Radiostrontium in Deciduous Teeth from Japanese Children. Result of the First Investigation

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Introduction

In 2011, the core meltings of the nuclear power plants (NPP) in Fukushima-Daiji resulted in the emission of radioactive material to the environment. Scientists estimate these emissions to be equivalent to about 10% of the fallout from the nuclear accident at Chernobyl in 1986. About 90% of these emissions were washed out into the Pacific Ocean. Nevertheless, the region of Fukushima and other near prefectures were contaminated with long-lived radionuclides of caesium (^{134}Cs and ^{137}Cs), strontium (^{90}Sr) and plutonium (^{238}Pu, $^{239,240}Pu$). Total fallout was estimated as 1.be $5x10^{14}$ Bq Iodine-131 (^{131}I) and $1.3x10^{13}$ Bq radiocaesium (^{134}Cs, ^{137}Cs). The emission of radiostrontium is estimated, according to its low volatility, to about 10^{10} to 10^{11} Bq [1]. The population incorporated the contamination by the consumption of contaminated food (e.g. vegetables of these contaminated areas). Some days after the radionuclear release, vegetables were seriously contaminated.

One has to consider that the environment and food in Japan were contaminated even before 2011. From 1945 to 1962, over 600 atmospheric bomb tests were executed, leading to a radioactive contamination of the northern hemisphere (about $6x10^{17}$ Bq of ^{90}Sr and $9x10^{17}$ Bq of ^{137}Cs). Today, this contamination is still present because of the long half-lives of these radionuclides, of about 30 years. In 1948, the Japanese government started the investigation of radiostrontium in deciduous teeth. From 1958 to 2011, 849 tooth samples were analysed based on 114,725 collected deciduous teeth. The contamination with radiostrontium was at a maximum in the mid-sixties (400 mBq/gCa) [2]. As far as we know, there are no results available of deciduous teeth from children born in 2011.

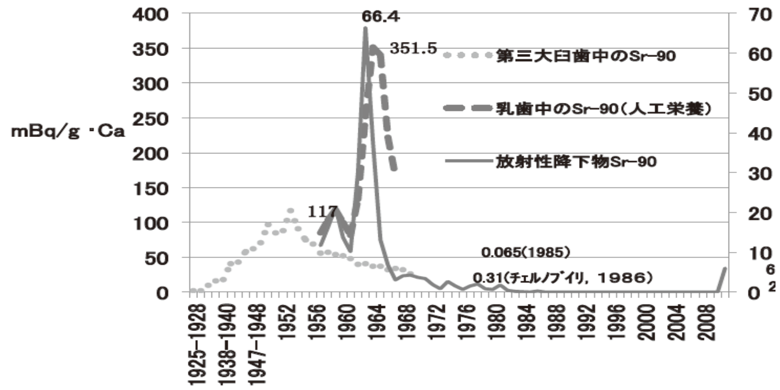

Figure 1 *^{90}Sr-data in deciduous teeth from Japanese children [1]*

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The network "Preserving Deciduous Teeth"

In 2011, Eisuke Matsui from the Institute of Environmental Medicine in Gifu made contact with us and asked for help in the investigation of deciduous teeth. They had founded the network "Preserving Deciduous Teeth" with the aim to collect milk teeth from children all over Japan and analyse them for contamination with radiostrontium [3]. In 2017, they intend to analyse deciduous teeth samples in their own laboratory, which will be performed in collaboration with the state-laboratory of Basel-City. From 2011 to 2015, different private citizens and dentists collected over 200 milk teeth from children of the prefectures of Aichi, Chiba, Fukushima, Ibaraki, Kanagawa, Miyagi, Saitama, Shiga, Tochigi, Tokyo and Yamaguchi and sent them to our laboratory for analysis. These 200 milk teeth are part of a preliminary investigation for the coming activities of the network. Milk teeth from children born in 2011 are not yet available. Therefore, the contaminations found in this paper are not caused by the core-meltings of Fukushima-Daiji NPP.

Toxicity of radiostrontium

Radiocaesium is incorporated and collected in muscle tissues. Its biological half-life is about one month. On the other hand, radiostrontium is enriched in bones and teeth and remains there for a long time (biological half-life of 40 years). The deposition of radiocaesium near the bone marrow, where blood cells are built, is considered very problematic. The inner radiation caused by the decay of ^{90}Sr and its daughter, Yttrium-90 (^{90}Y), may induce leukaemia and bone cancer. Radiostrontium is deposited into milk teeth during their genesis, from the last six months of pregnancy to some months after birth.

One has to note that scientists estimate the risk of radiostrontium differently. The International Commission for Radioprotection (ICRP) has published ingestion factors for babies of between 0.2 and 2.3 µSv/Bq of radiostrontium [4]. The European committee on Radiation Risk (ECRR) published factors of 45 µSv/Bq for babies and 450 µSv/Bq for foetuses. They explain the higher ingestion factors due to the ability of radiostrontium to bind to DNA [5].

Collection of deciduous teeth

First milk teeth were collected by Yuko Nishiyama. Then, dentists began to collect deciduous teeth from different areas. These collections were coordinated by Eisuke Matsui. Personal data from the children and the parents (birthdate, sex, age, birthplace, residence place after evacuation from the evacuation zone) were noted. Mothers were not asked how they fed their children (mother's milk, infant formula).

In total, 226 milk teeth were analysed at the state-laboratory of Basel-City. Milk teeth were analysed as the whole tooth (enamel, dentine and cementum together). For the analysis of radiostrontium, at least 2 g of tooth material is needed. Therefore, it was necessary to pool several teeth to obtain enough material for the analyses. Nevertheless, some analyses showed results below the detection limit. These results were included in the assessment with a value that is half of the detection limit.

Results were arranged by the birth year of the child and statistically interpreted. Outliers were determined using the Duncan's test. We found a total of 21 outliers.

Radiostrontium Analysis

The analysis of radiostrontium is time-consuming. In contrast to a gamma spectrometric investigation, radiostrontium has to be separated from the disturbing sample matrix (mainly calcium hydroxyl apatite). After several clean-up steps, the daughter of ^{90}Sr, ^{90}Y is isolated from the radiostrontium by several precipitation steps as an oxalate precipitate. The decay of ^{90}Y-oxalate is analysed using β-spectrometry over several days, and the purity of the isolated ^{90}Y-source is represented by the observed half-life. A half-life higher than 64 hours indicates impurities in the ^{90}Y-oxalate. Therefore, the retained ^{90}Sr-filtrate from the separation step has to be reanalysed.

Results

Overview

^{90}Sr-results from milk teeth of children born between 1999 and 2009 show a contamination level of 10 to 90 mBq/gCa. Mean values of each birth year show high variance. Therefore, no significant trends are visible. For 1999 and 2009, the mean value is based on too few values to represent a statistically improved mean value.

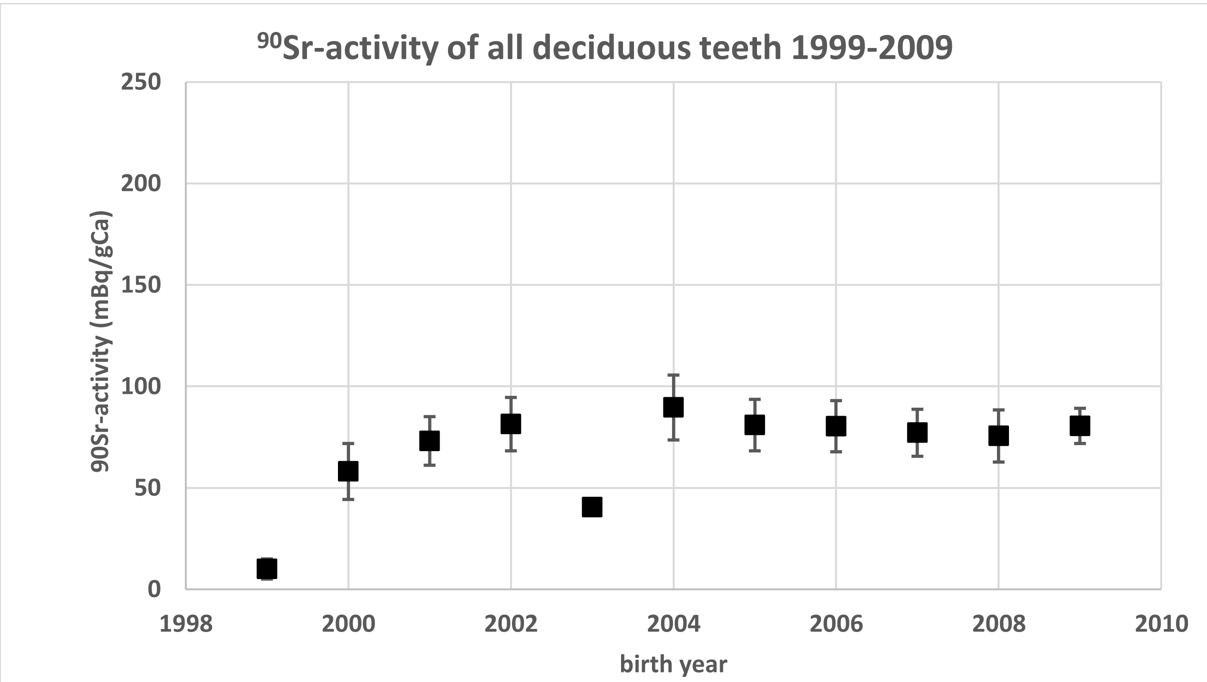

Figure 2 *^{90}Sr-mean values of the birth years 1999 to 2009*

From 2000 to 2009, the radiostrontium data of deciduous teeth are between 50 and 100 mBq/gCa. Mari Takenouchi reported similar results for teeth collected in 1992 to

1999. The mean value was 81 mBq/gCa and the teeth samples were all from Japanese children [6]. In any case, milk teeth of Japanese children seem to be more polluted than e.g. milk teeth of Swiss children. Swiss data show a lower contamination level of radiostrontium of 10 to 20 mBq/gCa [7].

^{90}Sr-activity versus residence place

Table 1 shows the radiostrontium data correlated with the place of residence of the children. Again, the mean values of each place of residence (prefecture) are higher than the median values due to the high variance of data. We received five samples without any indication of the place of residence; one child was living abroad in 2011. These data were ignored.

prefecture	tooth samples	median (mBq/gCa)	mean ± SD (mBq/gCa)
Aichi	3	43	57 ± 27
Chiba	68	50	67 ± 50
Fukushima	47	90	106 ± 83
Hokkaido	1		33 ± 10
Ibaraki	12	59	88 ± 55
Kanagawa	5	50	53 ± 24
Miyagi	6	44	55 ± 32
Osaka	1		54 ± 11
Saitama	11	44	49 ± 17
Shiga	4	52	49 ± 10
Shizuoka	1		120 ± 20
Tochigi	4	46	46 ± 9
Tokyo	21	35	71 ± 66
Yamaguchi	12	54	46 ± 11
Total	**196**	**51**	**74 ± 61**

Table 1 *^{90}Sr-activity of deciduous teeth from different prefectures*

SD: Standard deviation of the mean value: Mean values of two results or less are followed by the analytical error of the β-spectrometry.

The presented data show a high variance within each prefecture. Therefore, it is not possible to see any relation between ^{90}Sr-activity and the place of residence of the children.

^{90}Sr-activity versus sex

Within every year, data were analysed considering the sex. **Table 2** shows no significant differences between girls and boys. The variance within the age collective is too high.

	Girls		boys	
year of birth	**number of samples**	**mean ± SD**	**number of samples**	**mean ± SD**
1999	1	10 ± 5	0	
2000	5	58 ± 31	0	
2001	16	55 ± 47	5	93 ± 71
2002	13	103 ± 64	9	50 ± 40
2003	16	45 ± 23	13	33 ± 13
2004	10	124 ± 65	8	55 ± 60
2005	19	91 ± 84	14	67 ± 50
2006	16	78 ± 74	14	83 ± 63
2007	8	53 ± 32	15	90 ± 61
2008	11	69 ± 53	5	178 ± 45
2009	2	80 ± 16	1	80 ± 16

Table 2 *^{90}Sr-activity of deciduous teeth and sex*

SD: Standard deviation of the mean value: Mean values of two results or less are followed by the analytical error of the β-spectrometry.

Summary

The investigation of 226 deciduous teeth from Japanese children show a mean contamination level between 50 and 100 mBq/gCa. The nearest year of birth to the core-meltings at the Fukushima-Daiji is 2009. Milk teeth from children born in 2011 cannot be analysed yet. Therefore, one has to wait to see whether the contamination level will rise according to the NPP's accidents. Studies of teeth from cattle living in the evacuation zone show a contamination level up to 550 mBq/gCa, which is significantly higher compared to cattle from a non-contaminated zone. The contamination is also higher compared to cattle whose dentition had ended before 2011. They found a significant relation between the ^{90}Sr-activity of the teeth and the contamination of the soil where the cattle settled [8].

As mentioned before, we have eliminated some outliers. These were 22 tooth samples with ^{90}Sr-activities around 400 and 500 mBq/gCa and one highly-contaminated tooth with a level of 2000 mBq/gCa. These samples were collected in the prefectures of Chiba (5), Fukushima (9), Saitama (3) and Tokyo (2).

The investigations will be continued.

Literature

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