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Journal homepage: http://aij.batan.go.id

Monitoring and Analysis of Environmental Gamma Dose Rate around Serpong Nuclear Complex

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ARTICLE INFO

Article history:
Received 16 November 2015
Received in revised form 11 November 2016
Accepted 24 February 2017

Keywords:
Environmental gamma dose rate
Serpong nuclear complex
Continuous monitoring
Radiological emergency
GM probe

ABSTRACT

An environmental radiation monitoring system that continuously measures gamma dose rate around nuclear facilities is an important tool to present dose rate information to the public or authorities for radiological protection during both normal operation and radiological accidents. We have developed such a system that consists of six GM-based device for monitoring the environmental dose rate around Serpong Nuclear Complex. It has operated since 2010. In this study, a description of the system and analysis of measured data are presented. Analysis of the data for the last five years shows that the average dose rate levels were between 84-99 nSv/h which are still lower than terrestrial gamma radiation levels at several other locations in Indonesia. Time series analysis of the monitoring data demonstrates a good agreement between an increase in environmental gamma dose rate and the presence of iodine and argon in the air by in situ measurement. This result indicates that system is also effective for an early warning system in the case of radiological emergency.

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INTRODUCTION

Many scientific findings show that radiation exists around us even inside our body. However, since radiation cannot be detected by human senses, many people still do not realize the existence of radiation in nature. Usually, ionizing radiation is associated with nuclear weapons or the utilization of nuclear technology such as industrial applications, medical applications, or nuclear power plants.

Previous studies reported that perception in radiation risk was different according to knowledge level on radiation (*i.e.*, between general public and experts) [1-3]. If there are nuclear facilities near their residence, general public tend to be anxious. A survey conducted in Hong Kong showed that only 34.5 % of the respondents were confident about the operational safety of nuclear power plant in Daya Bay, and 23 % of the respondents stated they will leave Hong Kong immediately when an accident occurs [4].

One of the nuclear complexes in Indonesia is located in Serpong, Banten. The Serpong Nuclear Complex (also known as the KNS, *Kawasan Nuklir Serpong*, in Indonesian) is one of the research and development facilities owned by National Nuclear Energy Agency (BATAN). In the complex, there are several facilities such as the RSG-GAS (*Reaktor Serba Guna GA. Siwabessy*) research reactor, medical isotope production facility, radioactive waste treatment installation, and the Center for Nuclear Fuel Technology. The presence of these facilities may give insecurity to residents around the complex, especially after the Fukushima nuclear accident in March 2011.

In many countries around the world, such as Spain, Germany, Portugal, Hungary, Lithuania, India, Iran, and South Korea, in order to protect the public from radiation exposure, usually the government or related authorities establish environmental radiation monitoring system around nuclear facilities or uranium sites. The system usually consists of comprehensive radiation monitoring in soil, sediment, water, and air utilizing offline laboratory analysis and automatic continuous

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DOI: http://doi.org/10.17146/aij.2017.681

monitoring for air gamma dose rate measurement [5-14]. Similarly, in Indonesia, nuclear facility owners need to perform radiation monitoring around the faciltiy and submit its result to the Nuclear Energy Regulatory Agency of Indonesia (BAPETEN: *Badan Pengawas Tenaga Nuklir*).

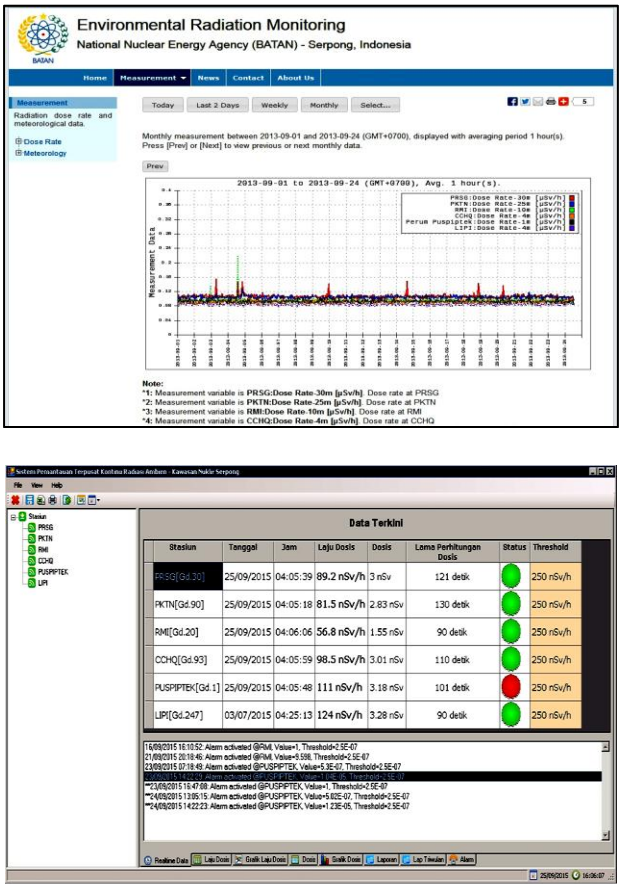

Fig. 1. Web interface and software at the control center of the environmental radiation monitoring system.

In order to fulfill radiation protection requirements defined by BAPETEN, especially for monitoring ambient gamma dose rate, we have developed an environmental radiation monitoring system for the KNS. The system was designed to continuously monitor environmental gamma air dose rate around the facility, and it plays important roles such as collecting environmental radiation data in normal condition (baseline data) and providing early warning to stakeholders. It can also be used to continuously monitor dose rate changes due to radiological accident [15-17].

The user interface of the developed system both for web interface and GUI interface used by operator are shown in Fig. 1. The software in the central control and monitoring room provides an alert to the operator in case any unusual increase in the dose rate. Web interface is also provided and can be accessed by public easily through internet at http://223.25.97.90/radmon.

In this study we would like to present and analyze environmental gamma radiation data that were measured since the establishment of the system in 2010. The objectives are to figure out the environmental gamma dose rate around the facility and to present the results to the interested public, investigate the effectivenes of the system to detect unusual increases of man-made radiation, and evaluate any challenges that were faced during operation of such a continuous system. Further research and development directions to improve current system are also discussed in this paper.

EXPERIMENTAL METHODS

Radiation monitoring system

Several MFM 203 multifunctional gamma monitors (Ames d.o.o., Slovenia) have been installed around the KNS to measure air dose rate since 2010. At the beginning, only two devices were installed. Presently, six MFM203 devices are installed around the facility as shown in Fig. 2. The devices are connected to a server computer at a central monitoring room through a wireless radio modem. Each device has two GM probes (L 31 cm × ∅ 5 cm) and can be used to measure gamma radiation of energies ranging from 60 keV to 1.3 MeV, within a dose rate range of 50 nSv/h to 1000 mSv/h.

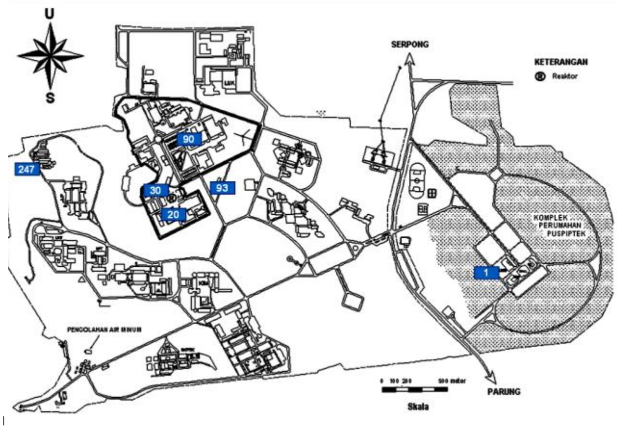

Fig. 2. Locations of environmental gamma dose rate monitoring devices.

Normally, the device calculates air dose rate every five minutes. If the radiation dose is high enough, it will calculate the dose rate within a period of less than five minutes. In our system, the dose rate along with calculation time stamp is collected every 10 seconds and then stored in a database. As a result, in normal condition, at a certain time stamp, usually there are 30 data points with the same time stamp and dose rate value. The objectives of selecting this acquisition period are to minimize missing data in case of communication error, and to quickly detect any increase in dose rate caused by man-made radiation sources or radioactive materials that are probably released from the facility to the atmosphere.

Since the monitoring system continuously monitors air dose rate, it produces a large amount of time series data. The time series data provides the time stamp and length of its period in which the dose rate level has changed. The system also generates an alert if the measured dose rate level is greater than the predetermined threshold value of 250 nSv/h, or one-tenth of the prompt gamma dose rate allowed by BAPETEN. This kind of event is recorded in database along with notes or comments given by the operator after investigating and verifying the cause of such an alert. Time series data along with alert information and other activity log recorded by operator are very useful for figuring out when and what factors are contributing to unusual changes in environmental dose rate.

Data analysis

The measured data was exported from the database in the CSV (comma separated value) format, and then were preprocessed and analyzed using Go language [18].

Preprocessing was perfomed to increase data reliability. First, the measured dose rates were grouped by device identification code at certain monitoring location (device identification numbers are given as 1, 20, 30, 90, 93, and 247) and year of measurement (2010-2015). Next, for each measurement data collected by each device, median value (m_i) of a data set within a certain period (usually five minutes) which consisted of N_i data points having the same time stamp t_i, was taken as measured dose rate. Finally, if the value of m_i was outside the measurement range, or N_i was equal to 1, it was excluded from analysis since this kind of outlier data usually indicated a measurement or communication error.

After preprocessing, calculations were done to get average annual dose rate for each location and year in which the measurement was performed. An average dose rate calculated over the period of monitoring was also calculated and compared to environmental gamma dose rates around Indonesia.

RESULTS AND DISCUSSION

Long-term dose rate variation

The results of environmental gamma dose rate monitoring around the KNS for past 5 years are summarized in Table 1. The monitoring periods were varied between 10.8 months and 4.25 years. The relative variation of annual average dose rate levels at the same location were ± 16 % for the location where device 1 were installed, and less than 6 % for the other locations. Average dose rates for all six monitoring locations were between 84-99 nSv/h. This value is corresponding to 0.736-0.867 mSv per annum (less than 1 mSv/a).

Table 1. Average environmental gamma dose rates for past five years

Location	Monitoring period (in Years)	Average air dose rate ± 2σ (nSv/h)
Dev. 1	2.00	99 ± 37.6
Dev. 20	3.01	95 ± 11.9
Dev. 30	4.08	96 ± 13.6
Dev. 90	4.25	92 ± 17.7
Dev. 93	2.95	92 ± 12.3
Dev. 247	0.88	84 ± 9.0

Figure 3 shows the timeline chart of data availability on each device since first installation at November 1, 2010 until November 4, 2015. In the chart, the date in which monitoring data were available from a certain location is marked as solid line. As shown in the chart, in priciple, monitoring data was available for each day during the period. However, data from several locations was still missing for quite a long period especially in 2014 due to device maintenance. Several factors such as budget, import procedure, and the availability of spare parts contribute to the delay of device reinstallation. The development of a new monitoring device that uses more components available in local market can be one solution for reducing maintenance time; hence, it will increase data availability. Furthermore, the new device can also be installed at new locations to increase the coverage of the monitoring area and to support BATAN's plans to build a new irradiation facility and an experimental power reactor in the Serpong Nuclear Complex.

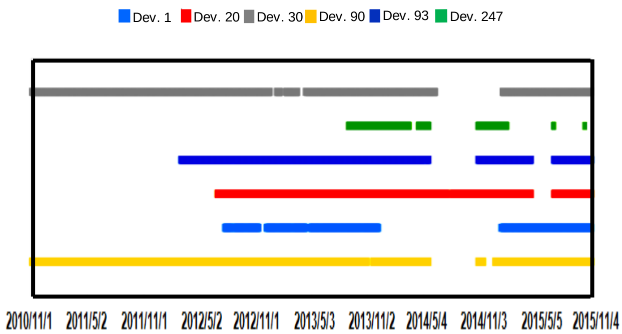

Fig. 3. Timeline chart showing availability of monitoring data since November 1, 2010.

Analysis of time series data

Figure 4 shows a typical environmental gamma dose rate profile observed in the date of inspection by BAPETEN as the nuclear regulatory body in Indonesia. A check source was used to verify whether the system would provide alerts in case there were radioactive materials releasing gamma ray in the environment. As seen in the figure, peaks with values greater than the threshold level were observed. At the same time, an alert was given by the monitoring software package at the control center and was verified by an inspector.

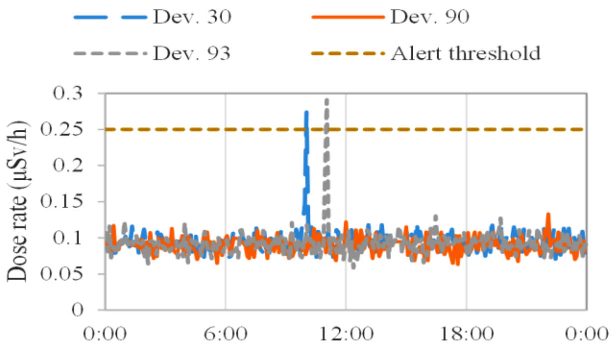

Fig. 4. Air dose rate profile during the inspection and testing of the monitoring system using check source.

During the usual operation of the monitoring system, sometimes alerts occurred. An example of typical environmental gamma dose rate profile observed when an alert occurs is shown in Fig. 5. As shown in the figure, increases of dose rate level were observed at monitoring location 30 and 90. Peaks with almost the same time stamp that were observed at several monitoring locations indicate high probability of the presence of radioactive materials in the atmosphere. Operator's note on alert

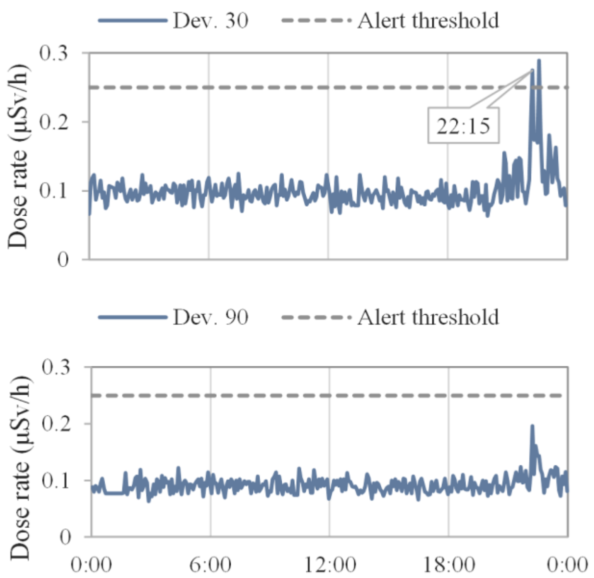

Fig. 5. Air dose rate profiles at locations 30 and 90 during operation of medical isotope production facility

information shows that the event was observed during the operation of the medical isotope production facility in 2012. An in-situ measurement using NaI(Tl) spectrometer performed in the same date by Syarbaini *et al*. reported an increase of the ^{131}I and ^{41}Ar concentration level in the air [19]. Furthermore, release of radioxenon (^{133}Xe) was also reported in the study conducted by P. W. Eslinger *et al*. during the operation of the facility [20]. The presence of man-made radionuclide reported by the studies and time-series response of the developed system demonstrate the effectiveness of the monitoring system to capture and quickly detect any short events that are probably related to release of radioactive materials into the atmosphere. However, since the current system only monitors the dose rate, it cannot give information on the kinds of radionuclide which were released. In the future, research and development of a new device having spectroscopy capability is needed [21]. The incorporation of such a device into the monitoring system could give a comprehensive information of radioactive materials that are probably released to the atmosphere.

The plot of time series data for the monitoring period of 2015 is shown in Fig. 6. The figure shows that there are many peaks in the data from location 1, in spite of its being far from the KNS compared to the other monitoring locations. Since there are no peaks that occur at the same time with the peaks observed at location 1, it is hard to conclude that these peaks indicate the presence of radioactive materials. Instead, they may come from measurement error due to hardware failure or communication error. Further investigation is needed to identify the cause of this phenomenon. However, this data is not excluded from the analysis. For this reason, as shown in Table 1, the average dose rate and the standard deviation for location 1 were higher than the other five locations.

Comparison of environmental dose rate

The environmental dose rates measured around KNS and several other locations in Indonesia were compared and are shown in Table 2. Compared to the average dose rate measured in other locations in Java, as well as locations in Bali, NTB, and NTT, the dose rate at KNS was higher. However, according to the study reported by G. Suhariyono *et al*. [22], several locations in Java such as Jepara, Tayu, and Rembang have environmental dose rate levels in the range of 100.44-150.78 nSv/h that were higher than the dose rate level reported in this study.

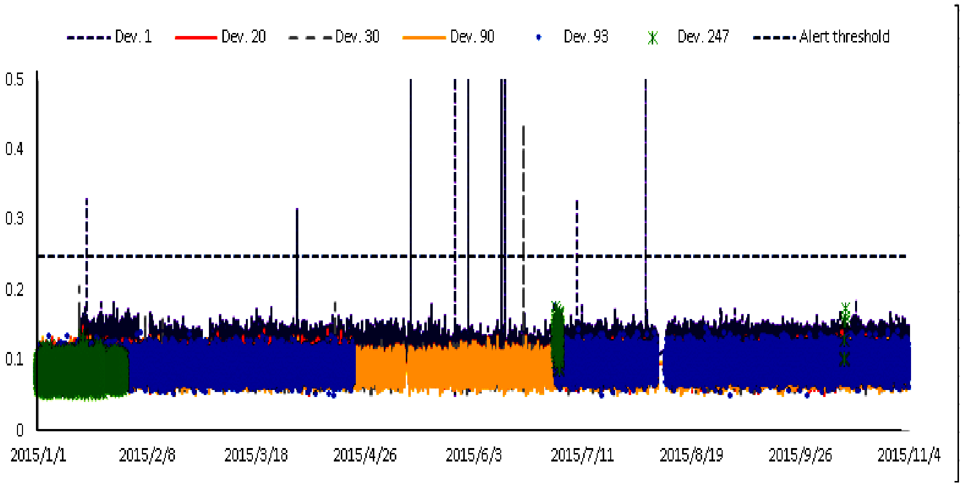

Fig. 6. Environmental radiation dose rates for all six locations measured in 2015.

Table 2. Air dose rates at several islands in Indonesia as reported in references [22-24]. In the table, measured air dose rate ranges and average dose level for the locations cited are presented (if available)

Location	Air dose rate range (nSv/h)	Average air dose rate (nSv/h)
Jawa	19-150	51.93
Sulawesi	18-632	n.a.
Sumatra	23-186	n.a.
Kalimantan	11-349	n.a.
Bali	16-38	n.a.
NTB	18-89	n.a.
NTT	14-66	n.a.
Maluku	8-420	n.a.
Bangka	43-511	183.45
Belitung	15-416	132.60

Furthermore, locations such as Bangka, Belitung, and parts of Kalimantan (Ketapang), Sulawesi (Majene and Mamuju), and Maluku (Kei Island) also have higher environmental dose rate levels [23,24]. In Bangka Island, the dose rates were between 43-511 nSv/h with an average of 183.45 nSv/h. In Belitung Island, the dose rates were 15-416 nSv/h with an average of 132.60 nSv/h [24]. Different concentration of ^{226}Ra, ^{232}Th, and ^{40}K in soil and geological structures or presence of other minerals in rocks may contribute to the higher environmental gamma dose rates in those locations. This result also demonstrates that the presence of nuclear facility or the utilization of nuclear technology will not significantly increase the environmental gamma dose rate.

CONCLUSION

An environmental radiation monitoring system was developed for continuous monitoring of gamma air dose rate at the Serpong Nuclear Complex. The system consists of six GM-based monitoring devices installed around the facility. It started operating in 2010. The average gamma air dose rates at the complex for the past five years are between 84-99 nSv/h which are corresponding to 0.736-0.867 mSv/a, lower than the dose rate level at several locations in Indonesia. Time series analysis indicates that the system was also effective for quickly detecting any short increase in dose rate level that is probably related to a release of radioactive materials into the atmosphere. For the long term operation of this system, budgetary and R&D supports are needed. In the future, a new monitoring device with spectroscopic capabilities can be developed and incorporated into the current system to provide real-time information on the radionuclides detected and their concentration in the atmosphere.

ACKNOWLEDGMENT

The authors acknowledge the National Nuclear Energy Acency (BATAN) for the financial support throughout this work. The authors would like to thank the members of the Meteorological and Radiation Monitoring Team for their technical assistance.

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