSD: 1.6 %) for three tube sources. It was found that the thoron exposure system developed in this study can control the thoron concentration by adjusting the amount of thoron source. These values for thoron concentration are higher than those in the facilities in other countries, which range from 4.1 × 10^3 to 2.6 × 10^4 Bq m^{-3} (Germany) and 4.2 × 10^3 to 4.6 × 10^4 Bq m^{-3} (Japan) (Janik 2017). Although high concentration may be a beneficial function for shortening the exposure time, the first advantage of the exposure system in this study over thoron exposure facilities in other countries is its small structure (Janik 2017) which can be easily developed. Therefore, methods in this study can be useful for scientific research institutions in countries wherein financial resources are a constraint for construction of such calibration systems.

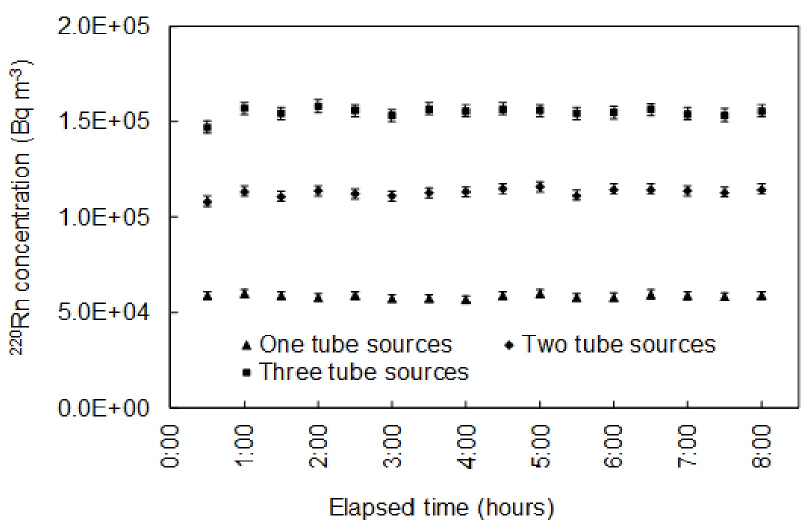

Figure 4. Values of thoron concentration in each condition for the tube source.

Table 1. Thoron concentration in each condition for tube source

Source condition	Thoron concentration (Bq m^{-3})
One tube source	5.9 × 10^4 (0.46)
Two tube sources	1.1 × 10^5 (0.43)
Three tube sources	1.5 × 10^5 (0.46)

The values of concentration were obtained by averaging 16 measurements. The parentheses mean the relative standard deviation (1 sigma) based on 16 measurements.

CONCLUSIONS

In summary, a thoron exposure system was developed in the Philippines to easily validate the devices for thoron measurements in the country. The performance for the system was tested. The thoron exposure system in this study can control the thoron concentration at the range of 5.9×10^4 to 1.5×10^5 Bq m^{-3} by adjusting the amount of thoron source. In future studies, prolonged working periods will be made to ensure the stability of the thoron exposure system. In addition, inter-comparison studies for performance improvement of the thoron exposure system will be conducted in collaboration with other research institutes for method validation.

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AUTHOR CONTRIBUTIONS

Kazuki Iwaoka designed the study and wrote the manuscript. Lorna Jean H. Palad contributed to the analysis and interpretation of the data, and assisted in the preparation of the manuscript. Eliza B. Enriquez and Fe M. dela Cruz contributed to installation of the chamber. All authors contributed extensively in the discussion of the work and in the review of the manuscript.

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Kazuki Iwaoka <iwaoka@hirosah-u.ac.jp> is a Visiting Scientist at the Health Physics Research Section, Atomic Research Division, Philippine Nuclear Research Institute - Department of Science and Technology (PNRI-DOST), Republic of the Philippines, and an Assistant Professor of Institute of Radiation Emergency Medicine, Hirosaki University.

Lorna Jean H. Palad is a Senior Researcher at the Health Physics Research Section, Atomic Research Division, Philippine Nuclear Research Institute - Department of Science and Technology (PNRI-DOST), Republic of the Philippines. She graduated with the degree of Bachelor of Science in Chemistry from the University of the Philippines. She is currently the leader of the NORM (naturally-occurring radioactive materials) project of the PNRI-DOST. She is mainly involved in the assessment of natural radioactivity in NORM industries in the Philippines.

Eliza B. Enriquez graduated with the degree Bachelor of Science in Fisheries from the University of the Philippines Diliman in 1981. She is currently the leader of

the marine radioactivity monitoring project of the Philippine Nuclear Research Institute, Department of Science and Technology (PNRI-DOST). She is mainly involved in the assessment of natural and artificial radioactivity in seawater, sediment and biota from various marine areas in the Philippines. She is the focal person of the regional database in marine radioactivity in the Asia-Pacific region.

Fe M. dela Cruz is a Senior Researcher at the Health Physics Research Section, Atomic Research Division, Philippine Nuclear Research Institute - Department of Science and Technology (PNRI-DOST), Republic of the Philippines. She graduated with the degree of Bachelor of Science in Chemistry from the Far Eastern University. She is currently the leader of the radon and thoron monitoring project of the PNRI-DOST.

Christopher O. Mendoza is a Registered Chemist and a Science Research Specialist II at the Health Physics Research Section, Atomic Research Division, Philippine Nuclear Research Institute - Department of Science and Technology (PNRI-DOST), Republic of the Philippines. He is also the designated Pollution Control Officer of the Institute.

Masahiro Hosoda is a Lecturer at the Department of Radiological Life Sciences, Hirosaki University Graduate School of Health Sciences.

Shinji Tokonami is a Director at the Institute of Radiation Emergency Medicine, Hirosaki University.

Juanario U. Olivares is a graduate of Bachelor of Science in Biology from the College of Arts and Sciences, Cagayan State University in 2006. He is currently employed at Health Physics Research Section, Atomic Research Division, Philippine Nuclear Research Institute - Department of Science and Technology (PNRI-DOST), Republic of the Philippines and holding a position of Science Research Assistant. His research interests include Radiation Biology, Environmental Radiation Monitoring and Biological Sciences.

Ryan Joseph Aniago is a Science Research Specialist at the Health Physics Research Section, Atomic Research Division, Philippine Nuclear Research Institute - Department of Science and Technology (PNRI-DOST), Republic of the Philippines.

Christian L. dela Sada is a Project Assistant II at the Health Physics Research Section, Atomic Research Division, Philippine Nuclear Research Institute - Department of Science and Technology (PNRI-DOST), Republic of the Philippines.