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STRONTIUM-90 IN TEETH
A COMPARISON OF METHODS

by
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INTRODUCTION

The strontium-90 content of the deciduous teeth of children born in the 1950s ranges from 0.15 to 6.56 pCi/gCa (*Rosenthal et al.*, 1966; *Aarkrog*, 1968, *D'arca Simonetti et al.*, 1969) As the result of nuclear tests in the 1960s, an increase occurred in the fall-out of strontium-90; this apparently led to an increase in the strontium-90 content of the deciduous teeth of children born in the years 1962—1964.

The results published have been obtained by the radiochemical separation of ^{90}Sr and measurement of the β-activity with a low-background Geiger counter. However, Čerenkov radiation seems to offer a simple and rapid method for the measurement of ^{90}Sr content in biological samples. This is indicated by the studies of *Haberer* (1965) and *Elrick & Parker* (1968), who have shown that Čerenkov radiation, produced by strong β-emitters, can be measured by means of an ordinary liquid scintillation counter. α- and γ-emitters, possibly present in the samples, do not interfere with the measurement. The lower energy limit of electrons capable of producing Čerenkov radiation in water can be calculated as 260 KeV (*Jelley*, 1958); the maximum energy of a β-emitter practicable for counting in a liquid scintillation counter must exceed 1 MeV. ^{90}Y, the daughter nuclide of ^{90}Sr, has a maximum energy of 2.2 MeV, thus being much higher than the energy limit required.

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Utilization of Čerenkov radiation for the determination of β-activity appears to be especially useful when dealing with a homogeneous material, such as teeth, which is not likely to contain strong β-emitters other than ^{90}Sr and ^{90}Y. We here describe a comparison of the methods used for analysis of the ^{90}Sr activity in teeth with measurement of the Čerenkov radiation with a liquid scintillation counter and the beta radiation with an anticoincidence beta counter after separating ^{90}Sr radiochemically by the well-known nitrate separation method (*Paakkola,* 1966). The possible presence of components interfering with the measurements was further studied by means of gamma spectra and X-ray fluorescence.

MATERIAL AND METHODS

Because of the shortage of large quantities of human teeth, the main part of the experiments was carried out with animal teeth. The strontium-90 content of cow's teeth is relatively high (*Giese et al.*, 1965); therefore the test material was obtained from 15 cows (1.5—10 years old) collected from different parts of Finland. The teeth were ashed for 24 hours at 600 °C and the ash (about 1 kg in total) was ground to a fine powder, which was carefully homogenized. This ash was analysed for ^{90}Sr and Ca. The gamma spectrum of the ash was also obtained and the inactive elements were determined by means of X-ray fluorescence. For the sake of comparison the gamma spectrum and the analysis for inactive components (X-ray fluorescence) were also made from human teeth.

Čerenkov radiation was measured in a liquid scintillation counter, using six essentially identical samples, each consisting of 5.0 g of ash. The ash was prewetted with distilled water and dissolved in hydrochloric acid by heating; a colourless and clear solution was obtained after removing carbon particles by filtration. Sample volumes were adjusted to 20 ml in 25-ml polyethylene counting vials. Optimal settings for the counting channel were determined by means of a ^{90}Sr standard; the other two channels were used to detect possible quenching by the channels ratio method. Quenching was also checked by means of external standardization; significant quenching was not observed as compared to samples used for background measurements. All test and background samples were counted successively in twelve cycles until 120 minutes was reached for each sample. The purpose of this procedure was to minimize possible effects of external variables (voltage, background radiation) on the counting rate. The background samples were prepared from human teeth extracted before 1940; the preparative technique was identical to that used for cow's teeth. The background measured with five

Table I.

Determination of ^{90}Sr activity in cow's teeth by means of Čerenkov radiation (liquid scintillation counter). Each sample was counted for 120 min with a counting error equivalent to about 0.4 pCi/gCa. The first column is based on titrimetric analysis of Ca content, the second on atomic absorption spectrophotometry

Sample No.	^{90}Sr(pCi/gCa)	
1	19.4	20.0
2	21.2	21.0
3	19.2	18.6
4	19.4	19.6
5	20.8	20.4
6	21.2	21.0
$\bar{x}$	20.2	20.1

samples was 10.9 ± 0.2 cpm. After determination of the radioactivity, the calcium content of the samples was measured by means of permanganate titration and atomic absorption spectrophotometry.

Control samples for the determination of ^{90}Sr activity with a low-background β-counter were prepared from the same pool of ash; six samples were analysed, each consisting of 10 g of ash. ^{90}Sr was separated by the nitrate separation method and the activities were measured with an anticoincidence beta counter which had a background of about 0.7 cpm and a counting efficiency of about 45 % for ^{90}Y (*Paakkola,* 1966). Calcium was separated as the oxalate and determined by titration with permanganate.

RESULTS

The results obtained by measuring Čerenkov radiation (liquid scintillation counter) and beta radiation (anticoincidence beta counter) are shown in Tables I and II, respectively.

X-ray fluorescence revealed that, in addition to calcium (36 %) and phosphorus (17 %), the ash contained trace amounts of K ($<$ 0.05 %), Cr, Fe, Cu, Zn, Sr, Ba and Cl. This indicates that the presence of pure β-emitters other than ^{90}Sr and ^{90}Y is most improbable in cow's teeth. It was further confirmed by gamma spectroscopy that the samples did not contain components emitting both β- and γ-radiation. The only findings were natural radioactivities, the main components being ^{226}Th, ^{232}Th and ^{228}Ra. The total radioactivity of these radionuclides was 1 pCi/g ash or less.

Table II.

Determination of ^{90}Sr activity in cow's teeth by means of beta radiation (anticoincidence beta counter). The columns show the results obtained in duplicate measurement on the same sample

Sample No.	^{90}Sr(pCi/gCa)	
1	20.2	20.1
2	20.1	19.7
3	20.2	19.9
4	21.1	19.6
5	19.4	19.0
6	20.5	19.7
$\bar{x}$	20.0	

Gamma spectra of human teeth were even more blank than those of cow's teeth. X-ray fluorescence analysis showed that human teeth contained only about half the Fe and K found in cow's teeth; this was probably due to smaller blood contamination of the samples. Further, in human teeth the content of inactive Sr was only about one fourth of that found in cow's teeth, and Ba was completely absent. These differences are due to discrimination against the heavier alkaline earth metals. The main source of Ca, Sr and Ba in cow's diet is grass, whereas in man's diet these elements mainly come from cow's milk, where the discrimination grass-milk has already occurred.

DISCUSSION

It is seen from Tables I and II that the mean ^{90}Sr content in cow's teeth was 20.1 pCi/gCa. The results obtained by measuring Čerenkov radiation do not differ from those obtained by the more conventional technique based on the radiochemical separation of ^{90}Sr and measurement of the radioactivity with a low-background β-counter. Thus the results indicate that the use of Čerenkov radiation is justified for the determination of ^{90}Sr activity in teeth. This technique has considerable advantages: preparation of the samples is rapid and easy, the possible presence of α- and γ-emitters does not interfere with the measurement, and the samples can be remeasured if necessary or can be used later for other analyses.

Gamma spectra and analyses for inactive components in cow's and human teeth indicated further that utilization of Čerenkov radiation for the measurement of ^{90}Sr content in human teeth would not be disturbed by other radionuclides. Attempts are therefore being made to utilize this technique for the measurement of ^{90}Sr in deciduous teeth of Finnish children born in 1956—1963. The radioactivity is expected to be lower than in cow's teeth, but this problem can be met by increasing the sample size and by prolonging the counting time.

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SUMMARY

The results showed that analysis of the ^{90}Sr activity in teeth is possible with measurement of the Čerenkov radiation with an ordinary liquid scintillation counter. The results did not differ from those obtained by the more conventional technique based on the radiochemical separation of ^{90}Sr and measurement of the radioactivity with a low-background β-counter. The mean ^{90}Sr content in cow's teeth in Finland was 20.1 pCi/gCa.

Gamma spectra and analyses for inactive components (X-ray fluorescence) in cow's and human teeth indicated further that utilization of Čerenkov radiation for the measurement of ^{90}Sr content in human teeth would not be disturbed by other radionuclides.

RÉSUMÉ

^{90}Sr DANS LES DENTS. COMPARAISON DES MÉTHODES

Cette étude a montré que l'analyse de l'activité du ^{90}Sr dans les dents peut être faite en mesurant les rayons Čerenkov avec un compteur à scintillation liquide ordinaire. Les résultats obtenus ne différaient pas de ceux qu'on obtenait par la technique plus classique basée sur la séparation radiochimique du ^{90}Sr et la mesure de la radioactivité avec un compteur de radioactivité β ambiante basse. La teneur moyenne en ^{90}Sr dans les dents de vaches en Finlande était de 20,1 pCi/gCa.

Les spectres gamma et les analyses des éléments inactifs (fluorescence en rayons X) dans les dents de vaches et les dents humaines indiquaient de plus que l'utilisation des rayons Čerenkov pour la mesure de la teneur en ^{90}Sr dans les dents humaines ne serait pas perturbée par d'autres radionucléides.

ZUSAMMENFASSUNG

STRONTIUM-90 IN ZÄHNEN — EIN VERGLEICH ZWEIER METHODEN

Die Resultaten dieser Untersuchung zeigen, dass die Aktivität von ^{90}Sr in den Zähnen mit einem gewöhnlichen Flüssigkeitsszintillationszähler gemessen werden kann. Diese Resultaten unterschieden sich nicht von denen, die mit üblichen Methoden d.h. mit radiochemischen Trennung von Strontium-90 und Messung der Radioaktivität mit einer β-Zähler mit niedrigem Nulleffekt erreicht wurden. Die mittlere ^{90}Sr-Gehalt in Zähnen der Kühe in Finnland war 20,1 pCi/g Ca.

Die Gammaspektra und die Analysen von inaktiven Komponenten (mit Röntgenfluoreszensanalyse gemessen) zeigten, dass die Messung von ^{90}Sr in den Zähnen von Kühen und Menschen mit Čerenkov-Strahlung nicht von anderen Radionukliden gestört wird.

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