Nucl. Sci. and Tech., Vol.8, No. 1 (2018), pp. 17-22

Nuclear Science and Technology

Journal homepage: https://jnst.vn/index.php/nst

Activity concentrations of ^{210}Pb in the aerosol at Hanoi

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Abstract: In this study, aerosol samples at Hanoi, Vietnam from February 2017 to January 2018 collected on the glass fiber filter were analyzed for ^{210}Pb by using HPGe spectrometry. ^{210}Pb weekly activity concentrations were in the range of 0.12 mBq.m^{-3} to 2.87 mBq.m^{-3} with an average value of 0.92 mBq.m^{-3}and ^{210}Pb monthly activity concentrations were in the range of 0.99 mBq.m^{-3} to 9.24 mBq.m^{-3} with an average value of 4.01 mBq.m^{-3}. The analysis of monthly averaged ^{210}Pb activity concentrations revealed a dominant seasonal variability: high activity concentrations of ^{210}Pb in winter and lower values in summer. The correlation between the activity concentrations of ^{210}Pb in aerosol and the meteorological parameters (average temperature, precipitation and relative humidity) were observed and the obtained correlation coefficients are -0.95, -0.58 and -0.71, respectively.

Keywords: *Activity concentrations of ^{210}Pb, HPGe, MCNP.*

I. INTRODUCTION

One of the important radionuclides in atmospheric air, regarding both scientific research and everyday air quality, is the naturally occurring radionuclide ^{210}Pb [7]. It is a member of the ^{238}U decay chain, which is naturally present in the Earth's crust [1,7]. As ^{210}Pb is formed in the chain after the alpha decay of ^{222}Rn, which is a noble gas and thus able to exhale through the soil and migrate to the atmosphere, transfer in air, and deposit to the ground [7]. A considerable amount of ^{210}Pb is constantly present around us in the environment [7]. Together with other ^{222}Rn progeny ^{210}Pb has a significant impact on the effective dose of ionizing radiation to a human via inhalation and ingestion [7,13]. Unlike the short-lived ^{222}Rn, the progeny ^{210}Pb has a half-life of 22.3 years, with a mean residence time in the atmosphere about 10 days (varying from 0 days to more than 5 weeks) and is thus a useful tracer for atmospheric movements. It has been noticed that ^{210}Pb atoms tend to attach to the sub-micron sized aerosol particles, which are widely used in atmospheric studies as characteristic indicators [1,2,3,7,10,12,13]. With its 46.5 keV full energy gamma peak, ^{210}Pb is comfortably detectable via non-destructive gamma-ray spectrometry when it is collected from the air on glass fiber filter [7].

In this study, the aerosol particles were collected from the atmospheric air using high-volume air samplers at the Institute for Nuclear Science and Technology (INST) survey sites in Hanoi, Vietnam. Collected filters were analyzed using HPGe gamma-ray spectrometry in the laboratory of the Center for Environment Monitoring and Impacts Assessment, INST.

II. MATERIALS AND METHODS

A. Sampling and sample process

https://doi.org/10.53747/jnst.v8i1.79
Received 20 March 2018, accepted 14 May 2018

Activity concentrations of ^{210}Pb were collected on the glass fiber filter samples. The duration time for sampling samples at the Hanoi station covers the period from February 2017 to January 2018. In total, the current study is based on the analysis results of 44 filter samples.

The used aerosol filters were general grade G653 glass fiber filters by Whatman (its size: 8 ×10 inch), whose efficiency for collecting particles of 0.3μm is considered to be 99% or better [5]. The air sample was sucked through the filter for a week by a high-volume air-sampling device - Total Suspended Particulate model TE-5170DV-BLX (TISH Environmental, USA). The volume of air pumped through the filter during that time was recorded when removing the filter from the device. The average weekly air volume passing the filter was 4092 m^3, with a minimum and a maximum of 3360 m^3 and 4356 m^3, respectively.

After sampling, the filters were folded and pressed into flat tablets with a diameter of 3.2 cm and a height of 0.5 cm by a hydraulic press.

B. Gamma spectrometry measurements

The activity concentration of ^{210}Pb was measured by the 46.5 keV gamma line using a gamma spectrometer with HPGe GMX 40P4 detector (ORTEC, USA) with an energy resolution of 1332 keV is 1.8 keV. The spectrometer is calibrated using the IAEA RGU-1 reference sample of comparable geometry. Because of relatively low-energy gamma ray, the results were corrected for self-attenuation via efficiency correction factors [4,7]. Several studies have shown that various theoretical and empirical methods have been used for estimating the self-attenuation coefficients; Monte Carlo simulations were proved to be somewhat time-consuming but the most accurate methods, including self-absorbed correction. [4,7]. MCNP 6.1 was used to simulate the efficiency of the detector. The activity concentration values were corrected for decay to the middle of the duration of sample collecting. This correction factor is very small because the ^{210}Pb half life is very large compared to the sampling time.

The meteorological data monitored at the Lang station, Hanoi as precipitation, relative humidity, air pressure and temperature were provided by the Vietnam Institute of Meteorology, Hydrology and Climate Change (Table I).

RESULTS AND DISCUSSION

The efficiency for the aerosol filters geometry ε_x is given by [15]

$$\varepsilon_x = \varepsilon_{ref}\left(\frac{\varepsilon_x^{MC}}{\varepsilon_{ref}^{MC}}\right)$$

Where ε_{ref} is the experimental efficiency for the IAEA RGU-1 reference sample, and ε_{ref}^{MC} and ε_x^{MC} are the calculated efficiencies (via Monte Carlo) for the IAEA RGU-1 reference sample and the geometry of aerosol filters, respectively. This method corrects the geometric differences and also includes a correction for the intrinsic detector efficiency, thus, it is not necessary to make corrections for the self-absorption in the low energy ranges because the self-absorption is taken into account in the Monte Carlo simulation of the sample of interest [15].

The composition of the IAEA RGU-1 reference sample was 52.92% O, 45.69% Si, 0.52% Na, 0.34% P, 0.27% Mg, 0.07 % Fe, 0.07% Ca and 0.01% U, [18]. Our reference sample density was ρ=1.25 g/cm^3.

The composition of the glass fiber filter was 82% of SiO_2, 12% PbO, 4% Na_2O and 2% Al_2O_3 with density of 0.87 g/cm^3 [17].

In our measurement $\varepsilon_{ref} = 0.0449 \pm 0.0027$, $\varepsilon_{ref}^{MC} = 0.0488 \pm 0.0001$ and $\varepsilon_x^{MC} = 0.2210 \pm 0.0002$ we have $\varepsilon_x = 0.2033 \pm 0.0012$. This efficiency value was used for calculating ^{210}Pb activity concentration in the aerosol filters.

The ^{210}Pb activity concentration in the aerosol demonstrates a considerable temporal variation. The weekly data (Fig. 1) varied in the range from 0.12 mBq.m^{-3} to 2.87 mBq.m^{-3} with an arithmetic mean value of 0.92 mBq.m^{-3}. The average activity concentration of ^{210}Pb measured in Hanoi is higher than that in North America (0.29 to 0.75 mBq.m^{-3}) and Europe (0.2 to 0.7 mBq.m^{-3}) [14].

For seasonal analysis, the seasons are defined according to the meteorological situation in Hanoi: spring lasts during February, March, and April; summer months are May, June, and July; and autumn lasts from August, September, and October, winter consists of November, December and January [16].

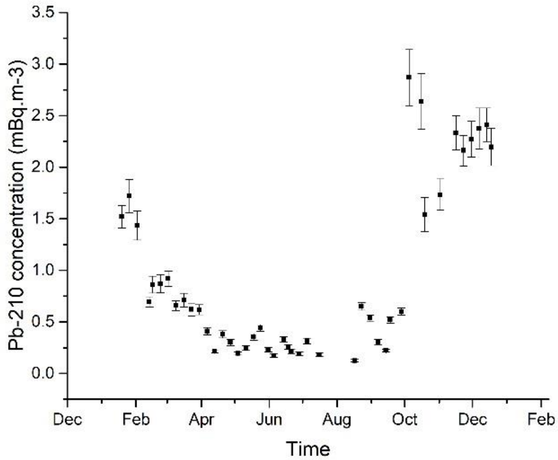

Fig.1. Activity concentrations of ^{210}Pb with combined uncertainties

Figure 2 shown that ^{210}Pb activity concentrations were the highest in the winter and the lowest in the summer. The dark horizontal line in the middle of the box indicates the median value, bottom and top lines for constructing the box are equal to the 25% and 75% of the data; thus 50% of the data lie 'in the box' [7]. Top and bottom values are the largest and the smallest.

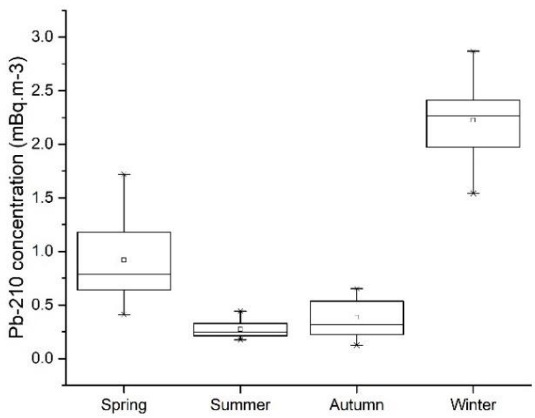

Fig. 2. Distribution of ^{210}Pb activity concentration according to seasons

Table I showed ^{210}Pb monthly activity concentrations and meteorological data such as temperature, rainfall and humidity [16]. The correlation between the ^{210}Pb monthly activity concentrations and temperature, precipitation and humidity have been studied and the results have shown in Figures 3, 4, 5 and Table II.

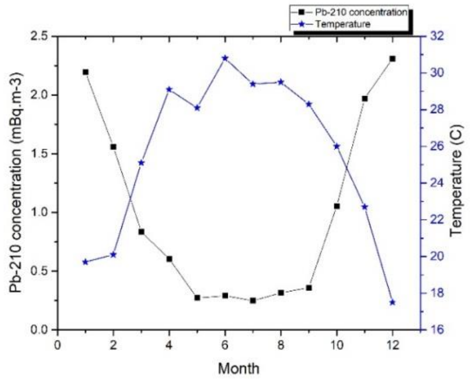

Fig. 3. The activity concentration of ^{210}Pb and the average temperature in monthly

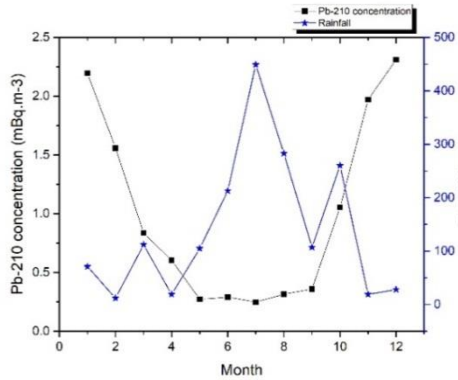

Fig. 4. The activity concentration of ^{210}Pb and the average rainfall in monthly

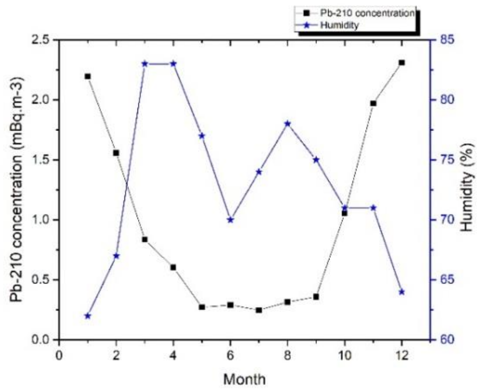

Fig. 5. The activity concentration of ^{210}Pb and the average humidity in monthly

Table I. ^{210}Pb activity concentrations and meteorological data [16]

Month	^{210}Pb (mBq.m^{-3})	Temperature (^{0}C)	Rain fall (mm)	Humidity (%)
Jan	8.78 ± 0.72	19.7	71	62
Feb	6.23 ± 0.55	20.1	12	67
Mar	3.35 ± 0.29	25.1	112	83
Apr	2.42 ± 0.21	29.1	19	83
May	1.09 ± 0.09	28.1	105	77
June	1.16 ± 0.10	30.8	213	70
July	0.99 ± 0.09	29.4	449	74
Aug	1.26 ± 0.11	29.5	283	78
Sept	1.44 ± 0.10	28.3	107	75
Oct	4.21 ± 0.35	26	260	71
Nov	7.88 ± 0.78	22.7	19	71
Dec	9.24 ± 0.68	17.5	28	64

Table II. Correlation coefficients of ^{210}Pb monthly activity concentrations with meteorological data

	^{210}Pb	Temperature	Rainfall	Humidity
^{210}Pb	1			
Temperature	-0.95	1		
Rainfall	-0.58	0.59	1	
Humidity	-0.71	0.69	0.16	1

The Table II showed that the correlation coefficients of ^{210}Pb activity concentrations with temperature, rainfall and humidity were -0.95, -0.58 and -0.71, respectively. It can be seen that the trend of ^{210}Pb activity concentrations in the aerosol is high as the temperature, rainfall, humidity is low and vice versa. A negative correlation between the ^{210}Pb activity concentrations and temperature was the highest.

CONCLUSIONS

We analyzed the weekly activity concentrations of ^{210}Pb in an aerosol of Hanoi, Vietnam from February 2017 to January 2018. ^{210}Pb weekly activity concentrations in Hanoi varied according to season quite obviously. It trends high in the winter and low in the summer. A negative correlation between the ^{210}Pb activity concentrations and temperature, rainfall, humidity are also obvious, especially with air temperature.

ACKNOWLEDGMENTS

This work was funded by Vietnam Atomic Energy Institute (Vinatom) under grant CS/17/04-01.

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