STRONTIUM-90 IN THE BONE OF DIFFERENT SOUTH AFRICAN POPULATION GROUPS*

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SUMMARY

The ^{90}Sr content of a large number of bone samples from South Africans of difference race and age groups has been measured. Significant differences were found between population groups especially in the age group 5 - 20 years. The ^{90}Sr content of foodstuffs which are the main contributors to the total ^{90}Sr in the diet, e.g. milk, bread and maize was also measured during the period 1966 - 1969.

The two main population groups, Whites and Bantu, have vastly different dietary habits and consequently quite different calcium intakes and sources of ^{90}Sr in their diets. Calcium and ^{90}Sr intakes from different foodstuffs were calculated from dietary surveys.

An inverse proportionality was found between the dietary calcium intake and the ^{90}Sr content of bone.

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Among the various nuclides present in the radioactive fallout from nuclear-weapon tests,[1] strontium-90 and caesium-137 are of special interest due to their long half-lives, their relatively high fission yields, and similarities to important body constituents. Strontium is chemically and metabolically related to calcium and must therefore be

classified as a bone-seeker, while caesium behaves similarly to potassium and concentrates mainly in the muscle, liver and spleen.

A collecting programme for samples of human bone was initiated. Samples from different South African population groups were analysed for strontium-90 using chemical extraction and subsequent radiometry.[2] Although the primary purpose was to determine radiation dose due to radioactive fallout in South Africa, this investigation led to a study of the effect of different dietary habits on the uptake of ^{90}Sr in the bone of people of the same age and living in areas with the same fallout levels. The uptake of ^{90}Sr by the body depends not only on the total ^{90}Sr consumed, but particularly on the ratio of ^{90}Sr to calcium in the diet. The two main population groups in South Africa, namely the Whites and the Bantu, have vastly different dietary habits and consequently quite different calcium intakes.

Milk is the main source of calcium and ^{90}Sr in the diet of the average person living on a Western diet and the ratio of $^{90}Sr/Ca$ in diet to that in milk has been found to be fairly constant. The average value of this ratio measured for the years 1963 - 1966 in 10 different Western countries varied between 0·9 and 1·7.[3]

Since 1966 normal rib-bone samples from the Bantu, Indian, Coloured and White population groups were obtained from different parts of the country and analysed for ^{90}Sr. The ^{90}Sr content of important dietary components, e.g. milk, maize and bread were also measured but no analyses were done on total diets. Total ^{90}Sr intakes were calculated from milk or bone values while calcium intakes were calculated from surveys on dietary habits of the different population groups.

Dietary Differences

While the diet of the Whites consists of 75% animal products and 25% cereals, the Bantu diet contains 70% cereals and 30% animal products. The average *per capita* calcium intake of the White population is 292 g/year[4] of which more than 70% is supplied by milk, 5% by bakery products and the rest by vegetables, meat, fluids, etc. The average milk consumption of Whites as measured in 1966 is 180 kg/year[5] and it forms 50% of the total ^{90}Sr intake.

The average annual calcium intake of the Bantu population is 102 g/year,[4] the main contributions being from milk (41%) and bakery products (35%). The *per capita* milk consumption of the average Bantu is 33 kg/year[5] providing about 10% of the total ^{90}Sr intake. A very important part of the daily Bantu diet is maize porridge of which the average *per capita* consumption is 1 kg/day,[6,7] equivalent to about 400 g of maize meal. Although responsible for only 5% of the total calcium intake, maize may contribute up to 50% of the ^{90}Sr intake.

The most important dietary differences are tabulated in Table I.

TABLE I. DIETARY DIFFERENCES OF THE MAIN POPULATION GROUPS

Population group	*Milk consumption (kg/year)*	*Calcium intake (g/year)*	*% Calcium intake*		
			Milk	*Bread*	*Maize*
White	180	292	75	5	Negligible
Bantu	33	102	41	35	5
Coloured	26	126	26	26	Negligible
Indian	41	135	38	16	Negligible

Two other population groups, namely the Coloureds and the Indians, have annual calcium intakes of 126 and 135 g[4] respectively. Their milk consumption is similar to that of the Bantu, but maize meal is not an important part of their diet.

^{90}Sr in Milk, Maize and Bakery Products

The method for ^{90}Sr analyses was based on the extraction of ^{90}Y, the decay product of ^{90}Sr, in di-(2-ethyl-hexyl) phosphoric acid (HDEHP).[2] After ashing and dissolution of the sample, an initial extraction was performed, yttrium carrier was added, and 14 days were allowed for ^{90}Y to grow to equilibrium with ^{90}Sr. The final extraction was followed by stripping of the yttrium into 3N HNO_3 and the preparation of an $Y(NO_3)_3$ source in a 50 mm planchette for counting in a low background counter.

Analyses of milk for ^{90}Sr commenced in 1966 on samples from 12 agricultural stations spread widely over the country. Results for the period 1966 - 69 give a distribution of ^{90}Sr in milk which agrees with the general rainfall pattern over the country. Higher ^{90}Sr levels are found in milk from the eastern and south-eastern parts of the country. There is a spread of a factor 3 between the area with the highest and the lowest ^{90}Sr concentration. The average annual ^{90}Sr content of milk is given in Table II.

TABLE II. STRONTIUM-90 IN MILK AND MAIZE IN SOUTH AFRICA (PCI $^{90}SR/G$ CA)

Milk	*1966*	*1967*	*1968*	*1969*
Average	3·0	2·3	2·5	2·1
Range	1·8 - 5·1	1·3 - 4·9	1·3 - 4·8	0·9 - 4·2
Maize				
Average	110	—	120	40
Range	—	—	—	29 - 53

Measurements for ^{90}Sr in bread were carried out during 1969 on samples from different Pretoria bakeries. Values for the calcium concentration in bread were taken from Lombard *et al.*,[8] who analysed bread from 6 bakeries in Pretoria over a period of 4 months and found average values of 41 mg Ca/100 g white bread and 47 mg Ca/100 g brown bread. Large variations were found in individual samples and were attributed to *creta preparata.*

The average ^{90}Sr concentration in bread was 1·4 pCi/kg brown and 0·7 pCi/kg white bread giving a $^{90}Sr/Ca$ ratio of 3·7 and 1·8 pCi ^{90}Sr/g Ca respectively. Maize meal from different harvests were analysed for ^{90}Sr. Samples of the 1966 and 1968 harvests were obtained from a single miller.

TABLE III. STRONTIUM-90 IN THE BONE OF DIFFERENT POPULATION AND AGE GROUPS (PCI $^{90}SR/G$ CA)

Age group	*Population group*			
	White	*Bantu*	*Coloured*	*Indian*
0 - 5 months	1·1	1·0	1·0	—
6 - 11 „	0·79	1·4	1·3	—
1 - 4 years	1·2	1·1	1·5	—
5 - 14 „	1·3	2·8	1·9	2·5
15 - 19 „	0·64	2·6	2·6	2·4
20 - 29 „	0·54	1·3	0·83	—
30 - 39 „	0·97	0·64	0·59	—
40 - 49 „	0·40	0·17	0·53	—
50 - 59 „	0·40	0·10	0·30	—
60 - 69 „	0·36	0·13	0·31	—
70 - 79 „	0·33	0·85	0·61	—

TABLE IV. CALCULATED DIETARY STRONTIUM-90 INTAKES OF DIFFERENT POPULATION GROUPS

Population group	*Equilibrium ^{90}Sr in bone (pCi/g Ca)*	*^{90}Sr in diet (calculated) (pCi/g Ca)*	*Total calcium in diet (g)*	*Total ^{90}Sr in diet (calculated) (pCi)*	*% ^{90}Sr*		
					Milk	*Bread*	*Maize*
White	1·0	4·0	292	1 168	47	4	Negligible
Bantu	2·7	10·8	102	1 102	9	10	20 - 50
Coloured	2·0	8·0	126	1 008	8	7	Negligible
Indian	2·5	10·0	135	1 350	9	7	Negligible

During 1969, representative samples from the 5 major maize producing areas were measured individually; variations of a factor 2 were found between different areas. The average ^{90}Sr values in sifted granulated meal are given in Table II. The large variation between values for 1969 and the other harvests may be the result of the more representative monitoring during 1969.

The extremely low calcium content of maize meal, viz. 30 mg/kg,[4] is responsible for the high $^{90}Sr/Ca$ ratio.

^{90}Sr in Bone

In the period from 1966 - 1969, 95 rib-bone samples from Whites, 175 from Bantu, 112 from Coloureds, and 24 bone samples from Indians were analysed.

Analyses were done on individual samples in the age group 5 - 20 years and on bulked samples in the other age groups. The standard deviation for the analytical procedure was 14% with a lower limit of detection of 1 pCi. No corrections for rib values to skeleton values were made.

The ^{90}Sr content in the bone of different population groups for the different age groups is shown in Fig. 1

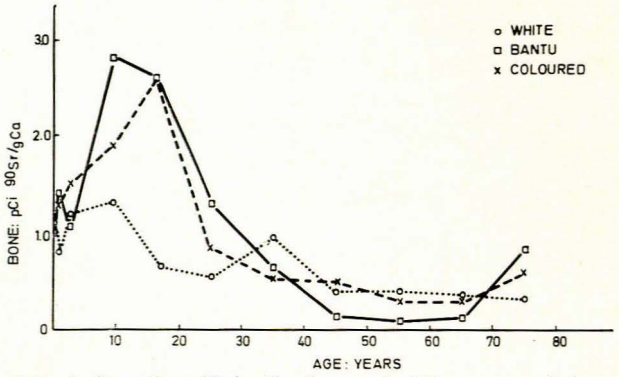

Fig. 1. Strontium-90 in the bone of different population and age groups.

and Table III. The age group 5 - 20 years is important as a constant $^{90}Sr/Ca$ ratio in the skeleton has been attained as well as equilibrium between skeleton and diet.[9] The average ^{90}Sr content in bone for the age groups 5 - 20 years are compared in Table IV.

DISCUSSION

The number of samples in the age group 5 - 20 years for the White population is rather small. However, these experimental values confirm the expected values calculated from dietary levels using the average ^{90}Sr level in milk, a factor 1·5 for the $^{90}Sr/Ca$ ratio in a Western diet to that in milk and a discrimination factor of 4 against ^{90}Sr in the transfer from diet to bone. The fallout pattern in South Africa[10] since 1958 was such that this dietary value is probably a fair average of the ^{90}Sr intake for the period 1958 - 69.

The discrimination factor of 4 against strontium in the transfer from diet to bone has been well established.[9,11-15] This factor appears to hold for a wide range of diets of normal people with both high and low milk consumption and high and low mineral calcium intake.[16] When this factor is applied to the $^{90}Sr/Ca$ ratios in bone of different population groups, the ratio of their $^{90}Sr/Ca$ dietary intakes are found. From the annual calcium intake of each group the total ^{90}Sr intake of that population group can be calculated. In Table IV it is shown that the calculated ^{90}Sr intake of the different population groups are fairly similar.

The main differences in the diets of the two main population groups, e.g. the Whites and the Bantu, are their different calcium intakes and the fact that the main contributor to ^{90}Sr in the White diet is milk with a $^{90}Sr/Ca$ ratio of 2·5, compared to the main ^{90}Sr contributor of the Bantu diet, e.g. maize with a $^{90}Sr/Ca$ ratio>40. It appears that the ^{90}Sr contents in the bone of all the different population groups are inversely proportional to the total calcium in their diets and independent of the mode of ^{90}Sr intake.

In the case of the Bantu population, the calculated ratio of $^{90}Sr/Ca$ in diet to that in milk is 4·3. This value can be compared to the value of 3·5 for India[3] where the relative contribution of animal products to cereals is of the same order.

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