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Measurements on the ground deposition of fission products from nuclear test explosions

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1. Introduction

The fission products injected into the atmosphere by the test explosions of nuclear weapons are dispersed on a world-wide scale. These are ultimately deposited on the ground surface by rain, gravity settling and impaction. The ground deposition of fission products constitutes the primary mechanism of contamination of foodstuffs and drinking water. This report gives the deposition levels of mixed-fission-products at the different sampling stations in India for the period 1956 to 1959. The cumulative deposition of the long lived fission product strontium-90 has been computed from the mixed-fission-products data using empirical relations. The deposition studies are made at five stations, namely, Srinagar (34° 06′ N, 74° 55′ E), Delhi (28° 45′ N, 77° 20′ E), Calcutta (22° 34′ N, 88° 25′ E), Nagpur (21° 12′ N, 79° 04′ E) and Bombay (18° 57′ N, 72° 55′ E).

2. Method of sampling and measurement

The monthly samples of surface deposition are collected using stainless steel pots of dimensions 30 cm dia. × 45 cm. The collection pots are exposed to the atmosphere keeping them about one metre above the ground in an open lawn to collect the rainwater and settling dust. After collection the samples are concentrated by evaporation and finally transferred to perspex planchets and covered with a protective film of rubber hydrochloride. The sample thickness is generally less than 2 mm. At Bombay daily samples of deposition are also collected, in addition to the monthly samples, using the same method. The beta activity of the samples is measured using an end-mica-window Geiger counter placed in a 2″ lead shield. The monthly samples are measured thirty days after the end of collection period and the daily samples are measured three days after collection.

The counting efficiency is determined using a standard potassium chloride source. The results are expressed in millicuries of fission-product-activity deposited per square kilometre of the ground area, knowing the surface area of the pot and the total activity collected.

3. Results of deposition measurements

The ground deposition levels and the amount of rainfall for different months of the period from 1956 to 1959 are given in Table 1.

The average daily levels of deposition and the corresponding precipitation levels at Bombay for different months of the period from 1956 to 1959 are shown in Fig. 1.

4. Cumulative deposition of Strontium-90

Fig. 2 shows cumulative deposition of strontium-90 at Bombay. The monthly deposition of strontium-90 is calculated from the monthly deposition of mixed fission products given in Table 1 using Hunter and Ballou (1951) ratios by assigning an average 'age' to the fission products. The 'age' is assigned on the following basis. It has been generally observed that appreciable tropospheric fallout occurs only on a few days during some months, as shown by our

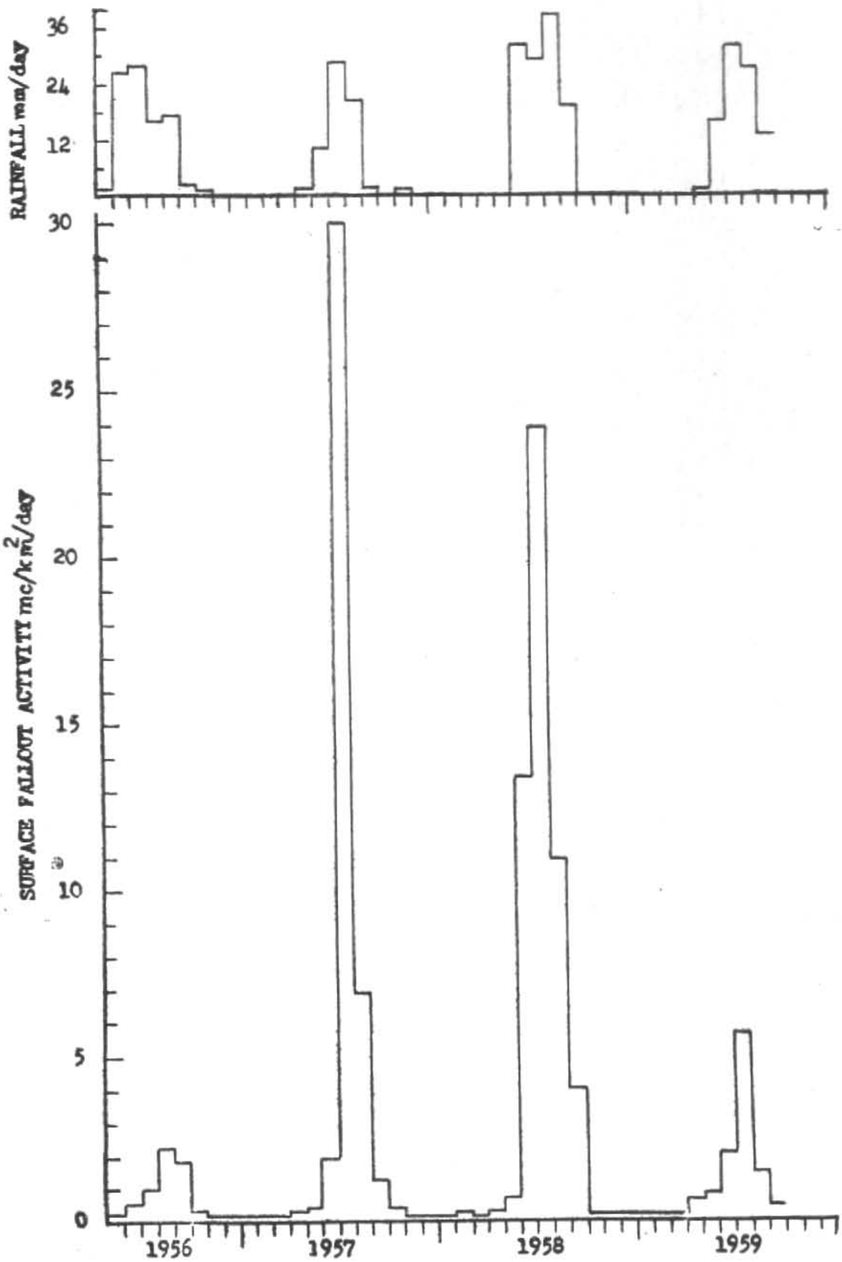

Fig. 1. Average daily fallout and rainfall, Bombay 1956-1959

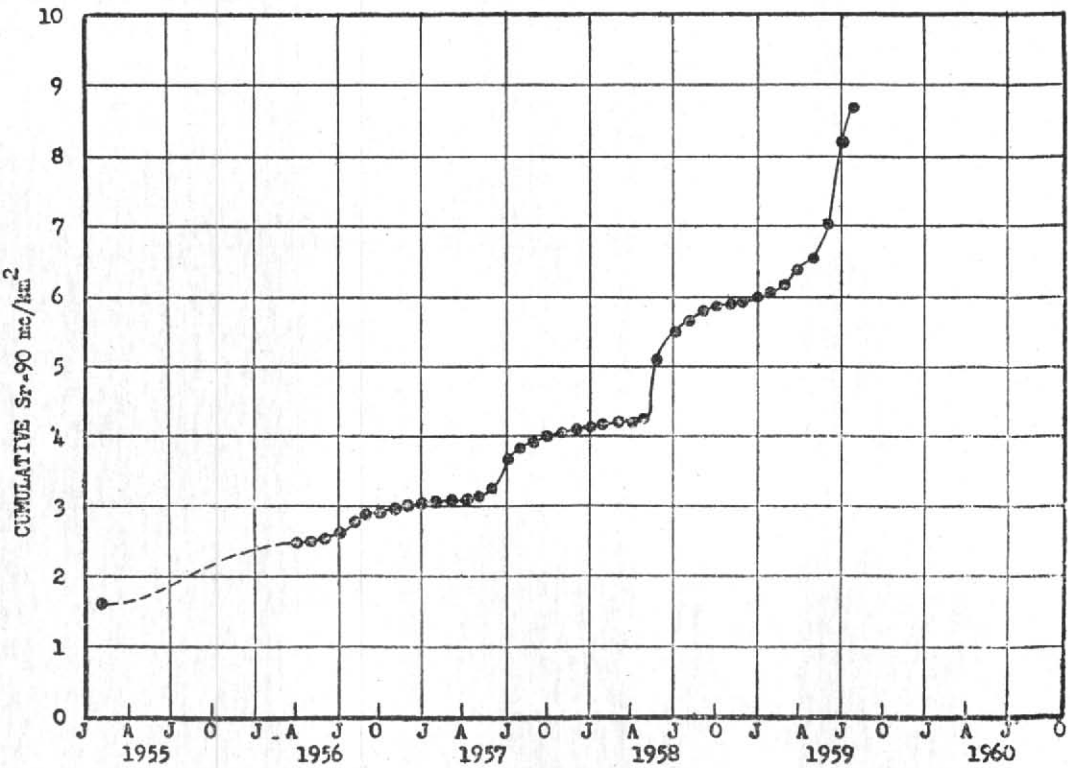

Fig. 2. Strontium-90 in Bombay fallout

daily deposition studies. The tropospheric fallout is distinguished from the normal stratospheric fallout by short duration of its appearance and faster decay of samples. The monthly deposition data are divided into two groups of values one with tropospheric fallout predominating and the other group with the stratospheric fallout predominating, and two empirical values of 'age' based on the study of decay curves of several samples, are assigned to the groups. The 'age' of the samples in the first group is taken to be 120 days giving a strontium-90 fraction of $2 \cdot 7 \times 10^{-3}$ and for the second group the 'age' is taken as 250 days giving a strontium-90 fraction of 9×10^{-3}. The fractions are taken from the Hunter and Ballou curves for strontium-90.

The cumulative deposition curve (Fig. 2) shows only approximate deposition levels because (*a*) the assumed values of the average 'age' of fission products are subject to errors and (*b*) no deposition data has been collected before May 1956. The base level of the cumulative deposition curve has been taken from the data on strontium-90 content of Bombay soil (US, AEC 1958) in February 1955. The April 1956 level is assumed to be 50 per cent higher than the February 1955 level, on the basis of the observed trend of deposition during 1956 and 1957.

5. Discussion

The data in Table 1 shows that there are large variations in the deposition level at different stations. Although higher deposition generally seems to be associated with high rainfall, there is no proportionality between the total rainfall and total deposition at any two stations, *e.g.*, the average deposition levels during 1958 at Bombay and Srinagar

TABLE 1

Monthly surface fallout and rainfall

	BOMBAY		CALCUTTA		DELHI		NAGPUR		SRINAGAR	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
					1956					
May	7·3	35·6	..	..	..	..	..	..	..	..
Jun	16·2	796·0	..	..	..	..	..	..	..	..
Jul	32·8	883·4	3·4*	320·0	..	..	7·8*	382·8	..	..
Aug	68·1	505·0	20·6	250·2	60·8†	209·2	31·8	204·7	..	..
Sep	30·2	512·0	12·5	371·3	5·1	12·7	21·6	317·0	..	..
Oct	12·8	79·6	7·5	202·0	16·3	227·8	2·1	25·4	..	..
Nov	4·0	13·2	0·3	9·4	4·5	0·3	2·1	61·7	..	..
Dec	1·4	0	0·3	0	6·6	0·8	5·2	16·5	..	..
Average	21·6	353·0	7·4	192·2	18·7	90·2	11·8	168·0	..	..
					1957					
Jan	4·1	0	0·7	38·4	12·1	48·9	1·4	12·4	..	..
Feb	3·0	0	1·1	30·8	2·9	0	1·4	0	..	..
Mar	3·0	0	1·0	0·6	29·8	37·9	5·4	104·2	..	..
Apr	8·1	0	0·7	25·6	34·1	3·8	2·1	92·6	..	..
May	9·4	25·6	2·2	7·1	37·7	6·9	3·2	14·3	..	..
Jun	42·4	310·0	2·2	146·6	41·3	38·6	..	101·7	..	..
Jul	169·5	883·0	3·5	387·4	8·9	232·3	9·6	282·7	..	..
Aug	57·3	635·0	1·2	233·2	5·2	48·0	20·5	326·5	..	..
Sep	18·4	59·5	0·6	228·1	1·6	198·9	13·7	86·2	..	..
Oct	6·6	4·1	1·3	50·0	3·5	34·0	3·5	8·2	..	..
Nov	7·3	23·4	4·9	0	3·9	10·4	1·2	0	16·3	102·1
Dec	3·4	0	7·6	0	2·8	16·9	1·1	0	27·5	51·9
Average	27·7	161·7	2·3	95·7	15·3	56·4	5·7	85·7	21·9	77·0

NOTE—(a) Surface fallout in mc/km²
(b) Rainfall in mm

* From 13 to 31 July 1956 only
† From 7 to 31 August 1956 only

TABLE 1 *(contd)*

	BOMBAY		CALCUTTA		DELHI		NAGPUR		SRINAGAR	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
					1958					
Jan	4·8	0	7·8	13·2	8·7	19·3	1·1	6·9	27·5	69·2
Feb	2·6	0	3·3	20·4	9·2	0	2·2	0	18·5	14·7
Mar	5·7	0	25·1	4·6	3·3	15·8	2·8	16·5		58·9
Apr	14·1	0	16·9	40·2	8·1	0	3·5	16·8		80·4
May	14·6	3·1	4·7	53·0	3·4	6·9	3·1	1·0	470·0*	61·4
Jun	315·3	966·0	24·5	133·6	7·0	7·1	10·6	124·5		12·9
Jul	149·5	917·4	19·5	220·0	13·1	428·0	11·1	248·7		37·7
Aug	49·5	1212·0	6·5	224·5	5·0	225·5	19·5	332·4	65·5	67·4
Sep	58·7	575·8	17·3	312·8	7·5	277·5	9·1	216·8	21·4	44·8
Oct	12·1	0	2·8	92·8	6·6	2·1	12·8	87·1	16·3	6·1
Nov	7·1	0	1·6	6·8	1·4	2·2	1·7	25·9	26·0	11·8
Dec	11·4	0	30·8	0	20·7	3·2	4·0	0	176·4	96·5
Average	53·8	306·1	13·4	93·5	7·8	82·3	6·8	89·7	68·5	46·8
					1959					
Jan	6·4	0	50·0	34·7	59·9	39·8	35·8	16·5	178·0	162·1
Feb	7·0	0	38·2	12·0	12·7	0·5	7·0	0	97·5	119·8
Mar	9·0	0	56·0	7·8	21·3	1·6	11·5	0·6	249·0	121·4
Apr	29·2	0	..	..	7·5	0	8·8	14·9	103·9	26·6
May	20·2	9·4	102·3	146·4	12·6	16·8	4·4	1·6	200·7	68·7
Jun	61·8	460·6	93·0	327·4	3·0	25·9	19·7	338·8	35·0	7·3
Jul	128·5	987·0	5·3	196·6	5·8	120·9	109·9	482·6	..	..
Aug	55·0	842·7	..	..	1·8	192·3	32·2	241·4	..	..
Average	39·6	287·4	57·4	120·8	15·6	49·7	28·7	137·0	144·0	84·3

NOTE—(*a*) Surface fallout in mc/km², (*b*) Rainfall in mm

* A single collection was made for the period March to July 1958. The value gives the total activity of the sample.

are 53·8 mc/km^2 and 68·5 mc/km^2 for average rainfall levels of 306·1 and 47·8 mm respectively. This seems to suggest that the degree of deposition also depends on other factors such as seasonal distribution of rainfall, winds, the previous history of the rain bearing cloud and geographical location of the station with respect to bomb testing sites.

The monthly deposition data for Bombay (Table 1) show that over 90 per cent of the yearly deposition occurs during the rainy season from May to September. The daily deposition data for Bombay (Fig. 1) show the highest total monthly deposition of about 900 mc/km^2 in July 1957. This may be explained to be due to the heavy rainfall during the month following a large series of tests.

It is seen from Table 1 that the deposition levels have been considerably higher at Srinagar and Calcutta during the period from December 1958 to June 1959. This increase is most likely to be due to the fallout from the tests conducted during the autumn of 1958. The winter monsoon winds causing rains at these two stations seem to have provided favourable conditions for deposition. Recent suggestion that the residence time of the fission products in the stratosphere is shorter than was formerly estimated (Martell 1959) would also account for the higher fallout observed during the above period. The highest deposition following the autumn 1958 injections has been observed at Srinagar which is located at 34°06′ N.

The cumulative strontium-90 deposition level at Bombay is estimated to be 8·7 mc/km^2 up to August 1959. There has been a substantial increase in this level during 1959 even though there were no tests after November 1958. This also suggests that the residence time of fission products in the stratosphere is shorter than was earlier estimated.

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REFERENCES

Hunter, H. F. and Ballou, N. E. 1951 *Nucleonics*, **9**, c-2.

US, AEC 1958 *U. S. Atomic Energy Comm. Health and Safety Lab. Publ. No. HASL-42.*

Martell, E. A. 1959 *Science*, **129**, pp. 1197-1206