RADIOACTIVE FOODCHAINS IN THE SUBARCTIC ENVIRONMENT

Progress Report
for Period Aug. 15, 1975-Aug. 14, 1976

Jorma K. Miettinen

Department of Radiochemistry
University of Helsinki

May 1976

PREPARED FOR THE U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION UNDER CONTRACT CH E (11-1)-3011
(until January 18, 1975 AT (11-1)-3011)

DISCLAIMER

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ABSTRACT

^{137}Cs is accumulated in the foodchain lichen-reindeer-man causing high body burdens in Lapps who have reindeer meat as staple food. A group of Finnish Lapps has been whole body counted for ^{137}Cs annually since 1961. Results of the measurements made in April 1976 show 18 per cent decrease in ^{137}Cs body burdens from the previous year. A dietary study confirmed that there was no mentionable change in the total amount of reindeer meat consumed although winter consumption has slightly decreased and summer consumption increased in recent years.

Plutonium analyses of stockpiled lichen and reindeer samples from 1960-73 were begun in 1973; since then the sampling has continued. Lichen had 200 pCi per kg dry weight in 1963-64, 100 pCi/kg in 1966-70, 20 pCi/kg in 1973-75. Biological half-time of plutonium in lichen is 2 years.

Reindeer liver contained about 20 pCi per kg fresh weight in 1963, 2 pCi in 1973. The ratio of plutonium in liver to its lifelong total intake gave a lower limit to absorption in reindeer, $2{,}5 \times 10^{-6}$. Of bones, plutonium concentration is highest in teeth, medium high in sternum, vertebra and humerus, and lowest in solid long bones.

Human autopsy samples gave for lungs 0,19, liver 0,02 and bone 0,09 pCi $^{239,240}Pu$ per kg of wet weight. In future, emphasis will be in analysis of human samples.

TECHNICAL PROGRESS REPORT FOR THE PROJECT RADIOACTIVE FOODCHAINS IN THE SUBARCTIC ENVIRONMENT

Contract CH E(11-1)-3011

Three-year Period 1973 - 1976

INTRODUCTION

Broad outlines will be given of problems studied and progress made during the last three years. Since the progress of the two first years has been covered in detail in the Annual Reports for 1974 and 1975, emphasis in this Report is on the newest results presented in papers Nos 73-82. The 1974 Report covered papers Nos 58-63, the 1975 Report papers Nos 64-72, titles of which are given in the "list of earlier publications".

The studies carried out can be divided into three groups:

1. ^{137}Cs in the foodchain lichen-reindeer-man.
2. Plutonium isotopes in the above foodchain.
3. Plutonium isotopes in the Baltic Sea.

The main emphasis has been in the area No 2. This is the first year when the capacity of our laboratory for plutonium analyses has reached large numbers. Only part of the analyses performed are included in the five primary reports on plutonium studies presented here, Nos 77-81. Many of the analyses not included were devoted to methodological research (some of these will be published later in several doctoral theses) and to analytical quality control.

^{137}Cs has been mainly studied to confirm the earlier results. For this purpose the same group of Finnish Lapps that has been whole body counted yearly since 1962 was still recounted this spring. Even their food consumption which was carefully studied in 1962 and 1971, was checked again. Measurements of the last few years give a better material for forecasting future long range trends in the whole body burdens of the reindeer consuming populations than would have been possible on the basis of the earlier years' measurements, in which there was a considerable contribution from fresh fallout. Annual variations are still considerable: activity of reindeer meat depends on the availability of lichen in that particular winter, while the body radioactivity of Lapps depends on the radioactivity and availability of reindeer meat. All these factors depend on weather conditions during the winter which vary considerably causing in Lapps body burden variations of about $\pm$ 10 % from the expected value. In the future, Lapps will not be recounted every year, because new scientific knowledge cannot be expected from frequent recounts. Yet, we plan to recount them occasionally, by 2- or 3- year intervals, and even promptly if a new fallout situation arizes.

The third group of studies, those on plutonium isotopes in the Baltic Sea samples, is a kind of spin-off from the main project.
The first analyses of aquatic samples, which were reported already last year (paper No 70), were carried out as a thesis work by Miss Marja Järvinen, M.Sc. They are briefly treated also in the review article presented in this report (paper No 82). The work has been continued as part of a doctoral thesis work by Mrs Kristiina Simola, M.Sc., who is studing plutonium in Baltic sediments (paper No 81). The study is being carried out in collaboration with the Institute for Marine Research which is taking the sediment core samples by its research vessel Aranda and which also provides expertise of marine research. The costs to the project of this research are minimal.

This sediment study on plutonium is not important from the point of the nuclear power reactors being built along the coasts of the Baltic. These reactors are not likely to release significant amounts of plutonium. Rather, the study belongs to the realm of basic research giving information on the environmental (aquatic) behaviour of the fallout plutonium. Since this area is very poorly known, a contribution from the Baltic Sea is useful. As discussed in papers Nos 81 and 82

only few laboratories have reported plutonium results on marine sediment cores and the number of analyses reported is still quite low.

As for the main area of our study, plutonium in the terrestrial food-chain lichen-reindeer-man, a large number of analyses on different organs of reindeer have now been performed. Many of these analyses belong to the doctoral thesis work of Mr Martti Hakanen, M.Sc. On the basis of these results it begins to be possible to evaluate the role of inhalation and dietary absorbtion to the total intake of plutonium by the reindeer. However, this study is only half-way, so far.

The first analyses of human tissue samples are now available. We have organized collaboration with the Department of Forensic Medicine of this University, and the Ivalo Hospital in Lapland. The former takes autopsy samples from normal subjects who have died in accidents in Southern Finland. These represent subjects with "normal" diet. In Lapland fatal accidents are rare because of the small size of the population. We can get, however, whole placentas of Lapps giving child birth in the Ivalo Hospital, and teeth from the local dentists curing Lapp children. By comparison with corresponding samples from the Southern Finland , where we can determine also the total body burden of some subjects by post mortem analysis as mentioned above, we hope to be able to evaluate Lapps' body burden of plutonium. The human material will be in the focus of the study during the next three years. So far, lichen and reindeer have been in the focus. The human material will be analysed by Miss Helena Mussalo, M.Sc., who has a doctoral thesis on the subject under preparation.

Plutonium studies have been carried out under this project during two years. Much of the attention has been on the methodology. The capacity of our laboratory has been built up and the personnel trained in. We hope that the project will continue because in the next few years the results will accumulate.

1. COMPLETING THE STUDIES ON ^{137}Cs IN THE FOODCHAIN LICHEN-REINDEER-MAN.

The main factors leading to the abnormally high accumulation of ^{137}Cs in Laplanders were elucidated during the 1960s' already. By counting about 60-100 Lapps annually it was found that in the male reindeer herders who had the greatest reindeer meat consumption the body burden was 40 to 50 times higher than in the northern hemisphere populations in general. Females of the reindeer herding families had about half, children about one quarter of men's body burden, even when expressed per kg body weight of per g potassium.

During the 1960s' there was a great seasonal variation, maximal body burdens being measured in the spring (April), minimal ones in the autumn (September). This variation was caused by the high radioactivity of reindeer's organs in the spring - after 9 months' feeding on lichen - and the high consumption of reindeer meat by the Lapps throughout the winter. In summer reindeer feeds almost solely on grass and perennial shrubs and its body radioactivity decreases sharply.

The dietary study of 1971 proved that about one third of the Lapps households were now able to use deepfreezers and extend the consumption of the highly radioactive winter-slaughtered meat later to the summer. A similar study was carried out this spring to find out if there were further changes in Lapps' diet. So far, only figures on reindeer meat consumption have been calculated of this study. In paper No 76 they are compared with the results of the 1971-study. It turned out, that there had been very little change in the total consumption of reindeer meat, particularly among the reindeer herders, but there was less difference between their winter and summer consumption than earlier, thanks to the increased availability of deepfreezers. This change has had an increasing effect on their body radioactivity. While their ^{137}Cs body burden decreased between 1965-69 by a half-time of 3-4 years, it decreased between 1969-76 by a half-time of 5-6 years (Fig 1). The average body burden in April 1976 , 121 nCi ^{137}Cs per person, was 82 per cent of the 1975-value for the same

subjects (paper No 73). The decrease of the radioactivity of reindeer muscle from last year, 19 per cent, was almost similar (paper No 74). All subjects were also counted with a small (3" x 3") NaJ-crystal using the "lap geometry" without a massive shield (paper No 75). The result was similar to that with the regular counter. The better geometry of the lap counter compensates to the smaller crystal size and higher background effect. This "lap geometry" would be a simple but quite satisfactory method for large scale emergency measurements.

We now consider that there is no need to continue the ^{137}Cs whole body measurements next year. The results of the whole body measurements of the last few years as well as the two dietary studies will subsequently be written up to publication form and sent to scientific journals.

2. PLUTONIUM ISOTOPES IN THE FOODCHAIN LICHEN-REINDEER-MAN

Plutonium is usually considered to be an inhalation risk to man, in occupational as well as general environmental conditions. This may be usually true, but not always. The foodchain lichen-reindeer-man is one exception. Particularly the reindeer obtains today the bulk of its plutonium burden from its fodder. The Lapps who consume large amounts of reindeer meat and especially reindeer liver may also get a small but not insignificant part of their plutonium body burden from their diet.

The study of this foodchain under this project was started about two years ago. During the first two years the emphasis has been on methodological problems and on analyses of lichen and reindeer samples stockpiled since 1960.

Results on lichen analyses are presented in Fig. 2. As can be seen, Cladonia alpestris lichen contained in 1964 ca 200 pCi, in 1971 ca 100 pCi, and in 1974 ca 20 pCi per kg dry weight. There exists some correlation between plutonium activity in lichen and in air (paper No 82).
Plutonium isotope ^{238}Pu was also measured. The ratio ^{238}Pu : $^{239,240}Pu$ in lichen increases from 0,03 to 0,08 during 1960-74 (see paper No 82).

A large number of plutonium analyses on reindeer tissues have been performed during the last year. They are reported in two papers, Nos 77 and 78.

Paper No 77 reports on a study in which all tissues in the same reindeer are analyzed in order to calculate the total body burden of the animal. Four animals of different ages have been acquired for this study, but only two have been analyzed so far. In this paper the methods adopted in our laboratory for plutonium analysis are described in some detail, too. The paper contains a number of results on different bones in the same animal. These show that the highest plutonium concentration is found in the teeth, medium concentrations in sternum, vertebrae and humerus, while the lowest concentrations are found in the long bones, particularly the solid parts. The ratio of ^{238}Pu to $^{239,240}Pu$ in skeleton is $6,4\pm0,8 \times 10^{-2}$. The ratio of the total body burden of a 13,5 year male to that of a 4,5 yr female was $9,0\pm0,9$, almost the same as that of their estimated life-time intakes of plutonium in feed. This suggests a very slow rate of elimination. The gastrointestinal absorbtion is estimated to be about 2×10^{-5}, ie. considerably lower than we estimated in the previous year on the basis of a small number of analyses.
In paper No 77 our results on reindeer tissues are compared with those of cattle from nuclear test sites in the USA. When the ratio of plutonium concentrations in lung and liver of cattle was compared with the distribution of $^{239,240}Pu$ in a 13,5 year old male reindeer, it was noticed that inhaled plutonium locates mainly in lungs and bones and the plutonium taken via food locates mainly in liver and skeleton (see paper No 77).

Results on plutonium in organs of reindeer slaughtered between 1963-1975 are presented in paper No 78. The highest $^{239,240}Pu$ concentration so far measured, 55,6 pCi/kg fresh wt, was found in the liver of a 12-15 year old reindeer slaughtered in December 1973. The highest average concentration was found in animals slaughtered in 1967-68. Liver and lung of reindeer and elk were compared, too. Plutonium concentration in the lungs of both animals was about the same but in the liver of reindeer 10-50 times higher concentrations were measured than in the liver of elk (paper No 78). The ratio of plutonium in liver to the total dietary intake in life-time was calculated for 45 reindeer analyzed: it was $2,5\pm1,7 \times 10^{-5}$. This gives the lower limit for the absorbtion of plutonium from the

diet . The value is in reasonable agreement with the corresponding value for absorbtion in man given by the ICRP, 3×10^{-5} to 10^{-6}.

Only a few bone analyses have been made, so far. In bones we hope to analyze the ^{90}Sr, ^{210}Pb and, eventually, ^{210}Po concentrations, too. ^{90}Sr will be a good indicator of the total man-made fallout, ^{210}Pb of the natural fallout to which the animal has been submitted. We do not have yet a suitable low level counter for the beta samples, however.

3. PLUTONIUM IN TISSUES OF SOUTHERN FINNS

Analyses of human samples have been started by analyzing today's post mortem samples from Southern Finland (paper No 79). We consider these results to be useful as comparison with Lapp tissues, which are more difficult to obtain. Since only lung and liver of two subjects have been analyzed so far, the results do not warrant much discussion. It is interesting to note, however, that our lung results are in relatively good agreement with the earlier results from Europe, but the two values of liver samples are considerably lower than those given in the literature. Our lung/liver ratio is 13,6, those in the literature vary from 0,23 to 1. WE do not yet understand the cause of this difference.

4. EXPERIMENT ON RETENTION AND LOSS OF ^{236}Pu SPRAYED UPON LICHEN (CLADONIA SPS.)

An experiment was started in July 1974 to study the residence time and distribution of plutonium-label on lichen. The first results of this experiment were reported last year (paper No 71). More results are reported in paper No 80. It can be estimated from these results that the biological half-time of ^{236}Pu in lichen (Cladonia) is short, 1-1,5 years. This estimation is in agreement with our results for fallout-plutonium in lichen, half-time ca 2 years. Longer half-times (4-6 years) are reported from Sweden for fallout-plutonium (see discussion in paper No 80). The tracer, ^{236}Pu, was sprayed as a freshly neutralized solution of plutonium nitrate. On lichen the tracer may have been oxidized to PuO_2, since it seems to behave very similarly with fallout plutonium in

longer time. The experiment will be contineud.

5. PLUTONIUM IN BALTIC SEDIMENTS

Study on plutonium in aquatic samples from the Baltic was started last year in form of a thesis work (paper No 70; see also No 82). It showed that fish (ruff, flounder and cod) contain 0,04 - 0,14 pCi $^{239,240}Pu$ per kg fresh wt, brown algae 5 pCi, and the top layer of bottom sediment 1,68 mCi/km^2. The fish values are somewhat higher than those in the North Atlantic. The study has been continued by analyzing sediment cores in sections. Two cores were taken from aerobic coastal areas, one from the central Baltic Sea, from a deep basin area the bottom of which is anaerobic. The integrated values of the three cores were: 3,3 and 2,5 mCi per km^2 in the coastal samples, 2,4 mCi per km^2 in the open sea sample. These results are rather similar with those reported by Noshkin from Buzzard's Bay (41°N, 70°W; see paper No 81), 2,3 mCi per km^2. There was considerable difference between our three profiles: in the anaerobic deep sea core a rather sharp maximum was found at the depth 2-6 cms, while the oxygenated coastal sediments had a broader maximum between 0-8 cms, evidently because of bioturbation and other disturbance. The study will be continued in collaboration with the Institute of Marine Research, Helsinki.

SUMMARY

The final measurements of ^{137}Cs in the body and diet of reindeer herding Lapps are reported. They confirm earlier results. The decrease of Lapps' body burdens has slowed down its apparent half-time being now about 5-6 years instead of 3-4 years in the 1960s.

The studies are now cosidered to be complete unless a new fallout situation will arize. The focus of the project will shift now completely to transuranium elements.

Large numbers of analyses of lichen and soft tissues of reindeer have now been completed and they give a comprehensive picture on these types of samples. The bone analyses have been delayed because we hope to analyze also ^{90}Sr as marker of man made fallout and ^{210}Pb as marker of natural

fallout but for this purpose we need one new instrument, a low background beta counter.

Collection of human tissue samples of southern Finns (accidentally died healthy adults) and of Lapps has now been organized and systematic studies have been started. It will take two to three years more to have a full picture on the distribution of plutonium in the body of southern Finns, Lapps and reindeer. The study will be widened to cover also ^{241}Am. We believe that this project will give valuable information on the absorbtion and distribution of these transuranium elements in fully natural conditions after chronic uptake in natural diets.

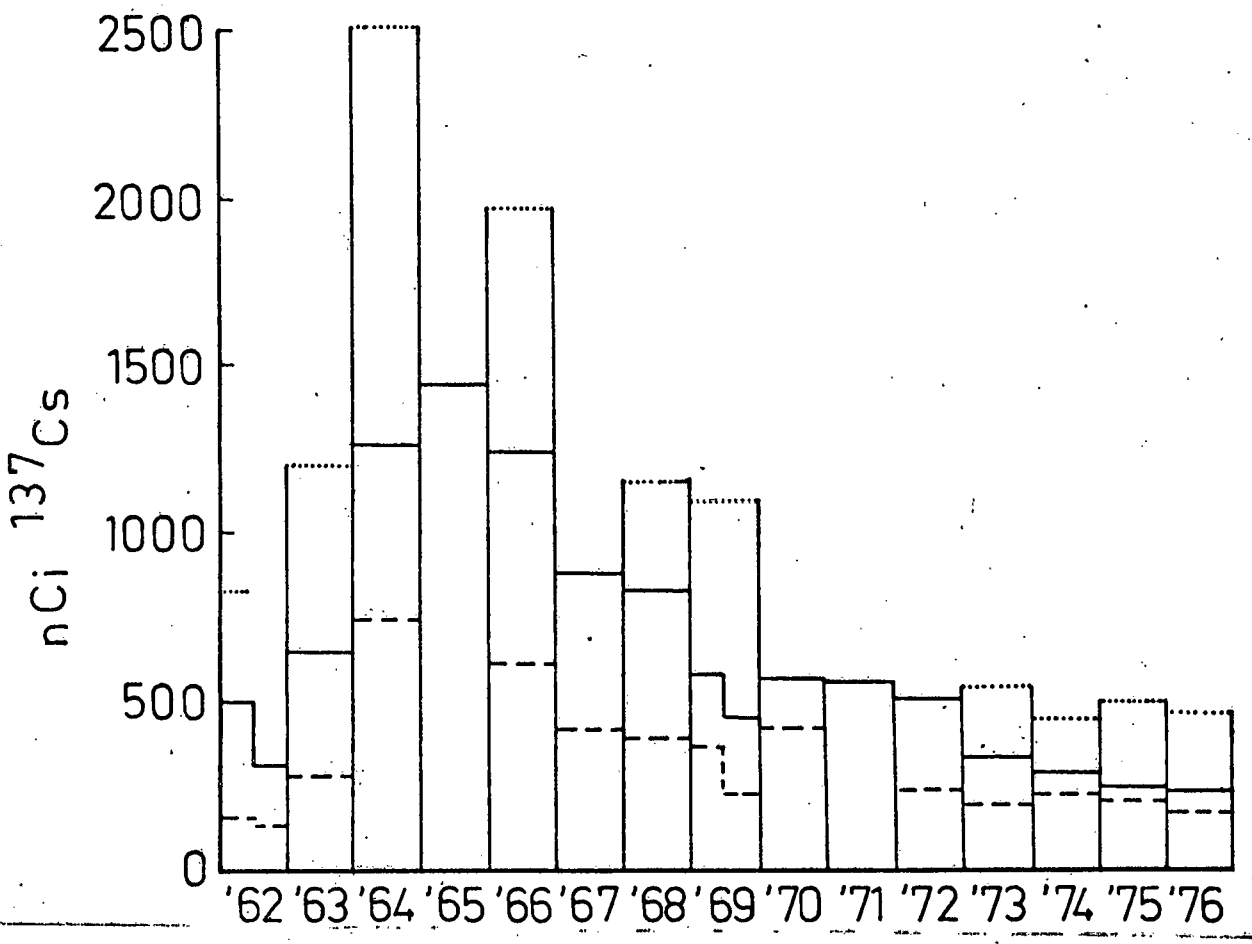

Fig. 1. ^{137}Cs body burden (nCi) in male reindeer-herders, 1962-76. Mean values _____ ; maximal value ····· ; value of a man with a low body burden-----. In 1962 and 1969 both spring and autumn values are marked.

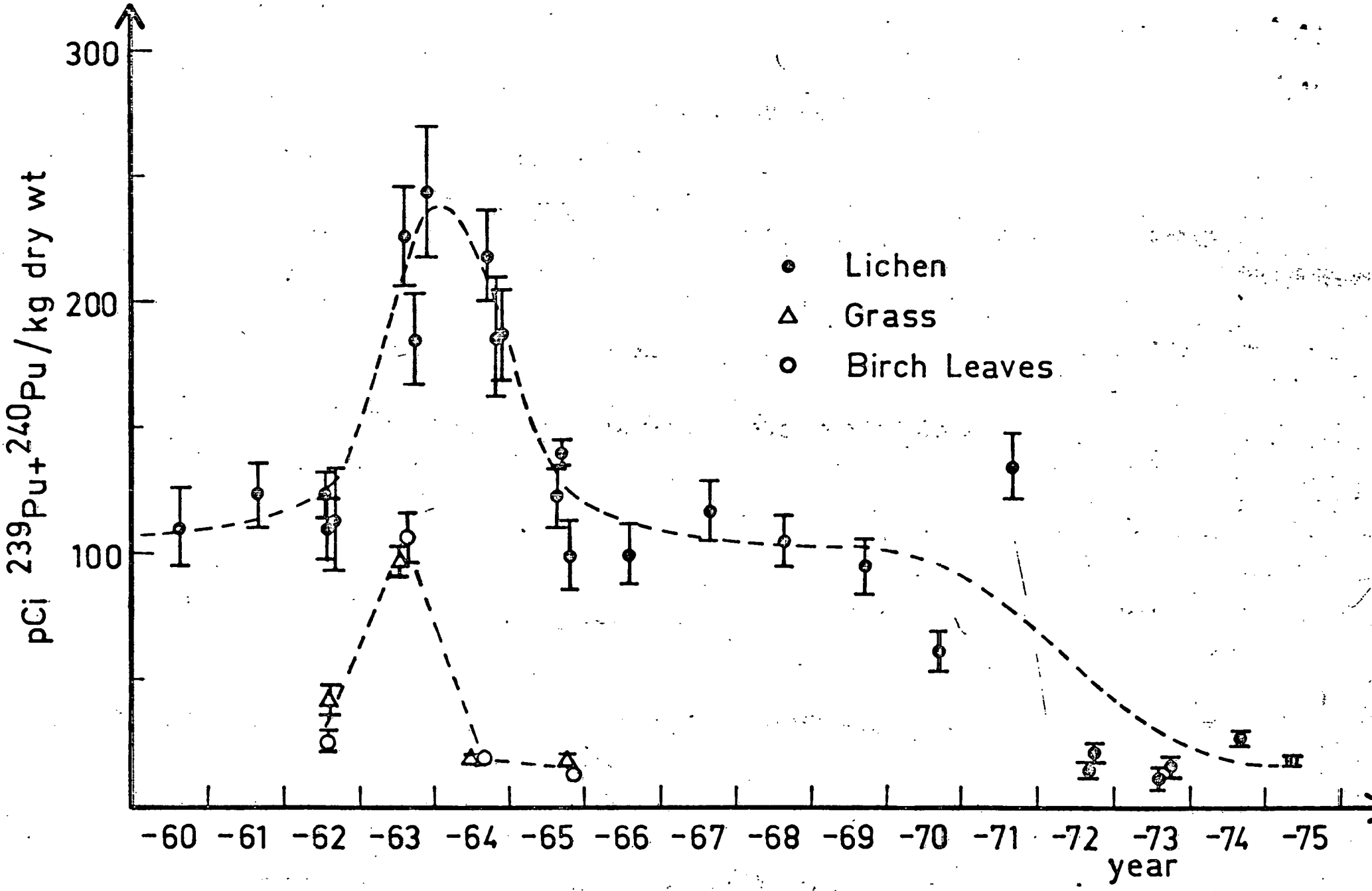

Figure 2. $^{239 + 240}Pu$ concentrations in lichen, grass and birch leaves in Finland during 1960-1975. Standard deviation of the radioassay ($\pm 2\sigma$) is indicated.

PUBLICATIONS OF THE US AEC PROJECT AT (30-1 -3446 AND FROM JAN. 18 1975 THE US ERDA PROJECT CH E (11-1)-3011

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