Annual Deposition of Cosmic Ray Produced Be^7 at Equatorial Latitudes

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Abstract

The concentration of cosmic ray produced Be^7 in rain water has been measured at two stations in the equatorial latitudes. Its rate of deposition at the earth's surface has been estimated to be about 5×10^6 atoms cm^{-2} yr^{-1} and the deposited quantity seems to be independent of latitude.

Introduction

The cosmic ray produced radio-isotope Be^7 has been detected in rain water (ARNOLD and AL-SALIH, 1955; GOEL et al, 1956) and aerosol (CRUIKSHANK et al, 1956). Its half life is 53 days and its production varies strongly with latitude and altitude (BENIOFF, 1956; LAL, MALHOTRA and PETERS, 1958). It, therefore, provides a useful tool for studying some meteorological phenomena.

In this paper, we present the analysis of Be^7 concentrations in rains collected at Kodai-Kanal (geog. lat. 10° N) and at Bombay (geog. lat. 19° N) between January and December 1956. Some qualitative checks indicate that the Be^7 observed in rain water is mainly cosmic ray produced and the contribution due to thermonuclear explosions, if any, is not substantial. The long term observations permit us to obtain its average yearly deposition in equatorial regions. Some very qualitative conclusions regarding general features of large scale air circulations and mean removal time for Be^7 from the troposphere can be derived.

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Experimental:

These days, a major part of the radio-activity in the atmosphere comes from nuclear explosions. The cosmic ray produced activities are much smaller in comparison. Consequently, in the study of any cosmic ray produced isotope, one is faced with the following two problems.

(1) One must find a chemical procedure which removes all the interfering fission activities.
(2) One must assess the contribution of nuclear explosions, if any, to the isotope under investigation.

These problems had to be faced in the present work with the isotope Be^7. A chemical procedure for its extraction from rain water was worked out. It was found to remove all the interfering activities. The details of the method have been described earlier (GOEL et al., 1956).

The solution to the second problem is not straight-forward. The possibility of producing Be^7 in thermo-nuclear explosions can not be ruled out. However, we believe that its contribution to the Be^7 observed in rain water is not substantial in our experiment. The basis

for this belief are the following three qualitative arguments.

(1) If substantial amounts of Be^7 originate from thermo-nuclear explosions, then its occasional high concentration in rain water should always be accompanied by high fission activity. No such correlation was observed.[1]

(2) The Be^7 deposition actually observed in the course of a year is of magnitude which one would expect on the assumption that it is produced by cosmic rays only.

(3) Some fraction of the activity produced in nuclear explosion must be expected to form a part of dust or metal grains. Some of this activity, therefore, may not be soluble in water at pH3. On the other hand the cosmic ray produced Be^7 must be in solution because there is no likelihood of its entering into the crystal structure of dust. The presence of dust carrying insoluble Be^7 would be difficult to understand if the isotope were produced by the cosmic ray induced disintegrations in the atmosphere. In order to check this we proceeded in the following way.

The dust was removed from the rain water by filtering it. The filtered water was passed through the resin (Dowex: 50). The resin extracts only the soluble part of the activity by cation exchange.

Beryllium was extracted from the resin using the method described earlier (GOEL et al., 1956). The same method was used for extracting Beryllium from the dust after it was fused with $K_2S_2O_7$ and digested with HCl.

The Be^7 activity recovered from the resin was 47.2 ± 2.0 cpm and that from the dust was 1.3 ± 1.2 cpm. This indicates that either Be^7 is already in solution in water or can be dissolved off the surface of dust grains at pH 3.

These considerations lead us to the conclusion that we are dealing primarily with cosmic ray produced Beryllium.

We have analysed 47 rain samples from Kodai-Kanal and 29 rain samples from Bombay. In some of our later samples, Beryllium was precipitated from rain water with Ferric Hydroxide carrier. The purification procedure was the same as described earlier (GOEL et al., 1956).

[1] We are grateful to Dr K. G. Vohra of Atomic Energy Establishment, Bombay, for making the fallout data available.

The geographic location and the annual rainfall at the two stations are summarised in table I.

Table I

Station	Kodai-Kanal	Bombay
Geographic latitude	10° N	19° N
Height above sea level	7,600 feet	0
Average annual rainfall	169 cms	180 cms
Rainfall during the year 1956	150 cms	256 cms
Rains from	Summer & Winter monsoons.	Summer monsoons only

The Be^7 concentrations at Kodai-Kanal and Bombay are given in tables II and III respectively.

Discussion:

As seen from tables II and III, the Be^7 concentration varies widely in individual rains. It will not only depend on the history of air mass, i.e. the time spent in the stratosphere and troposphere where the production rates of Be^7 are known to be widely different, it will also depend on local effects:

(1) Meteorological factors, in particular height and moisture content of the cloud.

(2) Topography of the station.

Measurements involving a single cosmic ray produced isotope do not give sufficient information for correlating concentrations in individual rains with such local phenomena. However, when one considers the average Be^7 deposition from a large number of rains over an extended period, one must expect that it will be roughly proportional to the amount of isotope produced in the air mass circulating in that particular latitude belt. It is known that circulation within zonal belts is fairly rapid and, therefore, we tentatively take the average Be^7 concentration observed at Kodai-Kanal and Bombay to be representative of their respective zones. On multiplying these concentrations by the mean annual rainfall (BROOKS and HUNT, 1932) in the respective belts, we obtain the yearly deposition of Be^7 at 10° N and 19° N geographic latitudes. These are listed in table IV, the results derived from the Be^7 observations made by ARNOLD and AL-SALIH (1955) at Chicago are given in same table.

Table II (Kodai-Kanal)

	Date of rainfall	Amount of rainfall (cms)	Number of Be^7 atoms per ml.	Number of Be^7 atoms deposited per cm^2 area
1	30-1-56	1.17	1,750 ± 170	2,000
2	25-2-56	0.48	6,200 ± 1,500	3,000
3	10-3-56	2.87	5,100 ± 300	14,500
4	4-4-56 & 5-4-56	3.98	6,400 ± 300	25,500
5	7-4-56	0.13	10,000 ± 800	1,300
6	18-4-56	0.71	2,800 ± 200	1,990
7	20-4-56	0.91	4,800 ± 350	4,400
8	22-4-56	3.71	5,350 ± 300	19,900
9	24-4-56	0.69	4,400 ± 300	3,000
10	25-4-56	1.78	7,900 ± 250	14,100
11	26-4-56	1.19	9,900 ± 300	11,800
12	28-4-56 & 29-4-56	1.60	7,200 ± 200	11,500
13	18-5-56	2.34	2,800 ± 150	6,600
14	23-5-56	3.15	2,400 ± 200	7,600
15	13-6-56	1.27	2,700 ± 120	3,400
16	14-6-56	0.97	2,100 ± 300	2,000
17	19-6-56	0.36	2,000 ± 350	700
18	21-6-56	0.81	1,600 ± 200	1,300
19	22-6-56 & 23-6-56	1.01	550 ± 350	600
20	25-6-56	0.71	4,900 ± 300	3,500
21	26-6-56 to 28-6-56	2.29	3,500 ± 200	8,100
22	30-6-56	0.53	2,800 ± 200	1,500
23	8-8-56 to 10-8-56	2.10	1,600 ± 150	3,400
24	15-8-56 to 18-8-56	3.13	1,700 ± 200	5,300
25	19-8-56	3.40	1,200 ± 200	4,100
26	21-8-56	1.88	5,500 ± 400	10,300
27	25-8-56	1.17	2,990 ± 550	3,500
28	28-8-56	2.59	11,000 ± 2,800	28,500
29	12-9-56	0.74	1,600 ± 1,400	1,200
30	15-9-56	1.37	2,400 ± 600	3,300
31	16-9-56	2.24	1,160 ± 1,500	2,600
32	29-9-56	0.97	1,840 ± 800	1,800
33	13-10-56	2.74	2,300 ± 350	6,300
34	15-10-56	1.85	600 ± 500	1,100
35	17-10-56	0.94	1,400 ± 650	1,300
36	19-10-56	0.99	3,200 ± 650	3,100
37	25-10-56	1.55	4,700 ± 500	7,200
38	26-10-56	3.81	1,000 ± 400	3,700
39	31-10-56	5.61	1,300 ± 1,000	7,500
40	1-11-56	2.72	900 ± 300	2,400
41	6-11-56	1.52	500 ± 250	700
42	8-11-56	1.12	1,100 ± 350	1,200
43	11-11-56	3.45	200 ± 180	600
44	16-11-56	0.13	1,200 ± 300	200
45	19-11-56	2.41	300 ± 160	600
46	21-11-56	1.37	400 ± 400	500
47	26-12-56 to 28-12-56	3.10	600 ± 600	1,900

85.3 cms

	Mean concentration	Weighted mean concentration
	$\frac{147,700}{47} = 3,100$ atoms/ml.	$\frac{250,600}{85.3} = 2,900$ atoms/ml.

Total Be^7 precipitated per cm^2 area at Kodai-Kanal during the year $1956 = 2,900 \times 150 = 4.3 \times 10^5$ atoms.

Table III Bombay

	Date of rainfall	Amount of rainfall (cms)	Number of Be^7 atoms per ml.	Number of Be^7 atoms deposited per cm^2 area
1	24-5-56 & 25-5-56	1.65	9,300 ± 250	15,400
2	27-5-56 & 28-5-56	0.61	9,250 ± 700	5,600
3	12-6-56	2.67	5,500 ± 320	14,600
4	14-6-56	2.03	8,000 ± 600	16,300
5	16-6-56	1.73	8,150 ± 350	14,100
6	17-6-56	4.83	7,900 ± 370	38,000
7	24-6-56	2.87	4,500 ± 550	13,000
8	26-6-56	9.07	4,100 ± 325	36,900
9	30-6-56	4.34	1,400 ± 300	6,000
10	12-7-56	1.65	4,400 ± 400	7,300
11	26-7-56	8.05	6,500 ± 300	52,100
12	13-8-56	0.56	4,100 ± 1,100	2,300
13	14-8-56 & 15-8-56	0.65	2,100 ± 500	1,300
14	18-8-56 & 19-8-56	2.00	2,500 ± 800	5,000
15	25-8-56 & 26-8-56	1.55	6,900 ± 430	10,600
16	30-8-56	2.98	6,600 ± 500	19,600
17	1-9-56	2.00	1,500 ± 1,000	3,000
18	3-9-56	0.43	7,200 ± 450	3,100
19	12-9-56 to 14-9-56	2.49	6,350 ± 800	15,800
20	23-9-56	1.52	4,250 ± 400	6,500
21	24-9-56	3.86	1,550 ± 500	6,000
22	26-9-56	1.32	2,250 ± 700	3,000
23	27-9-56	0.76	4,400 ± 700	3,400
24	30-9-56	1.22	3,300 ± 500	4,000
25	1-10-56	2.97	1,200 ± 500	3,600
26	3-10-56	0.48	1,650 ± 1,300	800
27	6-10-56	0.63	800 ± 650	500
28	8-10-56	1.30	4,750 ± 1,200	6,200
29	9-10-56	0.51	1,800 ± 600	900

66.7 cms

Mean concentration: $\frac{132,100}{29} = 4,600$ atoms/ml. Weighted mean concentration: $\frac{314,900}{66.7} = 4,700$ atoms/ml.

Total Be^7 precipitated per cm^2 area at Bombay during the summer Monsoon, $1956 = 4,700 \times 256 = 1.2 \times 10^6$ atoms.

Table IV

Station	Kodai-Kanal	Bombay	Chicago
Geographic latitude	10° N	19° N	42° N
Mean concentration of Be^7 in rain water (atoms ml^{-1})	2,900	4,700	6,000
Annual rainfall in the latitude belts (cms)	175	98	89
Deposition of Be^7 (atoms cm^{-2} yr^{-1})	5.1×10^5	4.5×10^5	5.3×10^5

The depositions calculated, on the basis of these assumptions, for three latitudes are nearly the same inspite of the very considerable variation of cosmic ray intensity with latitude. It has been pointed out by PETERS (1957) that this fact can be explained if one assumes that most of the Be^7 observed in rainwater originated in the troposphere.

Recent calculations of LAL, MALHOTRA and PETERS show that the average global production of Be^7 amounts to 7.5×10^5 atoms cm^{-2} yr^{-1} in the troposphere. A deposition rate of

5×10^5 atoms cm^{-2} yr^{-1} on the earth's surface, if all of tropospheric origin, indicates that about 34% of Be^7 decays in the troposphere before being brought down to earth by rainfall. This leads to an average tropospheric removal time of the order of forty days. However, a small fraction of Be^7 may be settling on earth directly from the air. In that case the tropospheric removal time would be correspondingly shorter.

Recently, other cosmic ray produced short-lived isotopes have been discovered in rain water. They are P^{32} (14d, 1.7 Mev β^-) (MARQUEZ & COSTA, 1955), P^{33} (25d, 0.25 Mev β^-) (LAL, NARSAPPAYA & ZUTSHI, 1956) and S^{35} 87d, 0.167 Mev β^-) (GOEL, 1956). A study of the ratios of Be^7 to these isotopes is likely to provide detailed information on the amount of radiation received by a particular air mass in the interval between two successive precipitations.

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