Analysis of gross alpha, gross beta activities and beryllium-7 concentrations in surface air: their variation and statistical prediction model

F. Arkian[1]*, M. Salahinejad[2], J. Amidi[1]

[1] National Radiation Protection Department, Atomic Energy Organization of Iran, Tehran, Iran
[2] Nuclear Research Center, Tehran, Iran

Background: Measurement of gross α, gross β activities, and cosmogenic beryllium-7 (^{7}Be) concentrations were made both daily and weekly during the years 2001- 2004 from samples of atmospheric aerosols filtered from the air at Tehran Nuclear Research Center (35º41' N) and Zahedan (28º29' N). *Materials and Methods:* Weekly aerosol samples were collected with the high-volume air samplers on cellulose filters to determine the ^{7}Be contents of samples, using a semiconductor gamma spectrometer. Airborne dust samples were collected on daily basis on fiber glass filters and used to determine the gross β and gross α activities with automatic beta analyzer and a ZnS(Ag) counter, respectively. In this study, the concentration and meteorological data were used to determine models for gross α, gross β and ^{7}Be. *Results:* The air concentrations of gross β and gross α activities and ^{7}Be concentrations displayed lognormal distributions during the study period. Both β and ^{7}Be had maximum activity concentrations during warm mid-year months. *Conclusion:* The models can be used to estimate the part of the trend in gross β and in ^{7}Be levels that can be accounted for by-trends in local meteorology. There has been a satisfactory agreement between the results of the model and the measurements. **Iran. J. Radiat. Res., 2006; 4 (3): 155-159**

Keywords: ^{7}Be concentrations, gross activity, gross activity, meteorology parameters.

INTRODUCTION

Radioactivity in the atmosphere originates from natural radioactive decay, cosmogenic production, nuclear weapons testing and nuclear accidents.

Results of the measurements have shown that cosmogenic ^{7}Be is the only gamma emitting nuclide found in the atmosphere of Iran [1].

^{7}Be ($t_{1/2}$ = 53d) is one of the radioactive products of the bombardment of the atmosphere by cosmic rays. About 75% of ^{7}Be is produced in the stratosphere, and 25% in upper troposphere [2]. Once ^{7}Be is formed in the troposphere, it rapidly associates primarily with sub-micron-sized aerosol particles. ^{7}Be in these aerosols may subsequently enter the marine and terrestrial environment via wet or dry deposition [3].

In this paper we report four years of continuous measurements of gross α and gross β activities, and concentrations of ^{7}Be in surface air. The present research was undertaken with the following principal goals: a) To perceive the variations of gross α, gross β and ^{7}Be concentration in Tehran as compared to Zahedan; b) To identify the main meteorological parameters which are responsible for the variation of those concentrations and c) To model the data obtained from our sampling sites as a function of meteorological parameters such as temperature, precipitation, wind speed relative humidity, etc. With the regression model, the ground level concentration associated with the changes in meteorological conditions could be estimated.

Experimental procedures

Airborne dust samples were daily collected on fiber glass filters, 47-mm diameter (collection efficiency 99.99% for 0.8 pore size) with an air sampler at a flow rate of 39 m^3day^{-1}. Aerosol samples have been weekly collected with high-volume air sampler on

*Corresponding author:
Foroozan Arkian, National Radiation Protection Department, P. O. Box: 4494-14155 Tehran, Iran.
Fax: +98 21 88009502
E-mail: farkian@aeoi.org.ir

cellulose filters (Petrianov). Both types of air samplers were 1 m above the ground, in Tehran and Zahedan stations.

The fiber glass and cellulose filters were used to count the gross α, gross β and ⁷Be, respectively. The measurements of the gross β and gross α activities were performed by an automatic beta analyzer and a ZnS (Ag) counter. Long-lived beta activity was defined as total beta activity four days after the end of sampling, when short-lived ^{222}Rn progeny have been decayed into ^{210}pb. The counting time was 30000 seconds and the background was also collected for the same period of time and subtracted from the samples count.

Aerosol samples were collected on weekly basis with the high-volume air samplers and cellulose filters were used to determine the ⁷Be contents of samples, using a semiconductor gamma spectrometer. Determination of ⁷Be concentration was made by means of its 477.6 keV gamma-ray using a CANBERRA Hyper-Pure Germanium (HPGe) detector (relative efficiency about 20% to the efficiency of 3×3 NaI at 25cm distance, resolution 2 keV for 1332 keV gamma-ray of ^{60}Co) connected to a 4096 channel pulsed-height analyzer. The counting efficiencies of the HPGe detector was determined by a standard sample containing a known amount of radioisotopes such as ^{133}Ba, ^{137}Cs and ^{60}Co. Counting time for each sample was 60000 seconds, leading to the detection limit of about 0.8 Bq per sample.

The ⁷Be concentration was calculated using a 53-day half-life, gamma counting efficiencies of 1.2% and branching ratios of 0.11. The concentrations were corrected for decay to the mid-collection period.

RESULTS AND DISSCUSSION

The gross α, gross β activities and ⁷Be data used in the analysis were daily and weekly values of concentration in surface air. Aerosol sampling for atmospheric radionuclides commenced in January 2001 and terminated in July 2004.

Temporal Variations of gross α, β and ⁷Be concentration

Table 1 lists the arithmetic mean concentration (AM) for gross α, gross β and ⁷Be and their standard deviation for each month, averaged over all sampling years for all samples collected the sites. The number of samples for each mean (n) is also given in the table. On examining this table, it can be said:

a) The highest values of gross β and gross α activities were registered in November, while those of ⁷Be concentration were obtained in July.

b) The lowest values of gross β and gross α activities were registered in February, while those of ⁷Be concentration were obtained in January.

c) The data of our sampling site have shown seasonal variations in the concentrations of ⁷Be. Seasonal variations presented 2 minimum averages in fall and winter months, and maximum averages during the summer months, probably reflecting the seasonal variations in the transport rate of air from the stratosphere to the troposphere.

The ⁷Be data for two sites (Tehran and Zahedan), which are at a different latitudes, show pronounced seasonal variation in surface air concentrations of this radionuclide [1]. Such seasonal variations have long been known to occur [4, 5]. Observed seasonal variations in the concentration of ⁷Be in the surface air have often been attributed to the influence of variations in the exchange rate of air between the stratosphere and the troposphere. Although this influence is clearly real, other factors are also important [6]. In the both sites, variation in the concentration was also resulted in part from seasonal variations in the rate of vertical mixing within the troposphere with the highest concentration being found during the warmer months [7].

Both sites have maximum concentrations during the warm, mid-year months. An important factor in the production of peak concentrations of ⁷Be during the warmer month has been increased rates of vertical transport of air between the stratosphere and

Table 1. Mean monthly measured concentration in surface air averaged over all sampling years.

Month	Gross α (mBq m⁻³)			Gross β (mBq m⁻³)			⁷Be (mBq m⁻³)		
	AM	S.D	n	AM	S.D	n	AM	S.D	n
January	74.58	27.61	64	196.47	56.91	64	5.62	2.10	19
February	71.04	25.12	54	174.91	66.04	54	6.25	2.20	17
March	94.57	29.81	30	243.38	89.38	30	5.88	3.69	9
April	73.25	15.21	47	196.37	44.44	47	6.87	2.46	18
May	78.30	28.37	59	209.24	66.09	59	8.15	1.67	16
June	79.21	37.16	61	206.32	82.25	61	9.03	1.85	21
July	77.90	20.53	69	194.22	68.86	69	9.61	2.92	22
August	79.91	17.29	66	209.16	54.51	66	8.03	0.58	20
September	93.76	12.26	61	247.22	37.47	61	7.41	2.86	19
October	110.01	8.69	58	277.28	26.18	58	7.49	2.79	21
November	121.20	20.81	54	305.46	63.80	54	5.65	2.71	17
December	80.17	18.39	67	211.19	45.03	67	6.87	4.44	19

the troposphere which occurred during those warm seasons. During the warm months, the solar heating of the surface of the earth led to the heating of the air in contact with the surface. Cooler air sinks, displaced the warm, less dense air and forced it upward. The new air has been heated in turn and forced upward. A convective circulation has been produced, carrying surface air upward and bringing downward the air from higher levels. This vertical transport carried down the ⁷Be to the surface layer which has been produced within the upper troposphere, as well as that which has entered the troposphere from the stratosphere.

The data showed seasonal variations in the concentrations of gross beta activities. The concentrations were highest during the warm mid-year months [8]. Duenas *et al.* [5] measured the mean ⁷Be concentration in surface air about 4.1×10^{-3} Bqm⁻³ during the years 1992-1995. The concentration of ⁷Be in their study was higher than the above mentioned value, since the stability of the tropospheric air was highest toward the cold polar region and decreased the rate of vertical mixing within troposphere [6].

Analyses of some meteorological factors affecting variation in concentration

Meteorology plays an important role in dispersion and transport of pollutants. A study has been performed to identify which meteorological parameters have been strongly associated with the fluctuations of daily concentration. During the period while this study was being conducted, meteorological data (wind direction, temperature, pressure, relative humidity, and precipitation and sunshine hours) were supplied by Geophysics institute weather station in Tehran.

Three factors play an effective role in the climate of Tehran: the Alborz Mountains, the western humid currents, and the latitude. As a matter of fact, the Alborz Mountains moderate the weather in Tehran. In northern Tehran, the weather is moderate and mountainous, and in the plains it is semi-arid. A major part of precipitation takes place in winter. Average annual rainfall is about 200 mm. The cold season usually begins in December, but in the mountainous regions, it begins earlier. The cold season lasts 3 to 4 months. In mid-March, the weather grows warm.

In this study, First, a simple regression of the gross β, gross α and ⁷Be concentrations against some meteorological factors was performed, and then the procedure has been carried out a stepwise multiple regression in order to determine the extent to which the variation in concentration might be attributed to the combination of these meteorological parameters. In the analysis, weekly average of the daily maximum temperature (T_{max}), daily precipitation (PR), daily average relative humidity (H), daily hours of sunshine (SS), daily average pressure (P) and daily average wind speed (V) were used.

In table 2, the correlation coefficients between concentrations and those meteorological factors are summarized. These correlation coefficients are in 99.9 confidence level.

Table 2. Linear co-rrelation coefficient between surface air concentrations and some meteorological factors.

Activity	T_{max}	H	P	PR	WF	WF
Gross α	0.088	-0.229	0.126	-0.169	0.017	0.203
Gross β	0.094	-0.234	0.132	-0.189	0.012	0.218
⁷Be	0.559	-0.455	0.338	-0.23	0.338	0.44

To evaluate the regression equations, the relative error of coefficient of each independent variable, the standard error of each independent variable, the standard error of the estimate and the R-squared value were taken into account. Using these criteria, the following equations were chosen for the gross β and ⁷Be, respectively, from the results of the forward regression method:

$$A_\beta (\times 10^{-3}) = -(0.47 \pm 0.741) + (0.002 \pm 0.001) \times T_{Max} + (0.001 \pm 000) \times P \quad (1)$$

$$A_{Be-7}(\times 10^{-3}) = (2.231 \pm 0.884) + (0.077 \pm 0.042) \times T_{Max} + (0.001 \pm 00) \times PR + (0.092 \pm 0.109) \times SS \quad (2)$$

These equations show the number of parameters that apparently modify the fluctuations of the gross β and ⁷Be. Analyzing these equations, it can be said that the meteorological variables which influence the daily gross β activity the most are: T (temperature) and P (pressure). For the weekly ⁷Be concentration, temperature (T), precipitation of that week (PR) and sunshine (SS) are the most important ones. For the gross α activity, standard error of estimate for the equations has been too large. Therefore, no relation between gross α and meteorology parameters has been considered.

Model as a function of meteorological parameters

To test validity of the equations for estimation of gross α and gross β activities and ⁷Be concentration in Tehran, Eqs. (1) and (2) to weekly data which were not used in the stepwise regression method was applied.

In figures 1 and 2, the theoretical line (dotted line) between the calculated values and those experimentally observed were plotted. The solid lines correspond to linear least-squares fit to the data. The regression equations obtained are given as:

$$\beta_{observed} (mBq\, m^{-3}) = 1.865 \times \beta_{calculated} + 0.2187 \quad (3)$$

$$^7Be_{observed} (mBq\, m^{-3}) = 0.2941 \times ^7Be_{calculated} + 6.838 \quad (4)$$

Our study revealed the validity of the relationship between gross β and ⁷Be and meteorological variables implied, and the similarity between the graphs slops in figures 1 and 2.

A significant feature of the present results is that it seems to be masked by the temperature in the regression process. This phenomenon can be quantified in figure 3 which represents weekly ⁷Be concentration and weekly rainfall data during 2002. The incidental very strong or very light may result in rather extreme activity values. Although this effect is clearly noticeable in special cases (our case), it does not play an important role in the overall evaluation of ⁷Be [5].

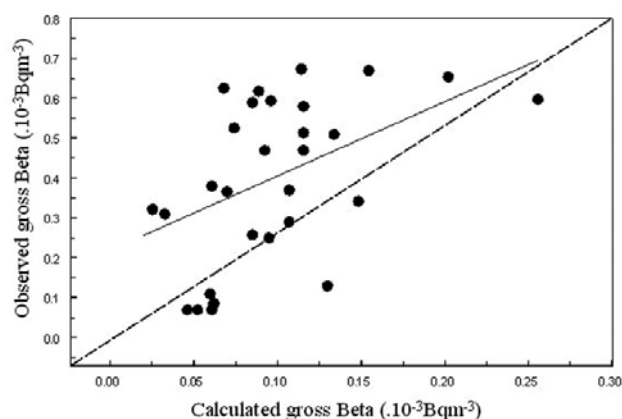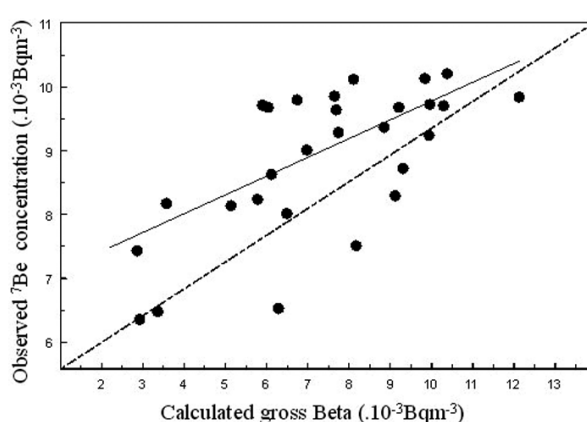**Figure 1.** Observed gross beta activity versus the calculated values.

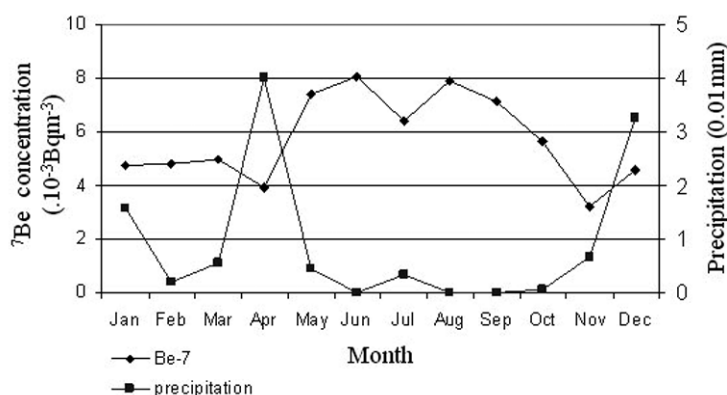**Figure 2.** Observed ⁷Be concentration versus the calculated values.

Figure 3. ⁷Be concentration and precipitation during the year 2002.

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