

IMPACT OF ENVIRONMENTAL CHANGE ON THE RADIOECOLOGY OF SPRUCE TREES IN UPPER AUSTRIA



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Abstract. In a two years project spruce needle samples of the Austrian Bioindicator Grid were analysed by gamma spectrometry to detect the geographical and temporal distribution of radionuclides in spruce needles of the last 25 years with the main focus on the radioactive contamination before and after the Chernobyl fallout in 1986. This radioecological evaluation is an important part of an existing environmental surveillance programme in Upper Austria in order to gain basic information on the impact of environmental changes on the radioecological behaviour of spruce trees. Moreover, the results of the current studies can be an important input for the discussion of using whole trees for biomass energy. Every year spruce needle samples of the two youngest needle sprouts are taken from two spruce trees at each location of the Bioindicator Grid. For this study samples of selected locations — evenly spaced out among the area of Upper Austria — were analysed for different natural and anthropogenic radionuclides: ¹³⁷Cs, ⁴⁰K, ²¹⁰Pb, ²²⁶Ra, ²²⁸Ra, ²³⁸U. Additionally, soil samples were taken at selected sites to study the relationship between ¹³⁷Cs- and ⁴⁰K-activity concentrations in soils and spruce needles and to estimate transfer factors. Another important question of the study is the correlation between anthropogenic pollutants and radionuclides. To date more than 500 spruce needle samples were analysed. ¹³⁷Cs- activity concentrations reach D.L. (2 Bq/kg)–5150 Bq/kg, whereas the maximum was measured after the Chernobyl fallout in 1986. In time series of ¹³⁷Cs-activity concentrations Caesium cycling was observed. The activity concentrations of ⁴⁰K reached D.L. (15 Bq/kg)–294 Bq/kg and ²¹⁰Pb reach D.L. (5 Bq/kg)–45 Bq/kg. The measured ²²⁶Ra, ²²⁸Ra and ²³⁸U concentrations were mostly below detection limits. Most samples of younger sprouts revealed higher ¹³⁷Cs-activity concentrations than older sprouts. ⁴⁰K-activity concentrations showed nearly the same level in different aged samples, whereas ²¹⁰Pb-activity concentrations were much higher in older sprouts. Furthermore, spruce needle samples with high ¹³⁷Cs-activity concentrations showed low ⁴⁰K-activity concentrations and vice versa in samples with high ⁴⁰K-activity concentrations low ¹³⁷Cs-activity concentrations were measured.

Introduction

For 25 years spruce needles have successfully been used as bioindicators for identifying the spatial and temporal distribution of atmospheric pollutants in Austria [1]. Spruce needles analyses are of special interest because of their bioindicator function as well as the possibility to study the longterm behaviour of radionuclides and radionuclide cycling in forest ecosystems [2, 3]. Due to the Chernobyl fallout in 1986 the Austrian environment became highly contaminated by ¹³⁷Cs. This has led to intensive radioecological research activities [4-8].

Materials and methods

- more than 500 spruce needle and soil samples at selected sites from the Austrian Bioindicator Grid (Fig.1) were taken and analysed by gamma spectrometry

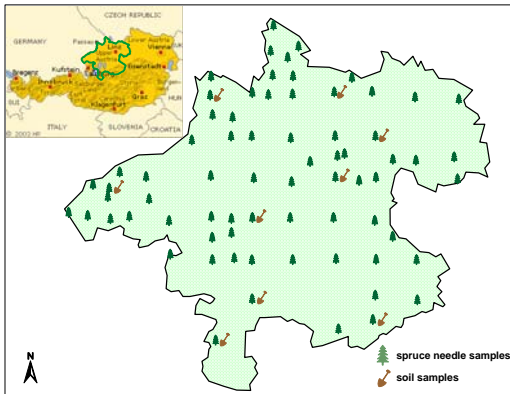


Fig. 1: tested measuring points of the Austrian Bioindicator Grid in Upper Austria

- natural and artificial radionuclides were analysed in spruce needle and soil samples by gamma spectrometry: ¹³⁷Cs, ⁴⁰K, ²¹⁰Pb, ²²⁶Ra, ²²⁸Ra, ²³⁸U
- ¹³⁷Cs and ⁴⁰K in the samples are detected by a HP-Germanium detector with coaxial crystal; energy spectra of these detector range from ~200 to 3000 keV
- for ²¹⁰Pb, ²³⁸U a HPGe detector was used; energy spectra range from 10 keV to 700 keV
- energy spectra of radiometric measurements were analysed on the basis of relevant gamma peaks (Tab.1) by Genie 2000® software from Canberra

Tab. 1: gamma peaks of radionuclides relevant peaks

radionuclides	relevant peaks
Cs-137	661.6 keV
K-40	1460.8 keV
Pb-210	46.5 keV
Ra-226	351.9 keV (Pb-214); 609.3 keV & 1120.3 keV (Bi-214)
Ra-228	338.4 keV (Ac-228); 911.1 keV (Ac-228)
U-238	63.3 keV (Th-234)

- additionally meteorological data from the hydrological office of the Upper Austrian Government were evaluated as well as data from an existing environmental surveillance programme in Upper Austria

Results

- no significant correlation in the geographical distribution of ¹³⁷Cs-activity concentrations in spruce needle samples and the soil contamination were found in the year of Chernobyl fallout
- ¹³⁷Cs-activity concentrations in spruce needles reach D.L.(2 Bq/kg) – 5150 Bq/kg, whereas the maximum was measured after the Chernobyl fallout in 1986
- younger needles (age group I) showed generally higher ¹³⁷Cs-activity concentrations because of the high nutritional requirements during the growth of the sprouts (Fig.2); with exception of the year 1986

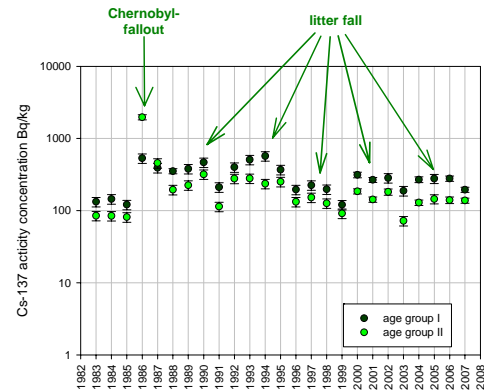


Fig. 2: ¹³⁷Cs-activity concentration of spruce needle samples at one of the selected sites incl. ¹³⁷Cs-cycle

- ¹³⁷Cs-cycling – caused by litter fall and root uptake – was observed at all measuring points; the duration off ¹³⁷Cs-cycles is between 4 and 5 years and varies from site to site
- soil is the main ¹³⁷Cs-source of longterm contamination
- ⁴⁰K-activity concentrations in the spruce needle samples reach D.L.(15 Bq/kg) – 294 Bq/kg; marginal variations of the ⁴⁰K-activity concentrations over the past 25 years; the trend for continuously higher activity concentrations in the younger sprouts was not found for ⁴⁰K.
- samples with high ¹³⁷Cs-activity concentrations showed low ⁴⁰K-activity concentrations and vice versa in samples with high ⁴⁰K-activity concentrations low ¹³⁷Cs-values were measured.
- ²¹⁰Pb-activity concentrations reach D.L.(5 Bq/kg) – 45 Bq/kg. To estimate the atmospheric input of ²¹⁰Pb the value ²¹⁰Pb excess (ex) was determined. Due to the longer atmospheric exposition, older spruce needle samples were mostly higher contaminated than younger sprouts
- To investigate the impact of precipitation events and the deposition of ²¹⁰Pb ex meteorological data were evaluated (Fig.3). No significant correlation between ²¹⁰Pb ex-activity concentrations in spruce needle samples and the number of precipitation events or the total annual precipitation was observed.

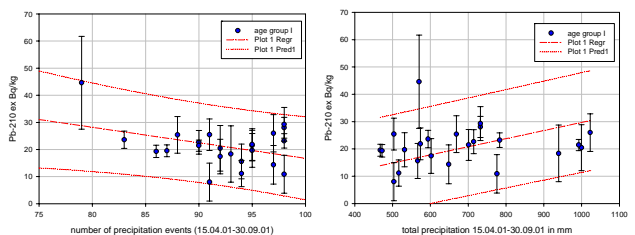


Fig. 3: Correlation between ²¹⁰Pb ex-activity concentrations and precipitation data

Outlook

- soil samples analyses to estimate transfer factors
- correlation between the ¹³⁷Cs- and ⁴⁰K-activity concentrations in the spruce needle samples
- correlations between anthropogenic pollutants and radionuclides in spruce needle samples
- supplementary meteorological data of the past 25 years will be evaluated to get basic information about the impact of environmental changes on the radioecological behaviour of spruce trees
- investigation of influencing factors for caesium-cycling
- based on the measured ¹³⁷Cs-activity concentrations in spruce needles, activity concentrations in ash products will be estimated

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