CLIMATIC VARIATIONS OF BERYLLIUM-7 ACTIVITY IN THE ATMOSPHERE OF PESHAWAR BASIN, PAKISTAN, DURING 2001-2006

by

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In the present study, the climatic variations of ^{7}Be in the Peshawar basin (longitude 71° 15 and 72° 45 E and latitude 33° 45 and 34° 30 N) of Pakistan was observed during the period of 2001-2006. Under the domain of environmental surveillance programme, air particulate samples were collected from Peshawar basin on fiberglass filters and analyzed for gamma emitting radionuclides using the gamma spectrometry system. The results of the last six years (2001-2006) range between 3.6 to 5 mBq/m^3, while the composite average concentration of this radionuclide for the whole period is 4.5 mBq/m^3. The measured values were significantly lower than the world average value of 12.5 mBq/m^3. The climatic variations in the concentrations of ^{7}Be were also checked by classifying the whole year into four seasons (winter, spring, summer, and fall) and a positive correlation between ^{7}Be activity and change in temperature was obtained.

Key words: beryllium-7, air particulate sample, Peshawar basin, gamma spectrometry, seasonal indices

INTRODUCTION

Regular monitoring of radioactivity in air particulates and aerosol samples provides useful information about radiation in the environment due to natural and manmade sources and helps to study their impact on human beings. Radionuclides of the cosmic origin are also present at the ground level and may also be used to provide a tool for studying changes in atmospheric processes.

The pollution of the biosphere, as a result of the improper management of socioeconomic development activities, has exposed natural resources and the ecosystem to a great stress. The industrialization process, power generation and intensive agricultural practices have helped in improving the quality of life; at the same time, however, these activities are adversely affecting the quality of environment due to the indiscriminate releases of noxious substances from natural and anthropogenic sources into the environment. The presence of toxic/radiotoxic pollutants in the indoor and outdoor environment constitutes a serious threat to human health.

The interaction of cosmic rays with air in the upper atmosphere results in secondary radiation. Beryllium-7 is produced in the upper atmosphere by cosmic rays spallation of nitrogen and oxygen. Being radioactive, ^{7}Be (half-life of 53.3 days) emits 477.6 keV gamma rays with 10.3% gamma abundance. About 70% of the ^{7}Be is produced in the stratosphere where the cosmic ray intensity is greater, with the remaining 30% being produced in the troposphere. The activity of ^{7}Be, produced in the stratosphere, has a residence time of about one year and is transferred to the troposphere. The residence time in the troposphere is about six weeks. Transfer to the Earth's surface is normally carried out to a larger extent, by gravitational settling and precipitation processes. Cosmogenic radionuclides activity may thus vary significantly with altitude as well as

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latitude, not only because of the location of their production but also because of the atmospheric mixing processes and half-life [1]. Moreover, different meteorological conditions and geographical locations also play an important role in variable concentrations of cosmogenic radionuclides. Generally, the maximum ^{7}Be values associated with the hottest months of the year may be accounted for by vertical air mixing. The rising hot air provokes the descent of the cold air from higher layers which contains greater concentrations of cosmic radionuclides [2].

Pakistan is a subtropical semiarid country characterized by four distinct seasons (winter, spring, summer, and fall) and a monsoon period which, in most parts of the country, brings heavy rains [3]. Peshawar basin is an intra mountain basin (>5500 km^2) situated at the southern margin of the Himalayas and northwest of the Indus plain in the North West frontier province (NWFP) of Pakistan. It is bounded by the mountain ranges of Khyber in the west and northwest, Attock Cherat in the south, and Swat in the north and northeast while the Indus river borders its southeastern side, where it is open for the discharge of water. Peshawar, the capital city of NWFP, Nowshera, Charsadda, and Mardan are the major cities of this basin. It is mainly irrigated by the Kabul and Swat rivers and their tributaries. The map of Peshawar basin is shown in fig. 1.

The air particulate monitoring of Peshawar basin is a regular feature of our countrywide radiological environmental monitoring and surveillance programme, being carried out in the entire country through a network of air sampling units installed at 12 different locations. These locations include Larkana, Peshawar, Karachi, Faisalabad, Lahore, Multan, Islamabad, Quetta, D. G. Khan, Mianwali, Tandojam, and Abbottabad.

In the present study, the climatic variations of ^{7}Be activity in the atmosphere of Peshawar basin, Pakistan during 2001-2006 have been presented. The results have also been compared with some other areas as well as with the world average values.

MATERIAL AND METHODS

Air particulate samples were collected on 55 cm 45 cm fiber glass filter papers having 99.99% collection efficiency using a high volume SECOMAK air sampler with an average flow rate of 209 m^3/h. The sampler was installed on the top of 15 m tall building of Peshawar region (34.01° N, 71.55° W). The frequency of the sampling period was kept as fifteen days with the mean value of the total volume of the gathered aerosol as ~5500 m^3. Prior to the radiometric measurement, the filter papers were normally converted in accordance with the specific geometry of the detector by folding and pressing into a disc of 6.5 cm diameter and 1.5 cm thickness using a hydraulic jack/press.

The radiometric analysis of each sample was performed by the measurement of gross gamma counts using NaI detector followed by the measurement of ^{7}Be radioactivity (gamma ray: 477.6 keV, half life: 53.28 d) by detailed gamma spectrometry on a high resolution gamma spectrometer. The system consisted of a high purity coaxial type germanium (HPGe) detector coupled with a PC based multichannel analyzer [4, 5]. The relative efficiency of the detector was 30% and its resolution (FWHM) for full energy peak of 1332 keV gamma ray of ^{60}Co source was 1.9 keV. The system was calibrated using the ^{166m}Ho source having the same geometry as the samples. The samples were normally counted for a counting time of 65000 seconds. To account for the background of the system, a blank sample of the same geometry was counted periodically for the same period of time. The results were analyzed using Genie-2000 software (Canberra).

RESULTS AND DISCUSSION

The collected samples were analyzed for the measurement of ^{7}Be concentration. The monthly values of the whole analysis period from 2001-2006 along with the minimum, maximum, and mean specific activities

Figure 1. Map of Peshawar basin

Table 1. Specific activities of ^{7}Be measured in air samples of Peshawar basin from 2001 to 2006

S. No.	Months	Activity [mBqm^{-3}]					
		2001	2002	2003	2004	2005	2006
1	January	2.7 1.2[a]	3.9 ± 1.3	2.8 ± 1.2	2.9 ± 1.3	1.8 ± 1.2	2 ± 1.1
2	February	3.8 ± 1.3	4.6 ± 1.3	3.7 ± 1.2	3.8 ± 1.2	2.4 ± 1.2	2.7 ± 1.2
3	March	3.7 ± 1.3	4.9 ± 1.5	5.3 ± 1.4	4.5 ± 1.4	3.9 ± 1.3	3.8 ± 1.3
4	April	5.7 ± 1.4	5.8 ± 1.5	5.1 ± 1.3	6.9 ± 1.5	4.7 ± 1.3	5.3 ± 1.4
5	May	6.2 ± 1.3	5.4 ± 1.4	6.1 ± 1.3	6.4 ± 1.4	4.6 ± 1.4	4.7 ± 1.3
6	June	5.6 ± 1.5	6 ± 1.5	5.6 ± 1.4	6.1 ± 1.4	6.5 ± 1.5	5.5 ± 1.5
7	July	6.3 ± 1.4	6.6 ± 1.5	7.1 ± 1.5	5.8 ± 1.3	4.7 ± 1.3	5.6 ± 1.5
8	August	6.1 ± 1.3	5.2 ± 1.4	5.4 ± 1.4	5.9 ± 1.3	3 ± 1.2	6.6 ± 1.4
9	September	5.8 ± 1.4	5.2 ± 1.3	4.8 ± 1.2	4.6 ± 1.2	3.9 ± 1.3	3.6 ± 1.2
10	October	4.4 ± 1.2	4.2 ± 1.2	4.9 ± 1.3	4.4 ± 1.4	3.1 ± 1.3	4.1 ± 1.3
11	November	4.9 ± 1.5	4.5 ± 1.3	3.6 ± 1.2	4.2 ± 1.3	2.6 ± 1.2	3.3 ± 1.3
12	December	3.5 ± 1.3	3.9 ± 1.4	2.4 ± 1.2	2.2 ± 1.2	2.3 ± 1.2	2.6 ± 1.2
Yearly average		4.9 ± 1.2[b]	5 ± 0.9	4.7 ± 1.4	4.8 ± 1.4	3.6 ± 1.4	4.1 ± 1.4
Minimum		3.6					
Maximum		5					
Composite average		4.5					

a – measurement uncertainty; b – standard deviation

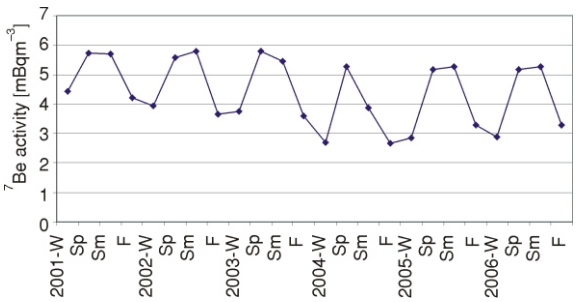

Figure 2. Seasonal variation of ^{7}Be concentration during 2001-2006 (W = Winter, Sp = Spring, Sm = Summer, and F = fall)

are given in tab. 1. The yearly averages were found to be 4.9, 5, 4.7, 4.8, 3.6, and 4 mBq/m^3 for the years 2001, 2002, 2003, 2004, 2005, and 2006, respectively. The average concentration of ^{7}Be ranged between 3.6 and 5 mBq/m^3 with the composite average for all the six years as 4.5 mBq/m^3, as shown in tab. 1.

Normally, the variations of ^{7}Be concentration in filtered air depends upon the latitude and climatic conditions (mainly the temperature). For the climatic variation, the specific activity of ^{7}Be was plotted against the quarterly temperature changes and a positive correlation is obtained as shown in fig. 2. It is obvious from the figure that ^{7}Be concentrations increase with rising the temperature. This phenomenon has been explained by Feely *et al*. [6] by proposing a model which states that this is due to an admixture of stratosphere produced ^{7}Be in the near surface air. This admixture can be brought down from the stratosphere by cold systems penetrating the troposphere. Another explanation for this phenomenon is the vertical transport of air within the troposphere. The troposphere is less stable in summer than in winter; thus, there is more air circulation in the troposphere in summer. The cause of this circulation is the following: during hot months, the solar heating of the Earth's surface leads to the heating of air in the near surface layer. This air is further forced upward and becomes cooler. Consequently, the denser air is lowered from higher levels. This vertical transport brings the parcels of air that have been irradiated in the upper troposphere down to the surface, and therefore their characteristic feature is higher ^{7}Be concentration. Figure 2 also indicates that the average concentration of ^{7}Be is slightly lower for the years 2005 and 2006 as compared to the rest of the years. This is due to the fact that during these two years, the duration of winter season was longer because of heavy rain and snow fall until the end of May.

In order to have better understanding of the impact / behaviour of ^{7}Be in the environment, seasonal indices were also calculated and given in tab. 2. Seasonal indices are normally used as a tool for reliable prediction of the future trends. It is an average that indicates the percentage of an actual observation relative to what it would be if no seasonal variation in a particular period is present. It is attached to each period of the time series within a year. This implies that if monthly data are considered, there are 12 separate seasonal indices, one for each month and 4 separate indices for quarterly data. For the present study, both monthly and quarterly indices were derived as shown in tab. 2. A monthly index was calculated by dividing

each monthly average value by the overall average of the entire period. The quarterly seasonal index is the average value of the three monthly indices for the corresponding season. These include January, February, and March for the winter season, April, May, and June for the spring season, July, August, and September for the summer season and October, November, and December for the fall season. It can be observed from tab. 2 that the values of both the monthly mean ^{7}Be activities and monthly indices drop below the overall mean for the first and last quarters (winter and fall) and increase for spring and summer seasons.

Table 2. Seasonal indices for ^{7}Be measured in air samples of Peshawar basin from 2001 to 2006

S. No.	Months	Monthly mean ^{7}Be activity [mBqm^{-3}]	Monthly indices	Quarterly indices
1	January	2.7	0.6	
2	February	3.5	0.8	0.7
3	March	4.4	0.9	
4	April	5.6	1.2	
5	May	5.6	1.2	1.2
6	June	5.9	1.3	
7	July	6	1.3	
8	August	5.4	1.2	1.2
9	September	4.7	1	
10	October	4.2	0.9	
11	November	3.9	0.8	0.8
12	December	2.8	0.6	
Overall mean		4.5	0.98	0.98

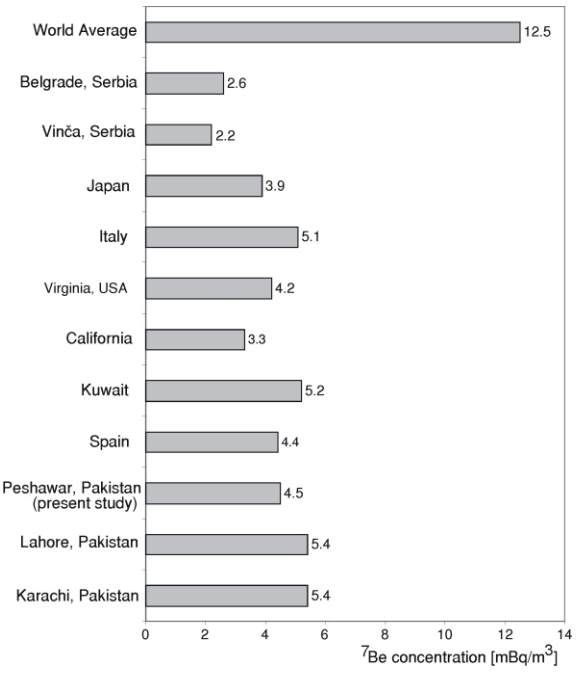

Figure 3. Comparison of ^{7}Be concentration with similar work carried out for other cities of Pakistan and with other countries of the world

A comparison of the present work with similar studies for other basins of Pakistan as well as with other countries of the world and world average values is presented in fig. 3 [7-13]. The figure shows that the average concentration of ^{7}Be in the air samples of Peshawar basin is about 17% lower than in Karachi and Lahore. This may be partially attributed to the temperature difference among these cities and partially to the various altitudes where the samplers are installed. As for the comparison with other countries, the data show that the average specific activity of ^{7}Be for Peshawar basin is about 60%, 13%, and 26% higher than in Serbia, Japan, and California, while it is about 12%, 13%, and 64 % lower than in Italy, Kuwait, and the world average values, respectively. It is also indicated from fig. 3 that the average value of ^{7}Be observed in the present study is comparable with that of Virginia – USA, and Spain. These variations may be attributed to different altitudes as well as to the different meteorological parameters and geological conditions.

CONCLUSIONS

The ^{7}Be concentrations were measured over the period from 2001-2006 in air samples collected from Peshawar basin of Pakistan. The results of the analyses represent yearly average values and range between 3.6 to 5 mBq/m^3 with the composite average concentration of this radionuclide for the whole period of 4.5 mBq/m^3. The measured values were significantly lower than the world average value of 12.5 mBq/m^3. The climatic variation due to the concentrations of ^{7}Be was also checked by classifying the whole year into four seasons (winter, spring, summer, and fall). By applying the model proposed by Feely *et al*. [6], a positive correlation between ^{7}Be activity and change in temperature was obtained.

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КЛИМАТСКЕ ПРОМЕНЕ АКТИВНОСТИ БЕРИЛИЈУМА-7 У АТМОСФЕРИ ПЕШАВАРСКОГ БАСЕНА У ПАКИСТАНУ ТОКОМ 2001-2006. ГОДИНЕ

У раду је приказано праћење климатских промена ^{7}Be у Пешаварском басену (источна географска дужина од 71 15 до 72 и северна географска ширина од 33 45 до 34) у Пакистану, током периода од 2001. до 2006. године. У оквиру програма осматрања животне средине у Пешаварском басену, узорци ваздуха сакупљани су на филтерима од фибергласа и гама спектрометријским поступком анализирани у погледу на гама емисију радионуклида. Резултати у последњих шест година (2001-2006) налазе се у интервалу од 3.6 mBq/m^{3} до 5 mBq/m^{3}, док је скупна средња концентрација радионуклида за читав период износила 4.5 mBq/m^{3}. Измерене вредности биле су знатно ниже од 12.5 mBq/m^{3} – средњих вредности у свету. Климатске промене концентрације ^{7}Be биле су такође провераване рашчлањавањем једне године у четири сезоне (зима, пролеће, лето и јесен) и добијена је позитивна корелација између активности ^{7}Be и промене температуре.

Кључне речи: берилијум-7, узорци ваздуха, Пешаварски басен, гама спектрометрија, сезонски показатељи