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Determination of warning level at Lang Son environmental radiation monitoring station

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Abstract: In this study, a method to estimate the baseline of ambient dose equivalent rate (ADER) of the Lang Son radioactive monitoring station was presented. The warning level is calculated from the arithmetic mean and standard deviation of the terrestrial background value. The terrestrial background value estimated from the Radon peak removal algorithm is 39.85 nSv/h with a standard deviation of 7.58 nSv/h. For comparison, the soil samples around the monitoring equipment were collected and analyzed the activity concentration of nuclides ^{226}Ra, ^{232}Th, ^{40}K. The terrestrial background value estimated from these values of activity concentration is of 41.10 ± 2.96 nSv/h. There is a good agreement between the results evaluating ADER from Radon peak removal algorithm and from the activity concentration of nuclides ^{226}Ra, ^{232}Th, ^{40}K.

Keywords: *Warning level, ADER, Radon peak.*

I. INTRODUCTION

At present, there are many nuclear power plants that are being built and operating in the southeast of China, close to our northern border. The construction of environmental radiation warning and monitoring stations in the provinces along the border is a necessity in order to: timely detect any unusual radiation levels; actively support for response to nuclear and radiological accidents; provide a national database of environmental radiation for serving the State management in the field of atomic energy and nuclear safety. Several online monitoring stations have been set up in some provinces.

Meteorological conditions greatly affect the ambient dose equivalent rate. Rain leads to the accumulation of Radon's progeny on the soil surface by depositing aerosols containing Radon progeny in the atmosphere. Radon progeny deposited on the soil surface has the ability to emit Gamma radiation (mainly ^{214}Pb and ^{214}Bi), leading to an increase in the ambient dose equivalent rate. These respective peaks are often referred to as radon peaks or rain peaks [1, 3] as shown in Figure 1. The elimination of this component's influence on the ADER is essential in order to better identify abnormal radioactive releases, that is, to be able to identify radiation events due to nuclear incidents at a far distance without confusing it with the random release of Radon and its progeny in the environment. From there, get more accurate radiation warning levels for proactively responding to radiation incidents, nuclear incidents.

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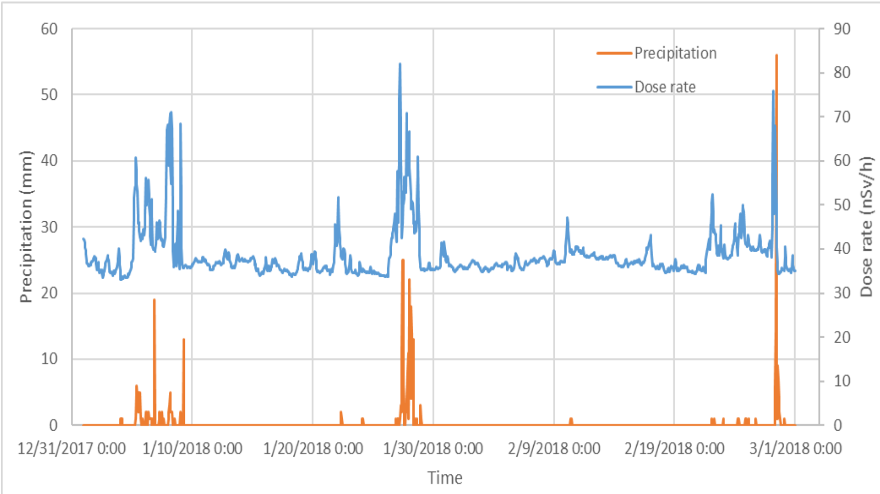

Fig.1. Time series of ambient dose equivalent rate and precipitation recorded during 2 months at the Lang Son station.

II. MATERIALS AND METHODS

A. Site and measurements

The study area is located in Lang Son, which is a mountainous province in northeastern Vietnam. The device monitoring the ambient dose equivalent rate of ENVINET firm (Germany) is located in the premises of Lang Son meteorological station (Figure 2). The vegetation coverage rate is high and no high radiation background area exists in the area.

The monitoring data of dose rate are logged every 10 minutes.

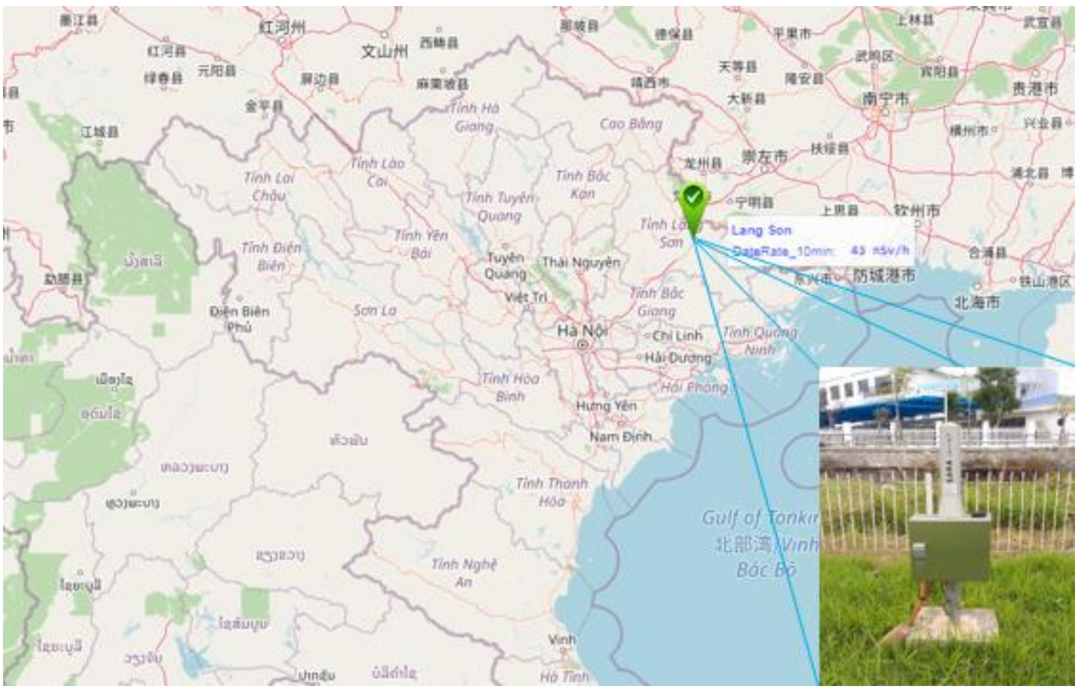

Fig.2. Location map and SARA device located in Lang Son

B. Radon peak removal algorithm - Average method

In the following, we present a method to estimate the baseline of ambient dose equivalent rate. All based on the analysing long-time data series of the 3-years ambient dose equivalent rate (from 2017 to 2019). The measuring device must not move during the period of data selected for processing. It can lead to errors in the determination of terrestrial background values because the natural radioactivity varies from place to place. The next step is to remove the Radon peak. Radon peak removal algorithm is written in Python software with the following content [2]:

Within a window of a given length, (20 days chosen) of 10 minutes averaged data of ADER, starting at the beginning of the series, arithmetic mean (AM) and standard deviation (SD) of the values are computed.

Values more than or less than AM ± α(remove) * SD are excluded (α(remove) = 1.65 chosen). The procedure is repeated until no more values are being excluded from the window. Then the window proceeds a one-time step ahead (1 day chosen), until the end of the series. Usually, three or fewer iterations are required.

The algorithm assigns a baseline value for each time step (1 day), resulting in an estimate of the baseline's time series. The AM of these values is calculated; This is defined as the mean of baseline or terrestrial background value. [3]

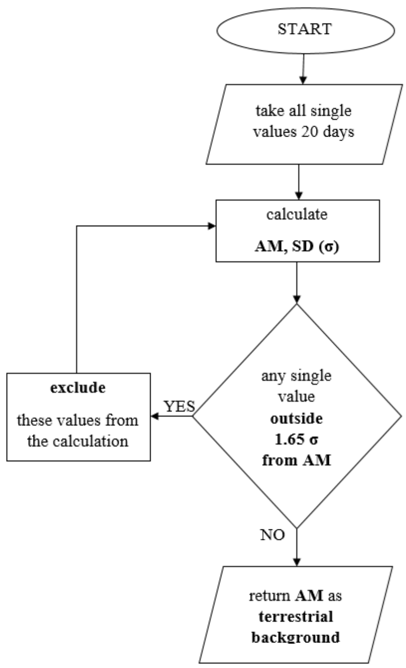

Fig. 3. Algorithm for terrestrial background calculation (AM is the arithmetic mean value, SD its standard deviation).

C. Gamma spectrometry measurements

Besides, we collected soil samples around the measuring equipment and estimated the value of the terrestrial background that contributed to the ambient dose equivalent rate to compare with the terrestrial background values obtained from the Rn peak removal algorithm. The total number of samples taken is 03 samples. The procedure for sampling and sample pre-treatment for gamma radioactivity measurement was as follows: surface soils of a depth of 30 cm were taken using a corer of 7 cm inner diameter. In each location, 1–2 kg of soil was collected. In the laboratory, the samples were first allowed to dry in the air, and then it was dried at 105°C overnight. The samples then were ground and sieved through a sieve of 1-mm mesh to remove gravels as well as plant roots and leaves. Afterward, Marinelli beakers were filled with ~ 600 g soil samples and then sealed off to attain the radioactive equilibrium. The sealed samples were left for a month to ensure the equilibrium of ^{226}Ra nuclide with its decay products in the uranium series. The activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K was measured on a low background gamma spectrometer with CANBERRA's HPGe GC5019 detector, which has the energy resolution and relative efficiency at the peak of 1332.5 keV of ^{60}Co being of 1.8 keV and 50%, respectively. The spectrometer is calibrated using the IAEA RGU-1, IAEA RGTh-1, and IAEA-soil 6 reference samples of comparable geometry. The procedure for measuring soil samples is in accordance with ISO - 17025.

III. RESULTS AND DISCUSSION

A. The results of the baseline of ambient dose equivalent rate and dynamical warning levels at Lang Son station

The dynamical warning level is intended to distinguish the increase in ADER due to nuclear incidents from the increase in ADER due to the influence of meteorological parameters. Natural radioactivity varies from place to place, the alarm level values are adjusted according to the respective local conditions.

The baseline of ambient dose equivalent rate and dynamical warning level results are shown in Figure 4. The mean value of the baseline or terrestrial background value at Lang Son station for 3 years (2017 - 2019) was 39.85 nSv/h with a standard deviation of 7.58 nSv/h (see Figure 5).

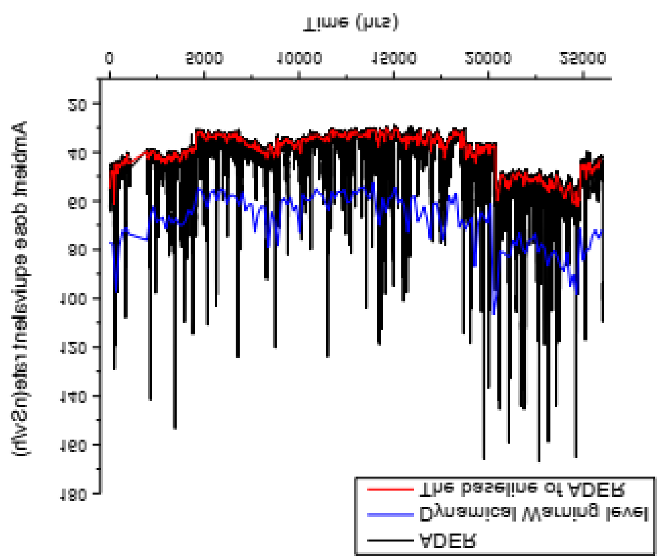

Fig. 4. Diagram showing the estimated baseline of ADER and dynamical warning level

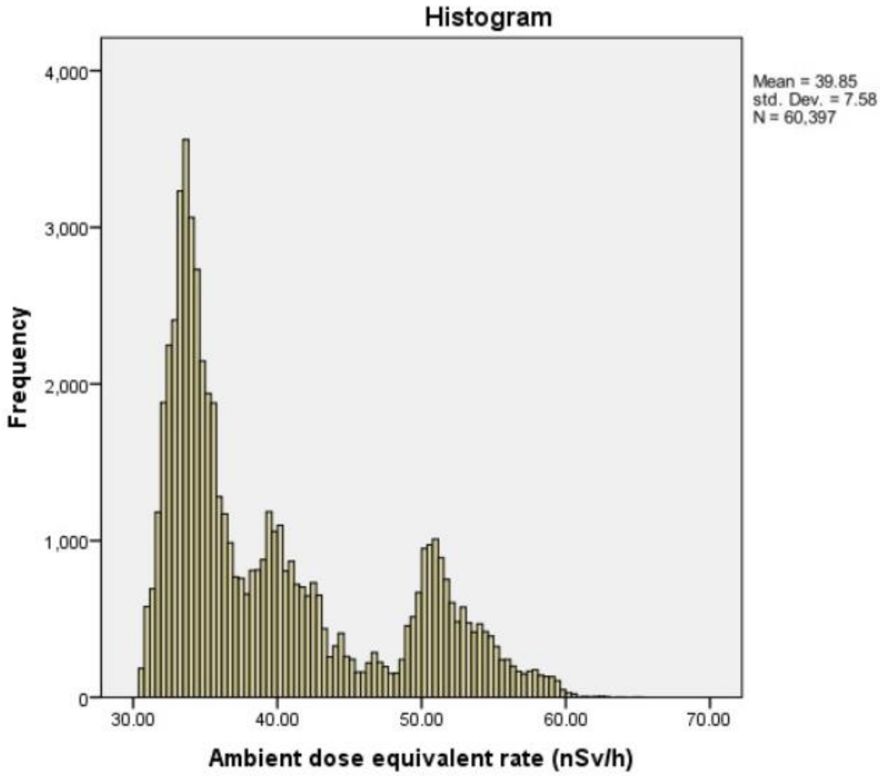

Fig. 5. Diagram of the distribution of terrestrial background values after algorithmic treatment

The dynamical warning level is determined by the formula [4]:

[Dynamical warning level] = ([Mean dose rate] + [standard deviation * 6]) (1)

Where: Mean dose rate is the mean value of the terrestrial background value over a period of 20 days. Standard deviation is the standard deviation of the terrestrial background value.

B. Results determining the ADER value from the activity concentration of nuclides ^{226}Ra, ^{232}Th, ^{40}K in Lang Son soil samples

The results of determining the activity concentration of radioactive nuclides ^{226}Ra, ^{232}Th, ^{40}K in soil samples collected at Lang Son station are presented in Table 1.

According to Ngo Quang Huy et al [5], the dose rate of gamma radiation in the air at an altitude of 1m above the ground will be calculated from the activity concentration of radioactive isotopes ^{40}K, ^{226}Ra, and ^{232}Th through the equation:

$$D = (0.5993 \cdot C_{Th} + 0.4368 \cdot C_{Ra} + 0.0417 \cdot C_K)\ \text{nGy/h} \quad (2)$$

Where C_{Th}, C_{Ra}, and C_K are the activity concentrations in the soils of ^{232}Th, ^{226}Ra, and ^{40}K, respectively (in Bq/kg), and D is the absorbed dose rate in the air (in nGy/h).

According to the error propagation formula, the standard deviation for the absorbed dose rates are:

$$\Delta D = \sqrt{\left(\frac{\partial D}{\partial C_{Th}}\right)^2 \Delta C_{Th}^{\ 2} + \left(\frac{\partial D}{\partial C_{Ra}}\right)^2 \Delta C_{Ra}^{\ 2} + \left(\frac{\partial D}{\partial C_K}\right)^2 \Delta C_K^{\ 2}} \quad (3)$$

Table I. The activity concentration of radioactive nuclides ^{226}Ra, ^{232}Th, ^{40}K (Bq/kg) in Lang Son soil

Samples	**^{226}Ra**	**^{232}Th**	**^{40}K**
DLS 20.1	23.59 ± 0.51	29.59 ± 0.61	128.09 ± 2.57
DLS 20.2	22.83 ± 0.50	29.19 ± 0.59	124.36 ± 2.51
DLS 20.3	23.29 ± 0.51	29.53 ± 0.60	126.37 ± 2.54

Table II. The dose rate values are contributed by radioactive nuclides in soil

Samples	**D (nGy/h)**	**H*(10) (nSv/h)**
DLS 20.1	33.38 ± 2.40	41.82 ± 3.01
DLS 20.2	32.65 ± 2.35	40.44 ± 2.91
DLS 20.3	33.14 ± 2.39	41.03 ± 2.95
Mean	33.06 ± 2.38	41.10 ± 2.96

We calculate the absorbed dose rate by formula (2), and the standard deviation is calculated using formula (3). The calculated absorbed dose rate (D) values are given in Table 2. The relationship between air kerma rates and ambient dose equivalent rates for the measured terrestrial radiation fields was found to be H*(10) = 1.21 Ka + 1.26 where H*(10) is the ambient dose equivalent rate in nSv/h and Ka is air kerma rate in nGy/h. [6]

From the value of H*(10) in Table II, we can see that the terrestrial background value contributed from natural radioactive nuclides in the soil is approximately the terrestrial background determined by the Radon peak removal algorithm. Thus, it can be seen that the Radon peak removal algorithm gives a reliable terrestrial background value.

IV. CONCLUSIONS

The research team has built up an algorithm to determine the baseline of the ambient dose equivalent rate and the dynamical warning level for Lang Son environmental monitoring station with high reliability. This dynamical warning level will be applied at the operating room of the national environmental radioactive monitoring network - Institute of Nuclear Science and Technology in the coming time.

From the developed algorithm, we have determined the terrestrial background value of ADER to be 39.85 nSv/h with a standard deviation of 7.58 nSv/h. Soil samples around the measuring equipment were collected and estimated the value of the terrestrial background that contributed to the ambient dose equivalent rate is 41.10 ± 2.96 nSv/h. There is a good agreement between the results evaluating ADER from Radon peak removal algorithm and from the activity concentration of nuclides ^{226}Ra, ^{232}Th, ^{40}K.

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