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# Radon ($^{222}$Rn) Radioactivity Level at the BATAN Workplace using RAD7

## *Level Radioaktivitas Radon ($^{222}$Rn) di Lingkungan Kerja BATAN Menggunakan RAD7*

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## ABSTRACT

Measurement of Radon ($^{222}$Rn) radioactivity level at BATAN office Jakarta has been done. Radon is a radioactive emitting alpha particle, very dangerous to the health because if it is inhaled, will be accumulated in the lungs and cause lung cancer. The purpose of the research was to determine the activity concentration of $^{222}$Rn in the workplace and to estimate the dose received by workers. The sampling method is purposive sampling, in several office rooms of the BATAN office (staff room, laboratory, and warehouse), measurement $^{222}$Rn using RAD7 continuously for 24 hours. Based on the activity concentration of $^{222}$Rn in the rooms, an estimate of the effective dose received by the workers while working indoors can be calculated. The results showed that exposure of $^{222}$Rn gas radiation in the workplace was relatively varied, radiation exposure in warehouses was 18.90–32.90 (25.90) Bq.m$^{-3}$ higher than in laboratory 8.20–34.00 (22.43) Bq.m$^{-3}$ and staff room 5.40–29.60 (16.68) Bq.m$^{-3}$. The estimated effective dose received by workers in the warehouse is 0.1865 mSv.year$^{-1}$, laboratory 0.1615 mSv.year$^{-1}$, and in the staff rooms 0.1267 mSv.year$^{-1}$, and this value still meets the quality standards of radiation exposure required by the Ministry of Health No. 7 of 2019 and is categorized as safe.

**Keywords**: Radon ($^{222}$Rn), BATAN workplace, radiation, effective dose, RAD7

## ABSTRAK

Pengukuran tingkat radioaktivitas radon ($^{222}$Rn) di kantor BATAN, Jakarta telah dilakukan. Radon adalah unsur radioaktif pemancar partikel alfa, sangat berbahaya bagi kesehatan karena jika terhirup akan terakumulasi di paru-paru dan menyebabkan kanker paru-paru. Tujuan penelitian adalah untuk mengetahui konsentrasi aktivitas $^{222}$Rn di tempat kerja dan perkiraan dosis yang diterima pekerja. Metode pengukuran $^{222}$Rn secara *purposive sampling*, di beberapa ruang kantor pusat BATAN (ruang staff, laboratorium dan gudang). Pengukuran $^{222}$Rn menggunakan RAD7 secara terus menerus selama 24 jam. Berdasarkan konsentrasi aktivitas $^{222}$Rn di ruangan-ruangan, dapat dihitung perkiraan dosis efektif yang diterima pekerja selama bekerja di dalam ruangan tersebut. Hasil penelitian menunjukkan bahwa paparan radiasi gas $^{222}$Rn di tempat kerja relatif bervariasi, paparan radiasi di gudang 18,90–32,90 (25,90) Bq/m$^3$ lebih tinggi dibandingkan di laboratorium 8,20–34,00 (22,43) Bq/m$^3$ dan di ruang staf 5,40–29,60 (16,68) Bq/m$^3$). Perkiraan dosis efektif yang diterima pekerja yang bekerja di gudang adalah 0,1865 mSv/tahun, di laboratorium 0,1615 mSv/tahun dan di ruang staf 0,1267 mSv/tahun, dan nilai ini masih memenuhi baku mutu paparan radiasi yang disyaratkan Menteri Kesehatan No. 7 Tahun 2019 dan dikategorikan aman.

**Kata kunci**: Radon ($^{222}$Rn*)*, lingkungan kerja BATAN, radiasi, dosis efektif, RAD7

## INTRODUCTION

In recent years, it has been reported that health risks are caused by exposure to radioactive Radon ($^{222}$Rn) gas and its decay products. Radon surveys have been reported in Europe and in the United States and more than that has been done in any country in the world. The study of $^{222}$Rn has increasingly developed throughout the world, including measurements of $^{222}$Rn radioactivity in the air. This is because most of the $^{222}$Rn in the

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dwelling or indoors comes from underground soil [1].

Radon is one of the natural radionuclides that have received much attention because it has the potential to harm the human health [2]. Radon is a noble radioactive gas which emits alpha particles [3].

Radon gas has several radionuclides, such as actinium ($^{219}Rn$) with a half-life of 3.96 seconds, thoron ($^{220}Rn$) with a half-life of 55.6 seconds, and radon ($^{222}Rn$) with a half-life of 3.82 days [2]. $^{222}Rn$ comes from decay of uranium ($^{238}U$) in nature and thoron ($^{220}Rn$) comes from decay of thorium $^{232}Th$ [4]. $^{222}Rn$ enters the human body through the respiratory tract, and radon will stick to the lung tissue so that it damages lung cells and possibly can develop into lung cancer [5].

Measurement of radon gas outdoors is usually carried out in soil and water, while radon gas in the air is generally measured indoors, such as; houses and caves. Measurement of radon gas is intended to determine the radioactivity level, the annual effective radiation dose received by the public so that the level of health risk can be determined [6]. Ministry of Manpower Regulation – Republic of Indonesia No. 5/2018 and the Ministry of Health – Republic of Indonesia No.7/2019 recommend limit values for radon that are considered safe for workplace and hospitals, i.e. 200 Bq.m$^{-3}$ and 148 Bq.m$^{-3}$, respectively [7], [8].

Abuelhia (2017) reported that the concentration of $^{222}Rn$ in two old building rooms in Damman and Al-Khobar (Saudi Arabia) varies on average, 18.80 Bq.m$^{-3}$ and 21.70 Bq.m$^{-3}$, respectively [10]. While the concentration of $^{222}Rn$ in the new building rooms at the Dammam University is 9.02 Bq.m$^{-3}$ [9]. This means that $^{222}Rn$ concentrations in old buildings are relatively high, up to two times greater than in new buildings, although both are still significantly lower than the world average value (40 Bq.m$^{-3}$) reported by UNSCEAR [10]. Finne *et.al* also reported that the average concentration of $^{222}Rn$ in housing built in 2008 and 2016 in Norway was 44 Bq.m$^{-3}$ and 29 Bq.m$^{-3}$, respectively. This shows a statistically significant difference, although the concentration is still below the required limit [11].

Based on these, it is important to monitor and measure $^{222}Rn$ radioactivity in the workplace and estimate the radiation exposure obtained by workers in the room in order to ensure safety while working. The purpose of this study was to measure the $^{222}Rn$ radioactivity level in the workplace (staff room, laboratory and warehouse) and to estimate the effective dose or radiation exposure received by workers while in the room and to find out whether the workers were still categorized as safe. Furthermore, the result obtained is compared with the $^{222}Rn$ quality standard required by the Ministry of Manpower Regulation Number 5/2018.

## METHODOLOGY

Research methods consist of materials and equipment, work procedures, and calculating the annual effective dose.

### Materials and Equipments

In this study, $^{222}Rn$ was measured in several rooms of workplace, such as: (i) staff room, (ii) laboratory, and (iii) warehouse. The $^{222}Rn$ gas measurements were carried out with an RAD7 device equipped with a dryrite dryer, a special cable for equipment stability testing, and a PC equipped with capture software.

### Work procedure

The work procedure consists of setting up the RAD7 device including the measurement of radon gas, and transferring measurement data to a PC and data processing.

#### *Setting of the device and measuring*

Before measuring, it is ensured that the data storage in the RAD7 device is empty otherwise the data cleaning process need to be done first. Furthermore, the process of setting up the RAD7 device is carried out by adjusting the time required for measurement. Initially the RAD7 is connected to the power supply, and the filter is attached to the inlet filter on the RAD7 and connected to the dryrite tube. The dryrite tube has two holes, the upper hole is the inlet for the air sample, while the bottom hole is the measured air outlet. The process scheme for measuring $^{222}Rn$ gas with RAD7 is shown in Figure 1.

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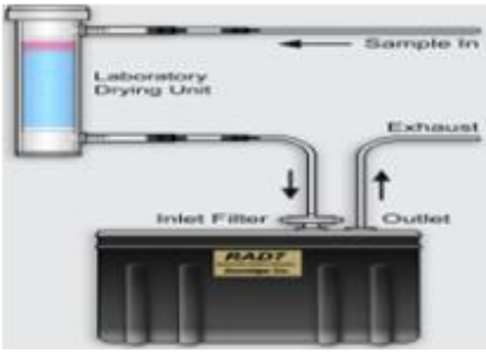


**Figure 1.** Schematic of the measurement process

Before measuring, purging process using air was done until the humidity in the RAD7 is below 10% (Figure 1).

The measurement of $^{222}$Rn radioactivity was carried out in several rooms, i.e. staff room, laboratory and warehouse for 24 hours, each repeated 3 times. The position of the tool can be placed anywhere because it does not affect if it is placed in the middle of the room when making measurements. Before taking $^{222}$Rn measurements, temperature and humidity are adjusted because these two parameters can affect the $^{222}$Rn measurement results in the room.

### *Transferring the $^{222}$Rn data to a PC and data processing*

The results of the $^{222}$Rn radioactivity measurement are stored on the RAD7 device. Storage is done by transferring data to a computer or laptop by opening the Capture program on a PC connected to RAD7 using an RS-232 to USB cable (Figure 2).

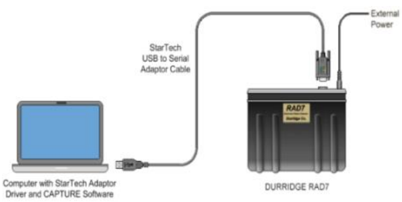


**Figure 2.** Transferring data process to the PC

### Calculation of annual effective dose

In this case, the annual effective dose is the dose received by workers for a year, while in the room which is thought to contain a number of radon gas. To calculate the average annual effective dose received for workers who carry out daily activities in the room, the following formula is used [12]:

$$D_{inRn}\ (\text{nSv/year}) = C_{inRn} \times F \times T \times DCF \quad (1)$$

Where :

$C_{inRn}$ : $^{222}$Rn radioactivity (Bq.m$^{-3}$)

F : Equilibrium factor 0.4 [13]

T : Occupational exposures, 2000 hours.year$^{-1}$ [14]

DCF : Dose Coefficients Factor, 9 nSv.h$^{-1}$.Bq.m$^{-3}$ [15]

## RESULTS AND DISCUSSION

### Measurement of Temperature and Humidity

The temperature and humidity of the room measured during $^{222}$Rn measurements is shown in Table 1. The measurement of these parameter are related to the presence of $^{222}$Rn gas because high air humidity (> 10%) has high moisture content, and will cause water vapor to inhibit $^{222}$Rn gas measurement. The fact that increasing humidity would decrease the collection efficiency of $^{222}$Rn [16].

**Table 1.** Temperature and humidity (RH)

| Sampling Locations | Sample Codes | Temperature (°C) | Humidity (RH, %) |
|---|---|---|---|
| Staff Rooms | S1 | 30.4 | 9.00 |
| | S2 | 27.8 | 7.37 |
| | S3 | 30.1 | 9.17 |
| | S4 | 30.4 | 8.60 |
| | S5 | 30.6 | 9.21 |
| | S6 | 29.6 | 9.03 |
| | S7 | 32.9 | 9.67 |
| | S8 | 33.3 | 7.06 |
| | S9 | 30.8 | 9.00 |
| | S10 | 31.7 | 4.57 |
| | S11 | 30.2 | 7.85 |
| | S12 | 27.8 | 7.34 |
| | S13 | 29.0 | 9.00 |
| Laboratory rooms | L1 | 29.9 | 8.83 |
| | L2 | 28.3 | 6.58 |
| | L3 | 30.6 | 5.13 |
| | L3 | 26.2 | 9.02 |
| | L5 | 26.0 | 7.25 |
| | L6 | 24.9 | 8.36 |
| Warehouse rooms | G1 | 30.4 | 7.96 |
| | G2 | 33.2 | 7.58 |

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**Radioactivity of $^{222}$Rn and annual effective dose evaluation**

The results of $^{222}$Rn radioactivity measurement in workplace are shown in Table 2. It can be seen that the average of $^{222}$Rn concentration in warehouse (25.90 Bq.m$^{-3}$) relatively high compared to the laboratory (22.43 Bq.m$^{-3}$) and staff room (16.68 Bq.m$^{-3}$).

**Table 2.** The average concentration of $^{222}$Rn and annual effective dose

| Sampling Locations | Sampel Codes | Radioactivity (Bq.m$^{-3}$) | Effect. dose (mSv/year) |
|---|---|---|---|
| Staff | S1 | 2,20 | 0,17 |
| Rooms | S2 | 19,60 | 0,14 |
| (n=13) | S3 | 29,60 | 0,21 |
| | S4 | 20,00 | 0,14 |
| | S5 | 12,40 | 0,09 |
| | S6 | 7,00 | 0,05 |
| | S7 | 20,60 | 0,15 |
| | S8 | 5,40 | 0,04 |
| | S9 | 11,20 | 0,08 |
| | S10 | 14,40 | 0,10 |
| | S11 | 10,50 | 0,08 |
| | S12 | 14,20 | 0,10 |
| | S13 | 27,70 | 0,20 |
| Laboratory | L1 | 27,60 | 0,20 |
| (n=6) | L2 | 10,90 | 0,08 |
| | L3 | 10,40 | 0,07 |
| | L3 | 8,20 | 0,06 |
| | L5 | 34,00 | 0,24 |
| | L6 | 43,50 | 0,31 |
| Warehouse | G1 | 18,90 | 0,14 |
| (n=2) | G2 | 32,90 | 0,24 |

The results showed that rooms with high radon radioactivity are found in rooms L5 and G2. These rooms are located on the basement floor, the condition of some of the floors is cracked, and it is always closed (without ventilation). Another trigger is the presence of a radiation source containing radon gas stored in the room. Meanwhile, rooms with low radon radioactivity were found in rooms S6 and L4. These rooms are located on the 2$^{nd}$ floor (the floor is not directly attached to the ground), which they were sometimes open leading to the release of the radon gas. Based on epidemiological studies and as input to public health policy, the International Commission on Radiological Protection (ICRP) has recommended an indoor reference level for radon gas, 300 Bq.m$^{-3}$ [18].

Other researchers reported that $^{222}$Rn concentration in the basement of the old building aged 150 years which had ventilation was found 330 Bq.m$^{-3}$, while the unventilated 1000 Bq.m$^{-3}$. This high $^{222}$Rn concentration observed in one of the rooms is obvious since there is no window and no ventilation in that room. Radon concentrations in the first floor rooms of 15, 25, 150 years old buildings were found 53, 69, and 86 Bq.m$^{-3}$ respectively [17]. Compared to this value, $^{222}$Rn concentration in our study is still low.

Table 2 shows that people who were working in staff rooms, laboratories, and warehouses received effective doses of 0.1267 mSv.year$^{-1}$; 0.1615 mSv.year$^{-1}$, and 0.1865 mSv.year$^{-1}$ respectively. As recommended by the Ministry of Manpower of Republic Indonesia No. 5 of 2018 and the Ministry of Health of Republic Indonesia No. 7 of 2019 concerning the safe radon limit value for workspaces and hospitals (200 Bq.m$^{-3}$ and 148 Bq.m$^{-3}$ respectively), the workers who work in those rooms (warehouse, laboratory, and staff room) are still in the safe category, although periodic monitoring must be carried out to ensure safety and security from exposure to ionizing radiation. Workers who work in these three rooms are still in the safe category, although regular monitoring must be carried out to ensure safety and security from exposure to ionizing radiation.

## CONCLUSION

From this study it can be concluded that $^{222}$Rn radioactivity in the BATAN office at staff rooms, laboratory, and warehouses were 16.68, 22.43, and 25.90 Bq.m$^{-3}$, respectively. These values were lower than the regulation of the Ministry of Manpower – Republic of Indonesia No. 5/2018 regarding safety and health. The estimated effective dose received in the staff rooms, laboratory, and warehouses were 0.13, 0.16, and 0.19 mSv.year$^{-1}$, respectively.

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