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Reconstructing nuclear events from annually laminated lake sediments in Northern Finland

Ari-Pekka Leppänen, Eeva Haltia, Antti Kallio, Timo Saarinen

P2.5-712

POSTER

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RADIATION AND NUCLEAR SAFETY AUTHORITY

UNIVERSITY OF TURKU

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ABSTRACT

The annually laminated sediments deposited in Lake Kevojärvi (69°45N, 27°00'E) in the municipality of Utsjoki in Northern Finland were investigated for radioactivity. A freeze core recovered from the 35-m deep basin preserve a distinct succession of annual laminations deposited between 1909 and 2010. A total of 53 annual laminations were taken for gamma spectroscopic measurements using low-background gamma spectroscopy. This allowed a reconstruction of ^{137}Cs, ^{241}Am and ^{210}Pb fallout history in the Lake Kevojärvi region and revealing a detailed record of anthropogenic radioactive fallout from atmospheric nuclear testing conducted in the 1950s and 1960s and the Chernobyl accident in 1986.

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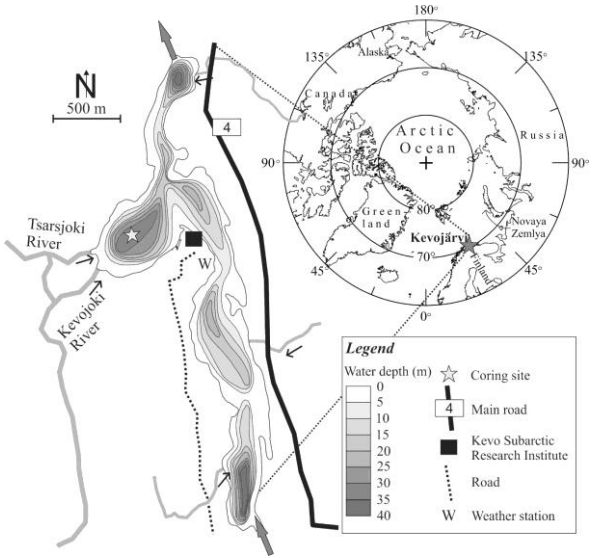
INTRODUCTION

The Study site:

Sediment cores were recovered from the western basin of the Lake Kevojärvi (69°45N, 27°00'E). The 35m deep basin forms annually laminated sediments.

The lake is situated about ~1000 km from the Soviet Union nuclear weapons test site at Novaya Zemlya where nuclear weapons were tested from 1955 to 1990. During 1955 to 1963 tests were conducted in atmosphere including the most powerful nuclear weapon ever tested; the Tsar Bomba. The Tsar Bomba was exploded in Oct. 30th, 1961 and had a yield of 50-57 Mt.



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METHODS

In April 2011, sediment cores were recovered from the lake bottom using freeze core technique where the sediment is frozen using CO_2 ice (”dry ice”) producing sediment ”fingers”..

In the core annual laminations (varves) were clearly visible. The light brown layer correspond to basal layer after the spring flood of the lake and river system connected to the lake. The dark layer is organic layer accumulated during the following summer. This structure is analogous to tree rings and the time can be counted backwards from the layers.

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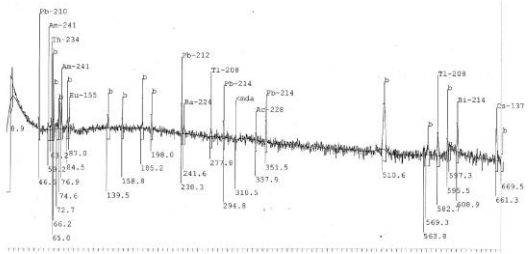
METHODS



Total of 53 dark organic layers from the core covering time period from 1909 to 2010 were taken for gamma spectrometry measurement. (Unfortunately, only non-destructive analyses were possible and thus no radiochemical uranium or americum analyses were performed).

- The sample size varied from 0.5 g to 3 g
- High-end HPGe detector with carbon fiber window was used. Low background lead shielding with 6-inches of lead.
- measurement times varied from 3 to 7 days/sample
- Identified isotopes were ^{210}Pb, ^{241}Am, ^{137}Cs, ^{40}K, ^{214}Pb and ^{214}Bi
- Anthropogenic ^{241}Am is the decay product of ^{241}Pu -> the source for ^{241}Pu is the atmospheric nuclear weapons tests
- Anthropogenic ^{137}Cs also originates from nuclear weapons tests but also from Chernobyl and Fukushima accidents
- Naturally occuring ^{210}Pb, and naturally occuring ^{214}Pb and ^{214}Bi are decay products of ^{226}Ra. This was needed to verify the varve counting and hence the age of a varve

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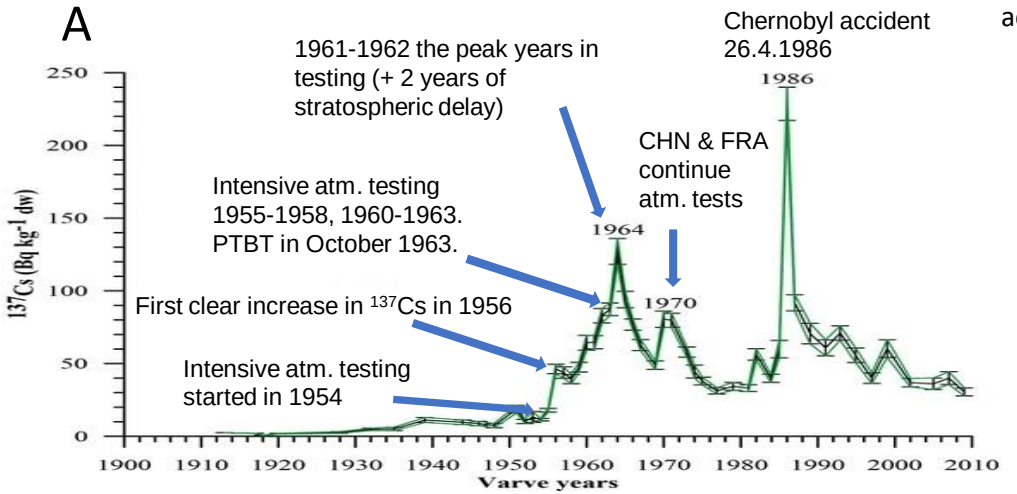
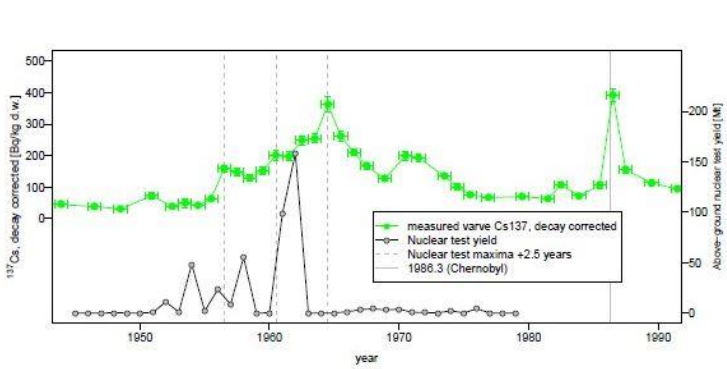
RESULTS

The figure A shows the observed ^{137}Cs concentrations in sediment varves when the ^{137}Cs decay correction is done to the sampling date (April, 2011). Events and some explanations are provided and indicated with arrows.



The figure B shows the observed ^{137}Cs concentrations in sediment varves when the ^{137}Cs decay correction is done to the varve year. This figure illustrates the level of fallout better. Also 2-year time delay is observed between the tests and deposition into sediments

The peak in 1964 is comparable to the peak in 1986. The cumulative fallout from atmospheric nuclear weapons tests caused a bigger impact in Northern Finland than the Chernobyl accident.



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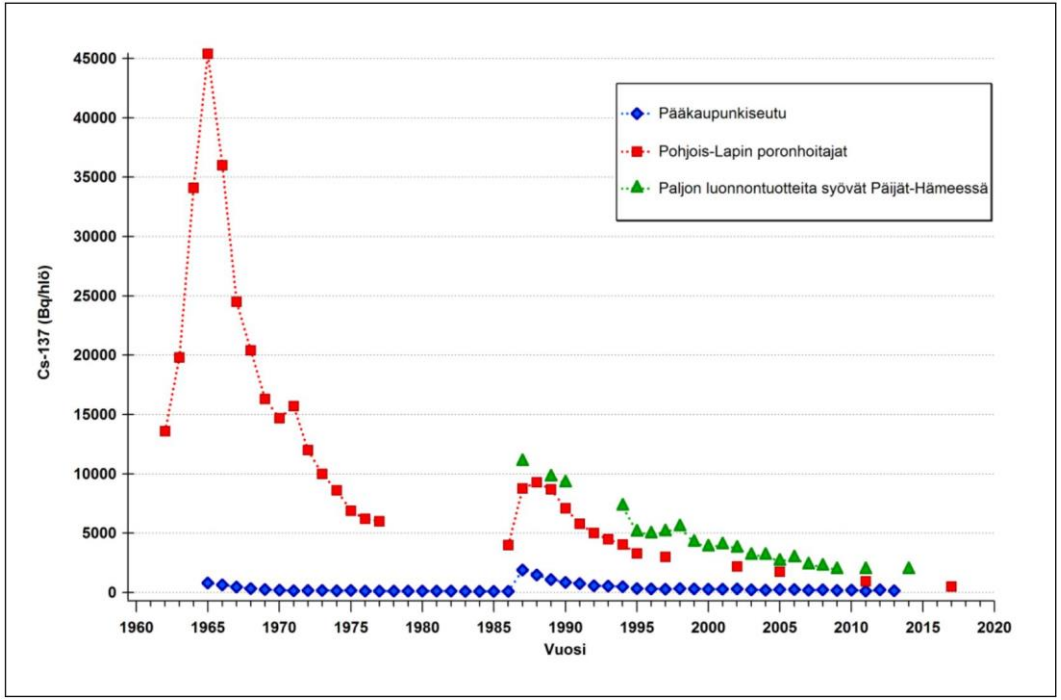
RESULTS

Comparing the level of fallout (fig. B from previous slide) to the whole body ^{137}Cs content



Whole body ^{137}Cs content in selected populaiton groups. The red line shows the reindeer herders in Utsjoki/Inari region (Kevojärvi).

Blue diamond = Helsinki region
Red squares = reindeer herders in Northern Finland
Green triangle = Central Finland

Figure adopted from

Muikku & Torvela, 2017.Väestön cesiummäärät ja sisäisen säteilyn aiheuttamat annokset – Pohjois-Lapin poronhoitajat, STUK report, ISBN 978-952-309-399-7.

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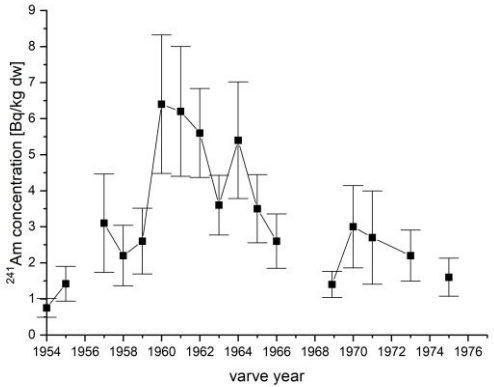
RESULTS

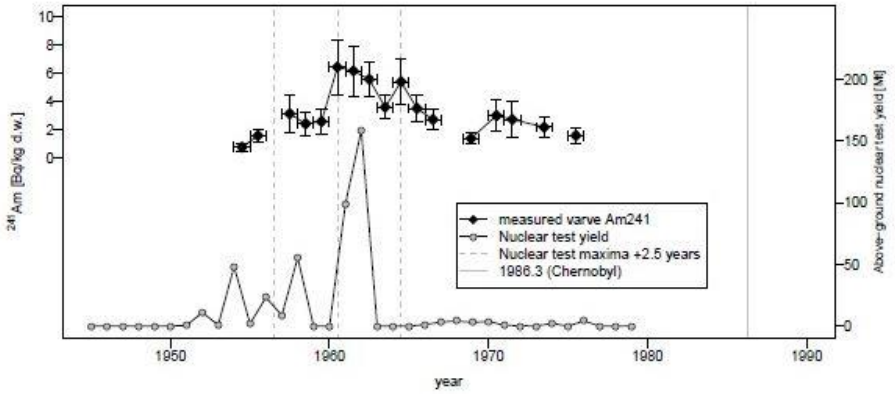
The figure A the measured ^{241}Am concentrations in each sediment varve . ^{241}Am was observed from 1954 to 1975 but not in 1986 varve. The concentrations varied between 0.6 to 6.4 Bq/kg dw. The peak concentrations were observed in 1960-1961, not in 1964 when ^{137}Cs concentrations peaked. 1960-61 peak may indicate tropospheric transport from lower yield tests.

The figure B shows the measured ^{241}Am concentrations (diamond, black line) together with atmospheric nuclear weapon test yields (circles, gray line). The dashed vertical lines represent high yield year added with 2 year time delay from atmospheric settling. Now the observed increases in match with years of high test yields.

A



B



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CONCLUSIONS

- The ^{137}Cs profile showed that radioactive contamination was introduced to Kevojärvi region in 1956 (or perhaps 1-2 years earlier).
- ^{137}Cs clearly peaked in 1964, 1970 and 1986 corresponding to intensive testing in 1961-1962, Chinese and French tests in the late 1960's and the Chernobyl nuclear power plant accident.
- The decay product of ^{241}Pu, ^{241}Am was also detected during 1957 – 1975.
- ^{241}Am peaked in 1960-1961, 1964 and 1970.
- ~2 year time delay was observed between the years of high yield tests and the peak in the sediment layer due to radionuclide input from stratosphere
- In Northern Finland the cumulative fallout from atmospheric nuclear weapons tests was larger than the one from the Chernobyl accident.

Kiitoksia, että jaksoitte katsoa loppuun asti !

Thank you for your attention !

This work has been published as
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https://www.sciencedirect.com/science/article/pii/S0265931X21000837