Network of Radon Gas Concentration Monitoring of Research and Development Centre – BMKG for Earthquake Precursor Research in Indonesia

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Abstract. The geographical position of Indonesia, which is flanked by several subduction zones and the presence of active faults in the sea and land make Indonesian territory prone to earthquakes and tsunamis which can result in many deaths and damaged. There are several efforts we can do to minimize the occurrence of earthquakes, including developing earthquake resistant buildings, increasing the ability/capacity of the community, and predicting earthquakes or better known as earthquake precursors. The BMKG Research Centre began conducting research on earthquake prediction using several methods, including the Radon monitoring method. Monitoring of Radon gas concentrations for earthquake precursors has several advantages, including the presence of radioactive gas which is abundant in ground water that has a half-life of 3.2 days. Radon is the result of decay of uranium 278U which is abundant in the earth's crust rock so that when rock friction occurs, the Radon gas can be detached. Based on the results of Radon monitoring at Tadulako and Palolo stations - Southeast Sulawesi province, there was a change in the pattern of radon gas concentration and water level rising up and down drastically and a gradual decrease in ground water temperature before the earthquake on 28 September 2018. In addition to Central Sulawesi, since 2012 the Centre for Research and Development of BMKG has been conducting research to monitor radon gas concentrations in the DI Yogyakarta region precisely in Piyungan and Pundong districts with the aim of monitoring radon gas concentrations in the Opak fault. In 2021, the BMKG Research and Development Centre added a new radon gas monitoring network in the active fault areas of Cimandiri and Lembang in the West Java province. There are 1 station in the Cimandiri fault segment and 2 stations in the Lembang fault section. It is hoped that in the future the results of monitoring can reduce the impact caused by the earthquake disaster in Indonesia.

1. Introduction
Geographically, Indonesia is located in an area of several active tectonic plates. This has resulted in the existence of many faults on land that can cause earthquakes throughout Indonesia. Figure 1 shows the earthquake events detected by BMKG that occurred in the period January to September 2020, with a magnitude of 1 to 7. In this period no less than 3500 earthquakes occurred in Indonesia's area.
Research and Development Center of BMKG has initiated efforts to predict the occurrence of earthquakes since the beginning of 2010 until now. Various methods have been applied and developed, ranging from geophysical, geo-atmosphere and geochemical anomalies. This year we are concentrating on improving the performance of monitoring the geochemical anomalies from the changes in radon gas concentrations before earthquakes occur. Radon gas (222Rn) is a radioactive gas resulting from the decayment of radium-226 which is found in soil, rock, air and water with varying concentrations with a half-life of about 3.8 days [1, 2, 3, 4].

Several studies have shown anomalous changes in radon gas concentrations prior to the earthquake, including changes in ground water and radon gas concentrations before the Kobe - Japan echo [5], increased radon gas anomalies in San Andreas faults [6] and the Nepal region [7]. Efforts to improve monitoring and analysis of radon data continue to be made, as well as methodologies and mathematical modeling, to strengthen the link between radon gas anomalies and geodynamic processes [8]. Precursor research based on the anomaly monitoring of radon gas concentrations in a fault is promising to be applied and developed in Indonesia. The Center for Research and Development of BMKG as an institution that has the task of carrying out research, assessment, and development in the field of Geophysics, has been started conducting pre-surgery earthquake research using this method since 2015. This year BMKG has installed radon monitoring stations in the regions of Central Sulawesi, Jogjakarta, and West Java.

2. Radon Monitoring Station System
In 2015, the Research and Development Center of BMKG began to intensify precursor research using the anomaly monitoring method for radon gas concentrations in the soil [9]. In addition to radon monitoring equipment, we integrate water level monitoring instruments and Geo Temperature (Figure 2). The integration is based on the success of previous researchers in predicting earthquake events using this method [5, 10, 11, 12].

![Figure 1. Earthquake Epicenter January - September 2020](image-url)
The Research and Development Center of BMKG for the first time built a radon monitoring station that is integrated with water level and geo-temperature monitoring in the DI Yogyakarta region (Figure 3). We use a monitoring system developed by TAIDE, where this system is integrated between radon gas concentration information, water level, geo-temperature in the well with meteorological information such as air pressure, temperature and rainfall. All this information is sent in real time to the Central BMKG Research and Development Center.

Figure 3. A) Location of two Radon Monitoring Stations in DI Yogyakarta, B) Radon Piyungan monitoring stations, C) Radon Pundong monitoring stations
We chose to install 2 radon stations in Jogjakarta by considering the presence of an active Opak fault which caused a devastating earthquake in 2006. The first station is located in the northern part of the Yogyakarta region, precisely in Piyungan District. The second station is located in the southern part of the DIY region, precisely in Pundong District. These stations are located close to the Opak fault, in the hope that before the earthquake occurs, radon that is released around the fault can be immediately detected by these stations. In 2016, the BMKG Research and Development Center built two radon stations with the same system in the Central Sulawesi region. The first station is located at Tadulako University which is adjacent to the Palukoro active fault and the second station is installed at a location adjacent to the Palolo fault (Figure 4). The second station is installed at a location adjacent to the Palolo fault.

The installation of a radon monitoring station in the same area but in different fault segments has the objective of monitoring radon anomalies in the same segment and different segments. It is hoped that we will be able to find out the effect of radon, water level and geotemperature anomaly before the earthquake occurs on the closest active fault and distant segments of the negative fault.

**Figure 4.** A) Location of two Radon Monitoring Stations in Central Sulawesi, B) Radon Tadulako monitoring stations, C) Radon Palolo monitoring stations

### 3. Monitoring of Yogyakarta Earthquake Precursors

Parameters observed in radon-based earthquake precursor monitoring in Yogyakarta include radon gas, subsurface temperature, water level, air pressure, surface temperature and rainfall. Figures 5 and 6 show the results of monitoring of precursor parameters at Pundong and Piyungan stations and maps of the surrounding epicenters for January - February 2019.
Figure 5. A) Graph of the observation of earthquake precursors at Pundong Station in January - February 2019 and their standard deviation, B) Map of earthquake epicenters around Pundong station for January - February 2019 (Yellow triangle is Radon Station, red circles are Earthquake Epicenter).

Figure 6. A) Graph of earthquake precursor observations at Piyungan station from January to February 2019 and their standard deviation. B) Map of earthquake epicenters around Piyungan station for January - February 2019 (Yellow triangle is Radon Station, red circles are Earthquake Epicenter).

There were 2 earthquakes around the Pundong and Piyungan precursor stations. The first earthquake occurred on January 9, 2019 with a magnitude of M2.4 at a distance of 17 km from Pundong Station and 18 km from Piyungan Station. The second earthquake occurred on 9 February 2019 with a magnitude of M1.9 at a distance of 19 km from Pundong Station and 25 km from Piyungan Station (Figures 5 and 6).

Figure 5 and Figure 6 show that the January 9 earthquake caused anomalies at Pundong and Piyungan Stations. At the Pundong station, the precursor to the 9 January 2019 earthquake, there was an increase in radon gas and a decrease in groundwater since 5 days before the incident, while at Piyungan station the increase in radon gas concentrations occurred 6 days before the incident but was not significant. The 9 February 2019 earthquake only caused radon gas anomaly at Piyungan Station. An insignificant increase in radon gas concentrations occurred at Piyungan Station since 9 days before the 9 February 2019 earthquake.
4. Monitoring Network of Lembang Radon Station - Cimandiri 2020

![Figure 7. Location of Radon Monitoring Station in West Java Region (Left) and Radon station above ground water well](image)

At the end of 2020 we started reinstalling 3 radon stations in the West Java region (Figure 7). We use the Rad7 instrumentation to measure radon and thoron values in groundwater wells. We installed 1 station in the Cimandiri fault segment right at the BMKG Earth Magnet observatory station, and 2 stations in the Lembang fault segment to be precise at the earthquake observation station and BMKG official residence. In this monitoring network 2 stations are placed in close proximity to each other around the Lembang fault segment in order to determine the anomalous effect of radon gas concentrations before the earthquake occurred at stations that have different distances from the source (Lembang Fault). All data on this network will be sent in real time to the Research and Development Center of BMKG, in order to monitor activities before an earthquake occurs in the research area.

5. Concluding Remarks

Monitoring of radon gas concentration anomalies for research efforts on earthquake precursors, we value is quite promising to be applied around active faults that are scattered throughout Indonesia. In the period from January to February there were 2 earthquakes in the Jogjakarta area which were adjacent to the Pundong Radon Station. The monitoring results at the Pundong Station showed a significant anomaly 4 days before the earthquake occurred, as well as the piyungan sensor which has a further distance from the epicenter of the earthquake, although the detected anomaly was not as significant as the Pundong station. Based on our observations in the Central Sulawesi and Yogyakarta regions, anomalies of radon gas concentration as an earthquake precursor can be detected depending on the distance, magnitude and length of the active fault that releases energy. We are currently starting to develop an algorithm for the relationship between the anomalous magnitude of radon gas concentration, water level and geo temperature to the magnitude and hypocenter of the earthquake that occurred.

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