Proc. Indian Acad. Sci. (Earth Planet. Sci.), Vol. 89, Number 2, July 1980, pp. 133–136.

Cosmogenic and bomb-produced ^{7}Be in stratospheric air

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MS received 18 October 1979 ; revised 20 February 1980

Abstract. Concentration of ^{7}Be has been measured in 15 air filters flown at 18·3 km in the latitudes 10 to 25° N and longitudes 80 to 96° W. Testing of nuclear weapons in atmosphere increased ^{7}Be considerably, on two occasions, above the expected cosmic-ray production level in the stratosphere. This provides evidence for the existence of interhemispheric mixing, *via* stratosphere.

Keywords. Cosmogenic radioactivity; bomb activity; stratospheric activity; airfilter analysis.

1. Introduction

The potentiality of cosmogenic ^{7}Be as tracer for various atmospheric phenomena has been recognised for many years (see Lal and Peters 1967; Karol 1974). Measurements on samples of rain, ground level air and high altitude air, have been made (Goel *et al* 1959; Rama and Honda 1961; Bhandari *et al* 1966; Aegerter *et al* 1966; Bhandari 1965, 1970; Luyanas *et al* 1970; Hartwig and Sittkus 1972, 1973; Marenco and Fontan 1974a, b; Reiter *et al* 1975, 1976; Shapiro and Forbes–Resha 1976; Husain *et al* 1977; Bleichrodt 1978; Dutkiewicz and Husain 1979). However, ^{7}Be measurements in stratosphere are only few (Rama and Honda 1971; Drevinsky *et al* 1964; Bhandari *et al* 1966; Hicks 1967; Bhandari 1970; Dutkiewicz and Husain 1979) most of which are from latitude higher than 30°.

Of the total cosmogenic atmospheric ^{7}Be, about 70% is produced in the stratosphere. The production rate varies with altitude reaching a maximum at around 24 km (Bhandari 1970). The production rate also changes significantly with latitude. At any given point, possible mixing of air mass from higher altitude could be detected by measuring ^{7}Be concentration, provided it occurs on the time scale of a month or less, transport of stratospheric air mass from high latitudes to equator may also be detected. None of these have yet been conclusively observed, probably due to their rather very slow time scales.

We have measured the concentration of ^{7}Be in 15 air filters (IPC No. 1478) flown during the Project Airstream Mission at 18·3 km altitude in the latitude range 10° N–25° N. During the period of sampling several nuclear detonations were carried out by France. Some ^{7}Be is likely to survive for several months

after a detonation. The dates of these nuclear tests affecting our data, conducted at 22° S, 139° W, are : 15 May to 6 August 1970 and 5 June to 14 August 1971. No French tests were carried out during 7 August 1970 to 4 June 1971. A Chinese thermo-nuclear test of high yield (3000 KT) was carried out on 14 October 1970 at 40° N, 90° E which showed no apparent effect on ^{7}Be contents of the samples collected on 25 February 1971, presumably due to the combined influence of decay and fallout.

2. Experimental

Air filters were cut into pieces, digested in HNO_3 and carriers of P and Be were added. After complete digestion, phosphate was precipitated with ammonium molybdate. Beryllium was recovered from the filterate as $Be(OH)_2$. The latter was purified and counted as BeO for gamma rays (energy, 0·477 MeV). The scintillation spectrometer consisted of a well-shielded 4 inch well type NaI(Tl) crystal in conjunction with a 512 channel nuclear data analyser. The overall error was less than 10%. The results are presented in table 1.

3. Discussion

Analysis of the production rate variation with height shows that at about 20 km, and latitudes lower than 30°, the equilibrium concentrations of ^{7}Be is around

Table 1. Data on airfilters and ^{7}Be concentrations at 18·3 km.

Sl. No.	Date of sampling	Sample code No.	Latitude (North)	Longitude (West)	Volume of air (SCM)	^{7}Be (dpm/SCM)
1.	18–8–1970	T3490	15–12	82–81	84·4	22·4
2.		T3492	21–18	86–84	99·7	73·4
3.		T3493	24–21	89–86	87·8	76·6
4.	25–2–1971	T4254	10–15	80–83	139·0	15·5
5.		T4255	15–20	83–86	157·0	15·9
6.		T4256	20–25	86–90	161·0	14·0
7.		T4257	25–30	90–96	211·0	3·8
8.	22–3–1971	T4489	21–18	86–84	88·0	17·2
9.		T4490	18–15	84–83	98·0	21·8
10.		T4491	15–12	83–81	86·0	17·0
11.		T4492	12–10	81–80	62·0	13·1
12.	5–10–1971	T5134	12–15	81–83	77·0	30·0
13.		T5135	15–18	83–84	82·0	48·0
14.		T5136	18–21	84–86	38·0	38·0
15.		T5137	21–24	86–88	74·0	33·5

18 dpm/SCM (Bhandari 1970). ^{7}Be concentrations measured on 25 February 1971 and 22 March 1971 are close to this value. This is also in agreement with other available data (Drevinsky *et al* 1964; Bhandari 1965, 1970; Hicks 1967). The abnormally low value of 3·8 dpm/SCM observed on 25 February 1971 is presumably due to mixing of tropospheric air. Low values have also been noted by others (Drevinsky *et al* 1964; Bhandari *et al* 1966; Hicks 1967; Bhandari 1970; Dutkiewicz and Husain 1979) and have been assigned to factors such as tropospheric stratospheric mixing (Rama and Honda 1961; Hicks 1967). According to Reiter (1975) tropical branch of Hadley cell is very effective in introducing large amount of tropospheric air into the stratosphere.

The high concentration of ^{7}Be on the other two dates, viz. 18 August 1970 and 5 October 1971, can conceivably arise as a result of either the combined effects of vertical and meridional mixing of air from higher latitude, or from 'artificial' (bomb-produced) contribution. The former is unlikely and has not been seen so far. On the other hand, high ^{7}Be concentrations have been noted in the lower stratosphere of the northern hemisphere during the period of bomb testing (Machta 1965). Since there were several nuclear tests conducted by France preceding the sampling dates, it is very probable that an artificial contribution is responsible for the observed increase in the activity.

The French tests were carried out in the southern hemisphere. Their influence in the northern latitude indicates a mixing between the two hemispheres. There are several evidences of inter-hemispheric transfer of nuclear test debris in troposphere based on fission-product-activity measured in rain and ground level air samples (Woodward 1966; Sotobayashi *et al* 1969; Peirson *et al* 1970; Gopalakrishnan and Rangarajan 1972; Telegadas 1972). This process is found to be fast (Peirson *et al* 1970) and is favoured in certain seasons (Gopalakrishnan and Rangarajan 1972; Rangarajan and Gopalakrishnan 1975). In view of the fast tropospheric washout, there is little chance for tropospheric radioactivity to enter the stratosphere. Our results therefore provide evidence for inter-hemispheric mixing *via* the stratosphere. But its intensity could not be assessed since we have no data on ^{7}Be concentration in the stratosphere of the southern hemisphere.

Acknowledgements

Dr M T Kleinman of USAEC, Health and Safety Laboratory, New York, is thanked for the air filter samples. Financial supports, initially from a PL–480 grant, No. E–137–67 (N) through NOAA, and later from the Indian National Science Academy (INSA), New Delhi, are gratefully acknowledged.

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