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Balance of Cobalt in Japanese People and Diet

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ABSTRACT

Measurements were made of the stable cobalt in total diet samples collected from a number of sites to know the normal daily ingestion of this element by average Japanese. Two thirds of Japanese adults should take 11–28 μg of cobalt daily and rural children, a half or less amount. The main contributors of cobalt in Japanese diet are plant products. Their contribution as a whole was estimated up to 88.2% of the total intake.

Biological half-life of radiocobalt was estimated as 106 days (f_w: 0.3) or 29.3 days (f_w: 0.92) for Japanese on the basis of assumed existence of an equilibrium condition between the stable element and radiocobalt.

Estimation of the daily intakes by Japanese of ^{60}Co through marine and land products was also attempted in the assumed situation of environmental contamination of sea-water and soils.

INTRODUCTION

The long-lived isotopes of cobalt were observed in fallout originating from nuclear detonations[1] and even in some marine organisms[2,3]. Of these isotopes, ^{60}Co must be considered to be mostly hazardous in the long-term environmental contamination because of its longer half-life (5.2 years) than any other isotopes, namely, ^{57}Co (270 days) and ^{58}Co (72 days). At all events, there can be found possibilities of the entry of radiocobalt which has been discharged to the surface

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of the earth into the food chain.

If the biological half-life of radiocobalt is short and an equilibrium has been reached between the human body and diet, the pattern of distribution of radiocobalt could be interpreted on the basis of that of normal stable cobalt, and the biological half-life would be assessed by means of studying the metabolic balance of the stable element between people and diet. This consideration inspired an examination of the distribution of the stable cobalt in man and his diet.

Following the previous report[4] which dealt with the distribution of cobalt in the human body, in the present study the total diet samples collected from a number of sites in Japan have been analysed and the balance between Japanese people and diet is discussed.

TOTAL DIET SAMPLES

The total diet samples used for this study are the same those used for similar studies for cesium[5] and zinc[6]. They consisted of the complete servings, similar in all respect to that eaten by a member of a family in a day, collected from ten families of each category as indicated in Table 1. Combined diet sample based on

Table 1. The daily intake of cobalt by Japanese people (Composite sample of actually consumed diet for individuals from 10 families each)

District	Category*	Time of collection	Co Concentration p.p.m/ash	Daily intake μg
Hokkaido	U A	Nov. 1960	1.02	15.2
	R A	〃	0.86	18.7
	R C	〃	0.30	3.9
	U A	Nov. 1961	0.75	11.2
	R A	〃	0.66	10.0
Niigata	U A	Feb. 1962	0.70	21.4
	R A	〃	0.98	22.3
Yamagata	U A	Nov. 1961	2.17	45.4
	R A	〃	1.60	42.9
Ishikawa	U A	Nov. 1960	0.16	3.2
	R A	〃	0.23	5.2
	R C	〃	0.23	2.4
Saitama	R A	Nov. 1960	2.39	26.7
	R C	〃	1.60	13.0
Tokyo	D A	Feb. 1962	0.86	14.5
	UpA	〃	1.58	30.3
Miye	R A	Nov. 1960	1.51	40.5
Okayama	U A	Feb. 1962	0.52	9.5
	R A	〃	0.65	11.2
Ehime	U A	Nov. 1960	1.74	24.2
	R A	〃	1.68	26.2
	U A	Nov. 1961	0.82	16.3
	R A	〃	0.53	15.9
Kumamoto	U A	Nov. 1960	0.48	7.1
	R A	〃	0.98	20.2
	R C	〃	1.00	14.8
	U A	Nov. 1961	0.80	16.1
	R A	〃	0.63	13.2
	Av. for adults		**1.01**	**19.5**

* Categories: UA: urban adult, RA: rural adult, RC: rural children, DA: downtown adult, UpA: uptown adult.

standard recipes was also used for contribution study.

ANALYTICAL METHODS

Two spectrophotometric methods were used in determining the cobalt. These methods were those of Torii using o-nitrosoresorcinol monomethylether[7] and Clark using 2-nitroso-1-naphthol[8]. Either method was proved satisfactory in the determination. Duplicate samples were used in obtaining the values reported and additional samples were analysed if the duplicates failed to coincide within the error of determination.

THE DAILY INTAKE OF COBALT BY JAPANESE PEOPLE

The results of determination are summarized in Table 1. Averages were calculated on the basis of assumed normal distribution.

The average daily intake by urban adult (17.9 μg) does not significantly differ from that by rural adult (21.1 μg). The average daily intake of cobalt by the Japanese as a whole would lie somewhere between and an approximate estimation by a simple averaging shows 19.5 μg. Excluding local peculialities in Ishikawa and Yamagata Prefecture, where lower and higher values were observed respectively, two thirds of Japanese adults should take from 11 to 28 μg of cobalt daily and rural children would take a half or less amount.

The present values obtained for Japanese are much higher than those by Harp and Scoular who reported an average adult diet of good quality as supplying 5–8 μg of cobalt daily in the United States[9]. It should also be noted that the recommendations of the International Commission on Radiological Protection, 1958 give in Table XII value of 7 μg of the daily ingestion for this element.

CONTRIBUTION BY DIFFERENT CLASSES OF FOODSTUFFS TO THE TOTAL INTAKE OF COBALT

A compilation of the cobalt content of plant products by Young[10] gives the cobalt content of plants consumed by man as varying from 0.07–1.20 p. p. m. of the edible portion of spinach to 0.006 p. p. m. of polished rice. Hurwitz and Beeson[11] gave values varying from 0.004–0.006 p. p. m. cobalt of dried milk to 0.4–0.5 p. p. m. cobalt of spinach on the dry basis. These values suggest the variability of cobalt intake as affected by the menus which might be caused by the variable levels of this element both within and between the different classes of foodstuffs.

The food channels through which the stable cobalt may enter into man would give informations not only on the nutritional picture but also the passage route of radiocobalt. The latter information would give further suggestions in the establishment of a planning of protection of a population from unnecessary exposure to radiation in connection with the environmental contamination with radiocobalt.

Combined diet samples based on standard recipes recommended by the National Institute of Nutrition, Japan have been collected under the instruction of Prof.

Y. Hiyama, Tokyo University from a number of sites in this country. One of these samples collected in Tokyo in January 1962 was divided into 6 categories of food groups as indicated in Table 2 and analysed for cobalt content.

Table 2. Contribution by each food groups to the total intake of cobalt (Japan) (Actual analysis of combined diet samples collected in Tokyo based on Standard Recipes recommended by the National Institute of Nutrition in Jan. 1962)

Food group	Daily consumption g, fresh	Daily consumption g, ash	Cobalt Concentration p.p.m. fresh basis	Cobalt Concentration p.p.m. ash basis	Cobalt Daily intake μg
I. Cereals	453	2.09	0.027	5.83	12.2
II. Pulses, nuts & fruits	204	6.80	0.029	0.87	5.9
III. Leafy vegetables	202	1.54	0.031	4.00	6.2
IV. Root vegetables	184	1.54	0.039	4.67	7.2
V. Marine products	101	4.48	0.031	0.70	3.1
VI. Meat, eggs & milk products	141	1.87	0.0078	0.58	1.1
Total	**1285**	**18.32**			**35.7**

The result indicates similar values of cobalt concentration in different food groups on the fresh basis except the lower value in Group VI as shown in Table 2. On the ash basis, however, cereals and vegetables are the richest source of cobalt. The result differs from the compilation by Underwood[12)] who stated that the cereal grains were the poorest source but agrees in that the dairy products are the poorest.

Percentage contribution by each food groups to the total intake of cobalt is schematically shown in Fig. 1. Contribution for the people with different dietary habits was also estimated on the basis of Tri-City diet composition given by Rivera[13)] for American assuming the average concentration of cobalt in each food groups the same as in Japan. Table 3 and Fig. 1 show the estimates.

Table 3. Estimated contribution by each food groups to the total intake of cobalt (U.S.A.) (Estimates for Tri-City Diet composition* on the basis of the average concentration of cobalt in each food groups as shown in Table 2.)

Food group	Daily consumption g, fresh	Cobalt Daily intake, μg
I. Cereals	236	6.4
II. Pulse, nuts & fruits	348	10.1
III. Leafy vegetables	118	3.7
IV. Root vegetables	224	8.7
V. Marine products	25	0.8
VI. Meat, eggs & milk products	897	7.0
Total	**1848**	**36.7**

* J. Rivera, HASL-117, p. 220, Dec. 30, 1961.

Total daily intakes for Japanese and American incidentally coincide and these values appear to be greater than actual intakes in Japan. Contributions by plant products as a whole are estimated up to 88.2% and 78.7%, respectively in Japan and the United States. Meat, eggs,

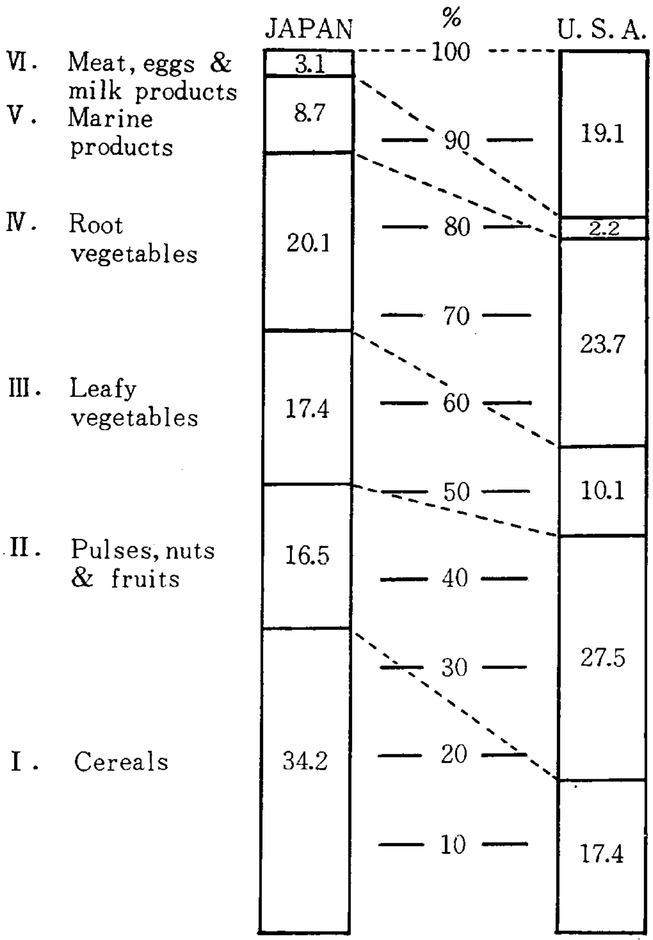

Fig. 1. Percentage contribution by each food groups to the total intake of cobalt

poultry and milk products insignificantly contribute to the total intake of cobalt in Japanese ordinary diet, in contrast to minor contribution by marine products in the United States. In either case, it should be noted that plant products are the main channels through which cobalt may enter the human body.

There is no doubt, however that the cobalt content of vegetables, especially the leafy vegetables, could be greatly influenced by cobalt content of soils. For example, cobalt contents of red clover and rye grass grown on different soils in north-east Scotland are reported varying from 0.07 to 1.49 and from less than 0.03 to 0.92 p.p.m. in oven dry material, respectively[14]. Hence, it appears that the green leafy vegetables are the most variable source of this element.

ENVIRONMENTAL CONTAMINATION WITH RADIOCOBALT

The liver of tuna which was caught in the Pacific in August 1956, a few months after a series of nuclear tests around Eniwetok and Bikini Atolls, contained 22 $\mu\mu$c of ^{60}Co, 42 $\mu\mu$c of ^{57}Co and 18 $\mu\mu$c of ^{58}Co in gram of wet tissue[2]. The viscera of tunas caught by the recent survey conducted by the cruiser Shōyō Maru in the Pacific contained a small but measurable amounts of ^{60}Co, namely, 0.06—0.147 $\mu\mu$c (average, 0.093) in gram of wet tissue[3].

Recent activities found in tunas could naturally be ascribed to the recent series of nuclear tests in the Pacific but it might also be possible to assume residual and ubiquitous activities from the past tests in the oceanic waters. If the latter is the case, it would be possible to compute the specific activity of ^{60}Co in sea-water assuming the existence of an equilibrium condition between the stable element and ^{60}Co in the fishes and sea-water.

The cobalt content of tunas is not known but some species of Gadus are reported to have 0.065–0.1 p. p. m. Co in living material[15]. These values are in good coincidence with the concentration in the marine products as a whole as presented by the authors. Values for some fishes reported by Bertrand and Mâcheboeuf seem to be astonishingly high (0.028–0.11 mg/100 g fresh)[16]. The concentration of cobalt in sea-water is reported as 0.1–0.67 μg/l[17]. Assuming the concentration of cobalt in the fishes as 0.031 p.p.m. and the average value in sea-water as 0.3 μg/1, the specific activity of 2-5 $\mu\mu$c/μg Co would be obtained for recent waters in the Pacific.

If this estimate is valid for all of the daily consumption of marine products (101 g), a rough estimate of the daily intake of ^{60}Co by Japanese would result in 6–15 $\mu\mu$c and the total body burden would be 0.3–0.7 mμc assuming that ^{60}Co enters only through marine products. The figures given could not be taken as more than maximum estimates in the assumed situation of continuing level of ^{60}Co in sea-water.

Estimation of the total ^{60}Co in sea-water can be made roughly on the assumption that the mixing layer extends to the depth of 100 m on average in the ocean[18]. If the figures thus obtained, 60–150 mc/km^2 is also valid for the cumulative deposit for land area, possible contamination of the foods raised on land could be estimated.

Since cobalt is important in the nutrition of ruminants, there have been numerous determinations of the cobalt contents of soils. Normal soils have 1–40 p. p. m. Extractions with 0.5 N acetic acid give values of 0.10–1 p. p. m. and neutral 1 N ammonium acetate usually extracts $<$0.1 p. p. m.[19]. Assuming the depth of ploughing as 10–20 cm, the volume weight of soil as 1 and the available cobalt content as 0.1 p. p. m., the specific activity of ^{60}Co in soil which is assumed being deposited in the same proportion as in the ocean would be computed as 3–15 $\mu\mu$c/μg Co. A similar calculation as that has been made for marine products will lead to 90–450 $\mu\mu$c of the daily intake through land products by Japanese. This would be more than ten times that through marine products and the total body burden would amount up to 4-21 mμc. This is not likely to be true, since ^{60}Co from nuclear tests has not been reported in people.

The assumption of equal deposition of ^{60}Co on land area to the ocean should not justifiably be made, but probably much injection occurred of this induced radioactivity in the Pacific and the effect of close-in fallout raised the deposition over the sea. However, the foregoing estimation was made as being of value in establishing a preliminary planning of radiological protection following the release of radioactivity into the environments.

ASSESSMENT OF BIOLOGICAL HALF-LIFE OF RADIOCOBALT IN MAN

A study of the balance of the normal stable element between people and diet may possibly be substituted for the experiment with radionuclides of this same element if the distribution of the stable element in man is assumed typical of the distribution that would result from chronic human exposure to radionuclides and the way of incorporation is assumed similar.

If the average body weight of Japanese adult (m) is assumed as 56×10^3 g[5], the average concentration of cobalt in the body (C) as 1.6×10^{-8} g/g wet tissue[4], and the daily ingestion (I) as 19.5×10^{-6} g as presented in this report, the biological half-life in total body would be calculated from the following equation:

$$T_b = \frac{0.693\ mC}{If_w}$$

where f_w is the fraction of that taken into the body by ingestion that is retained in the total body. A reliable value of f_w is not known for Japanese diet but if the value of 0.3 as given in the recommendations of the International Commission on Radiological Protection, 1958 is also valid for Japanese, the biological half-life of cobalt can be calculated as 106 days.

A balance study in young college women performed by Harp and Scoular[9] gave the value ranging from 73 to 97% (average, 92%) of absorption. If this value of f_w (0.92) is used for the foregoing calculation, the biological half-life would be given as 29.3 days. The value of f_w greatly affects the calculation of the biological half-life. Nevertheless, these calculated values are in disaccord with the value of 9.5 days as given in the recommendations of the I. C. R. P., 1958 for the biological half-life of radiocobalt, which is supposed to be derived from an experiment with radiocobalt, probably on animals. If a similar calculation as given above is made on the basis of m being 70×10^3 g, C being less than 4.3×10^{-8} g/g, I being 7×10^{-6} g and f_w being 0.3 as given in the Table XII in the recommendations of the I. C. R. P., the biological half-life would be calculated as less than 993 days.

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