

## Radon Concentration in Workplace Indoor Air

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**ABSTRACT:** Radon exists naturally in the air. It can accumulate inside the buildings which may affect the indoor air quality. Radon is a radioactive gas that produces alpha particles during decay time. The alpha particles might cause harm to the human lungs and stomach. Inhalation of radon is one of the causes of lung cancer disease. Samples of inhaled radon in different rooms at the workplace were taken hourly through a passive diffusion chamber. The detection method was done using Alpha Spectrometry. The short term measurement was applied in the study to monitor the average weekly radon reading in different rooms in the Medical Imaging Laboratory of the University of Selangor (UNISEL). All tested rooms showed the existence of radon gas with different concentrations. Some of them showed the maximum reading of radon concentration which was higher than the radon action level of 148Bq/m<sup>3</sup> or 4pCi/l. Their weekly average of radon concentration is contributing almost 50% of the accumulated radon concentration in the laboratory. It is highly recommended that monitoring the concentration of radon in indoor air is performed to ensure it is at a safe and healthy level.

**Keywords -** Air, Indoor, Inhalation, Measurement, Radon

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### 1.0 INTRODUCTION

Radon exists inside the buildings which may affect the indoor air quality. It was found that different buildings may have different measurements of radon concentration (Mohamed & Marlia, 2018; Nisar et al., 2015). Radon is a natural radioactive element occurred in the form of gas, which emits alpha particles when it decays into Polonium. The alpha particles may cause harm to human organs such as lungs during breathing time or even to the stomach after drinking the contaminated water with radon. The possibility of radon causing harm to the lungs depends on the concentration level in the inhaled air. It was found that radon is the second cause of lung cancer after smoking (Nancy & Gary, 2018). The lung cancer risk increases when radon exposure is also increasing. The high concentration of radon in indoor air has a high considerable risk of lung cancer in the range from 3% to 14% (Hajo & Ferid, 2009).

Most of the Malaysian workers spend one-third of their day time at the workplace. It is very important to perform radon monitoring because there is a possibility of some workers may expose themselves to a high concentration of this radioactive gas (Martin et al., 2012). Some studies (Font et al., 2008; Espinosa et al., 2009; Rosabianca et al., 2012) showed that the average radon levels in underground workplaces are more than action level of 148 Bq/m<sup>3</sup> or 4 pCi/l as per recommended by the United States Environmental Protection Agency (EPA).

According to Health Facts 2017 report published by Ministry of Health Malaysia, the respiratory system diseases are the second highest cause of death in government hospitals after the circulatory system. There are many causes of respiratory system diseases, including radon inhalation. The aims of this study were to investigate the concentration amount of radon in the inhaled air at the workplace, to identify the rooms with a potential risk of having high concentration of radon, and to analyze any potential ways to avoid a high concentration of radon in indoor workplace.

## 2.0 METHOD

### 2.1 Room Specification

The samples of radon concentration in different rooms at Medical Imaging Laboratory of UNISEL Shah Alam’s campus have been performed hourly using a passive diffusion chamber as per reference of study by Rydock in 2001 (Rydock et al., 2001). The Medical Imaging Laboratory is located at ground floor consisting of an x-ray room, darkroom, mammography room, lecture hall, two lecturer’s rooms, and filing room. Fig. 1 represents the layout of the laboratory.

These rooms have different dimensions and specifications. The inner walls of x-ray and mammography rooms were built up from barium plaster. There is a window in the wall of lecturer’s rooms while the mammography room, darkroom, filing room, X-ray room and lecture hall do not have any built-in window. The rooms have a door with different feature and design. The floor of the lecture hall is totally covered by carpet and the rest of the rooms are vinyl flooring. All rooms are equipped with the air-conditioning system except the filing room. Only darkroom has a fan type of ventilation device.

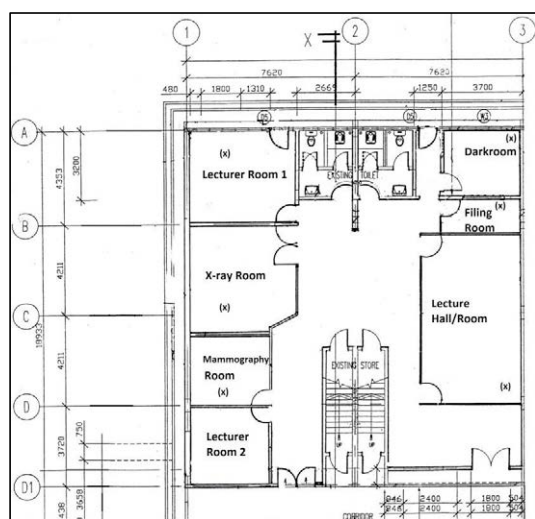


Figure 1 UNISEL Medical Imaging Laboratory Layout

### 2.2 Radon Detector

There are many types of detectors used to measure the radon level. Most of the detectors are used as a continuous radon monitor (Nisar et al., 2017). In this study, the Airthings Wave radon detector as shown in Fig. 2 was used to measure the amount of radon gas, temperature, and humidity in each room. Alpha Spectrometry is the method used to detect radon gas. The detector was placed at least 50 cm above floor level and at least 150 cm from the nearest door, window or ventilation device as recommended by the manufacturer. Its location inside each room is indicated as (x) in Fig. 1. The detector was placed at a breathing level height to make sure that the measured radon level represents the radon in an inhaled air. The amount of radon gas was monitored continuously for seven days, including weekends as per previous research study was done in 1998 (Mahat et al., 1998). The short-term measurement was applied in the study to monitor the average weekly radon reading and the maximum reading of radon.

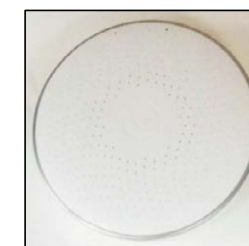


Figure 2 Airthings Wave Radon Detector

## 3.0 RESULTS

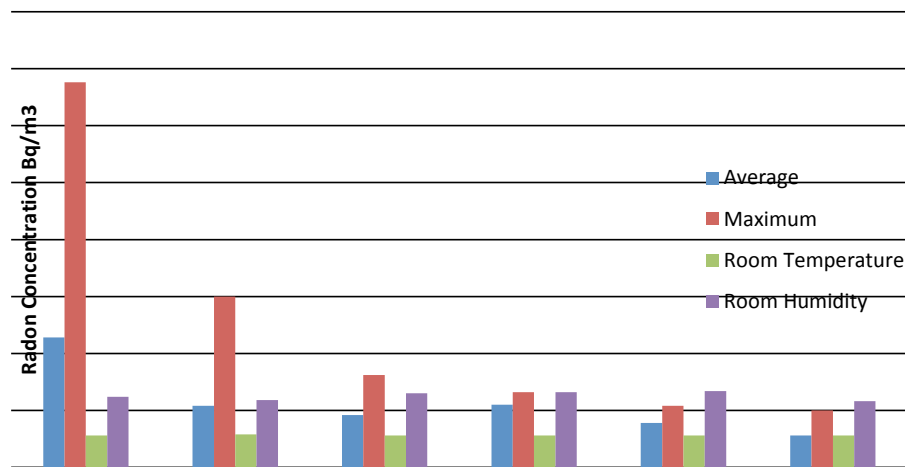
According to a study in 2011 by Chambers, it is useful to produce maps of the indoor radon level in order to identify its hazard (Chambers & Zielinski, 2011). Table 1 showed the existence of radon gas in all testing rooms. Each room had different values of radon concentration. Some rooms showed high concentrations of radon gas level while the other rooms maintained its value at a safe and healthy level.

There were no noticeable changes in room temperature. Most of the rooms maintain their temperature at 28°C. The room’s humidity was maintained in the range of 55% to 70%. The highest room humidity was 66% which was measured in the lecture hall.

Table 1 Radon Concentration at Each Room

Location	Weekly Average Radon Reading Bq/m <sup>3</sup>	Max. Radon Reading Bq/m <sup>3</sup>	Average Room Temperature (°C)	Average Room Humidity (%)	Room Wall Barium Plastering	Room Window	Fan Type Ventilation Device
Mammography Room	114	338	28	62	Yes	No	No
X-ray Room	54	150	29	59	Yes	No	No
Lecturer’s Room 1	28	50	28	58	No	Yes	No
Lecture Hall	55	66	28	66	No	No	No
Darkroom	46	81	28	65	No	No	Yes
Filing Room	39	54	28	67	No	No	No

The highest reading of radon concentration above the maximum level was in the mammography room as shown in Graph 1. Its maximum reading had reached 338 Bq/m<sup>3</sup>. This reading represents the accumulation of radon gas over the weekend when the room’s door was closed. Its value has gradually reduced to an acceptable safe level in the late evening of Monday when the door was totally open for the whole day that causes the radon to flow out of the room. Fig. 3 represents the process of radon accumulation and dissipation for the mammography room. In general, the monitoring of radon concentrations showed a lower radon concentration during working hours as compared to the day time (Sami & Riaz, 2015).



Graph 1 Maximum and Average Radon Concentration

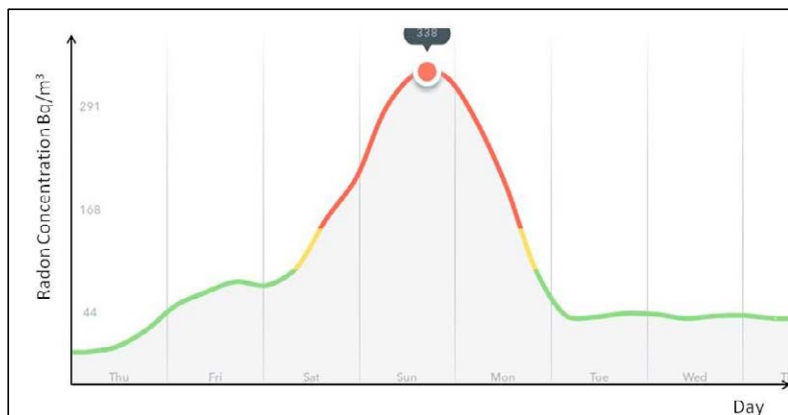


Figure 3 Radon Accumulation Graph for Mammography Room

The second highest maximum reading of radon concentration was in the X-ray room and its reading was 150 Bq/m<sup>3</sup>. These two readings in mammography and x-ray rooms have maximum radon concentration more than radon action level of 148 Bq/m<sup>3</sup>. The rest of the rooms showed the maximum radon concentration less than the action level. Their readings were measured below 100 Bq/m<sup>3</sup>.

All rooms except Lecturer's room 1, have a weekly average radon concentration more than the worldwide average indoor radon concentration of 39 Bq/m<sup>3</sup> (Hajo & Ferid, 2009). Besides its maximum reading of radon concentration, the mammography room also has the highest weekly average radon concentration and its value is 114 Bq/m<sup>3</sup>. It contributes almost 34% of the accumulated weekly average radon concentration in Medical Imaging Lab of UNISEL as shown in the chart of Fig. 4. X-ray room and lecture hall have similar average radon concentration of 16%. Darkroom showed less average radon concentration as compared to the X-ray and lecture hall. Subsequently, the Lecturer's room 1 showed a safe and healthy radon concentration. The previous Table 1 showed both Mammography room and the X-ray room have a combined weekly average radon reading of 168 Bq/m<sup>3</sup> that contributes 50% of the total weekly average radon reading of 336 Bq/m<sup>3</sup> in Medical Imaging Laboratory of UNISEL.

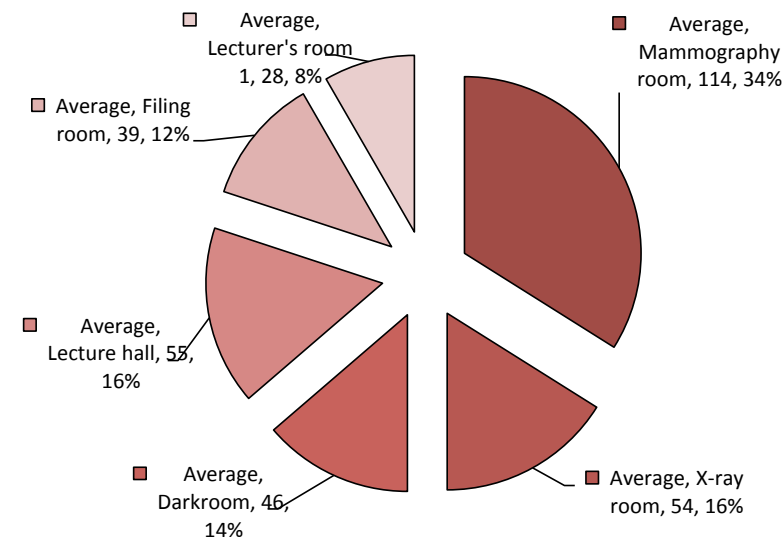


Figure 4 Percentage of Average Weekly Radon Concentration at Each Room

#### 4.0 DISCUSSION

It was observed that the amount of radon concentration fluctuated over the measured time. There is no fixed value of radon concentration at selected locations or defined time. In general, the measurements can only give an idea regarding the level of radon during measuring time for a certain location.

The study showed that the room temperature does not have a significant role in maintaining the radon concentration. Most of the rooms had almost the same room temperature with different values of radon concentration. The percentage value of humidity in each room also does not have a direct relation to the radon concentration. Some rooms have almost the same humidity, but having different concentrations of radon.

The highest concentration of radon in Mammography and X-ray rooms is possibly because of the barium plaster coated wall. Radon gas is accumulated and trapped inside these rooms during the weekend time. It has less ability to flow out of these two rooms. There is a potential possibility to be exposed to high radon gas that exceeds 148 Bq/m<sup>3</sup> if someone is staying there for a long time over the next working day after the weekend break (Hajo & Ferid, 2009). This may induce any chances of getting respiratory disease related as illustrated in the AII process of Fig. 5.

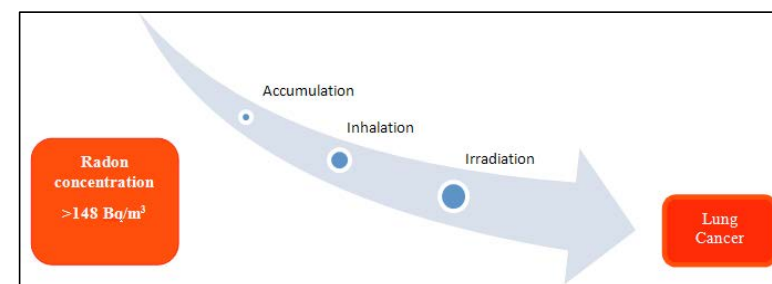


Figure 5 Process of Radon Cause Lung Cancer (AII Process)

The room size may affect the amount of radon concentration. The maximum and average radon concentration in Mammography room is more when comparing it to an X-ray room. It showed that the radon gas has the ability to be spread easily throughout the bigger size of the room.

The lecture hall with carpet flooring design had the average radon concentration almost the same as an X-ray room in the Medical Imaging Laboratory. It is possible that the carpet can trap the dust particles that may later become the source of radon gas.

The lowest amount of average radon concentration was recorded in the Lecturer's room 1. The dimension of the room is quite reasonable. It has a big size window and the room is located at the end corner of the laboratory. There is less possibility for radon gas to be accumulated in this room with high concentration and the mechanism of radon gas to flow out of the room is much easier and more practical.

## 5.0 CONCLUSION

Monitoring radon using basic conventional method is highly recommended to avoid any possibility of health risk caused by inhaled radon. It gives a significant finding regarding the concentration of radon in the indoor air to assure it is within the acceptable healthy level. It may also be applied to any rooms that have a possibility of containing a high concentration of radon. This study was carried out for prevention purposes to avoid any possible health risk caused by indoor radon concentration. For those rooms with a high concentration level of radon, it is most advisable to have safety features of the room and general guidelines to avoid high exposure to radon gas by implementing APP process as illustrated in Fig. 6.

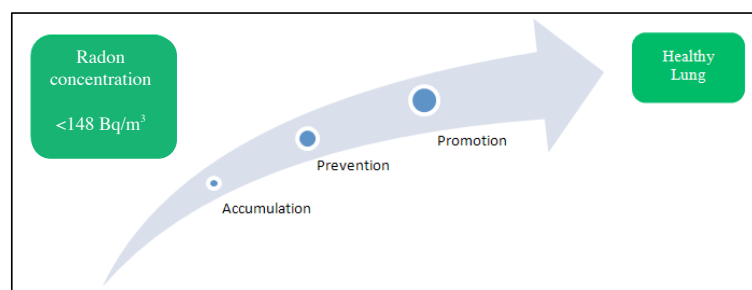


Figure 6 Prevention of Radon Exposure (APP Process)

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