Experience after 10 years of monitoring ^{14}C in the vicinity of the Nuclear Power Plant Krško, Slovenia

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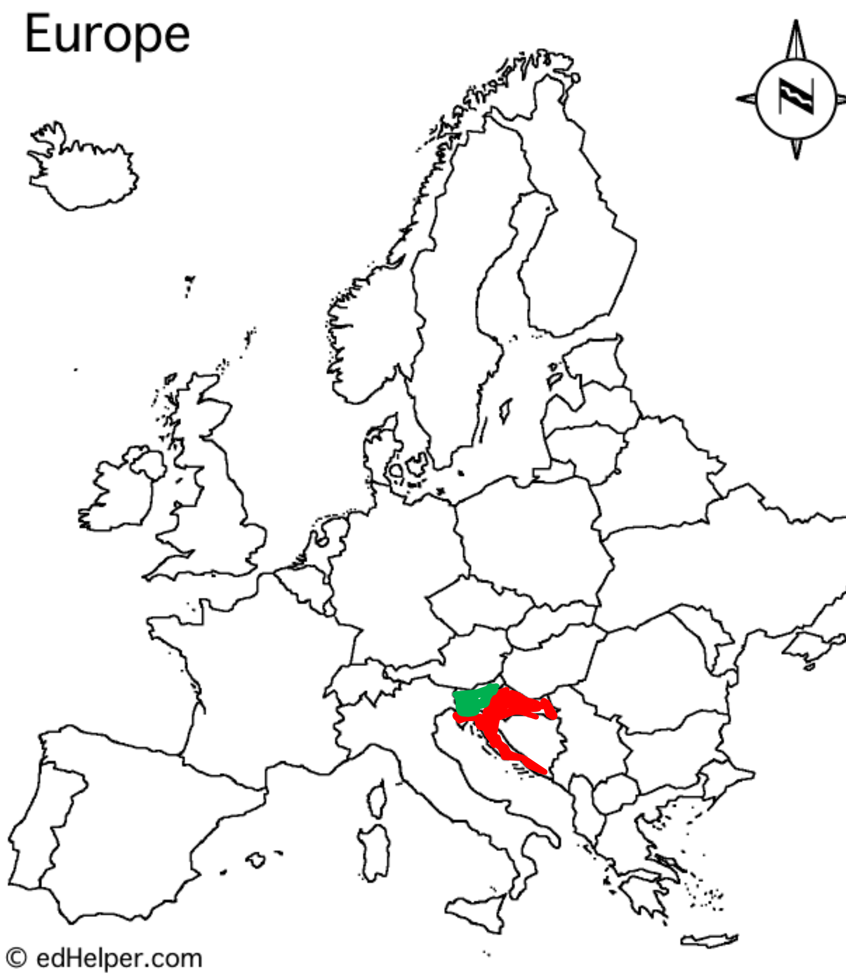
INTRODUCTION

- Systematic monitoring ^{14}C activity in atmospheric CO_2 and in biological samples (fruits – mostly apples; vegetables, cereals, corn) in the vicinity of the Nuclear Power Plant Krško (NEK) has been performed since 2006
- Aim: estimation of the influence of NEK on the environmental ^{14}C level and on the effective dose of the local population due to ingestion (through food chain)
- Special attention paid to the estimation of the influence of the refuelling (performed in 18-month periods) on environmental ^{14}C level.
- Here: show some characteristics of the ^{14}C in the environment of NEK and some conclusions based on a 10-year monitoring

We are here….



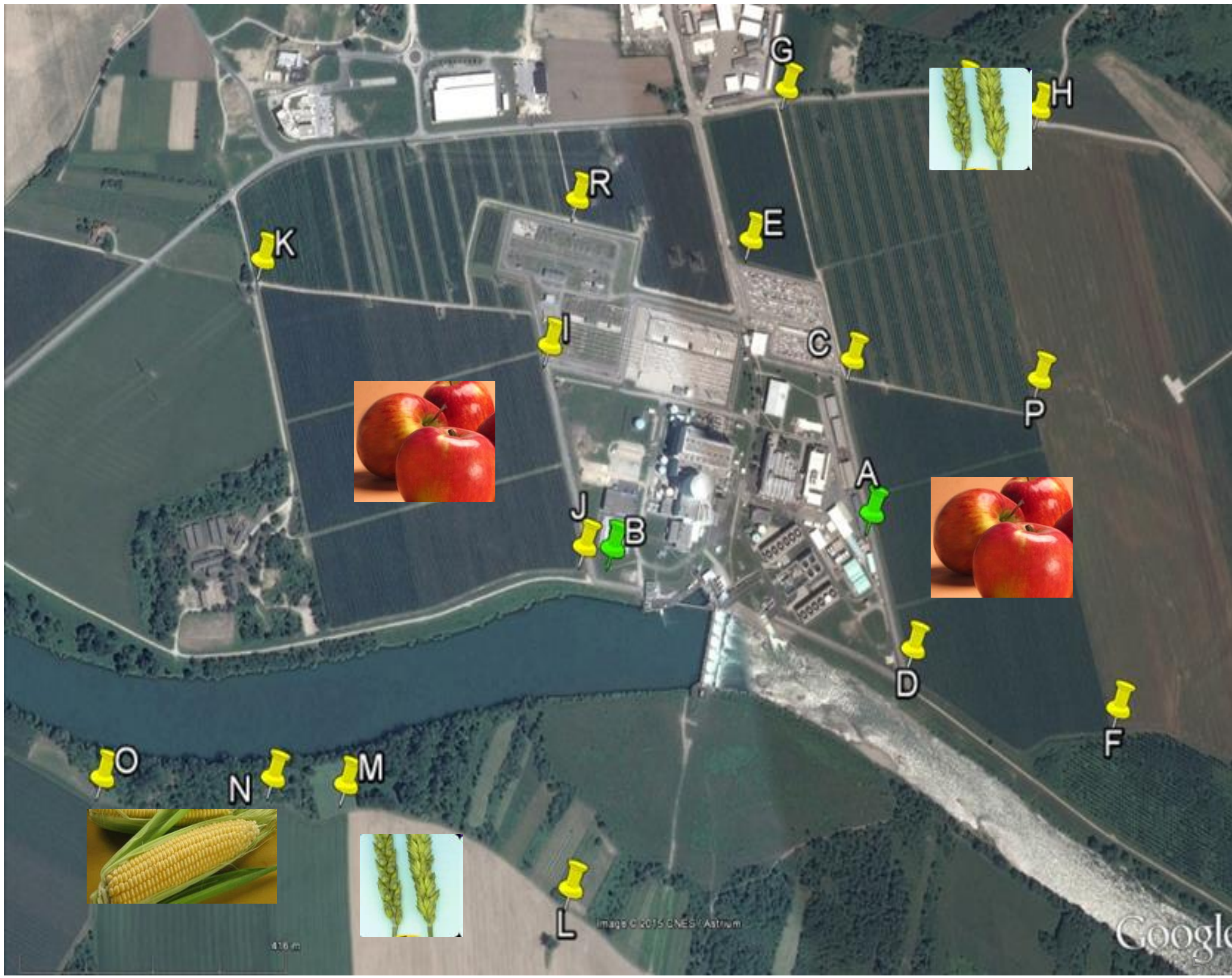
Sampling sites Krško and Dobova.

SAMPLING

- Atmospheric CO_2 sampled on locations A and B within the NEK, in 2-month periods, more often during refuelling
- Biological material integrates ^{14}C from the atmosphere during (relatively short) vegetation period; collected twice per year, usually in June or early July and in autumn, in September or early October, at the end of the vegetation period, just before harvesting, locations C – Q, in two circles around the NEK
- Biological samples also collected at the control site Dobova, 11.2 km SE from NEK, where no effect of air effluents is observed.

Sampling locations

A, B – atmospheric CO_2, C – O - plants



MEASUREMENT METHODS

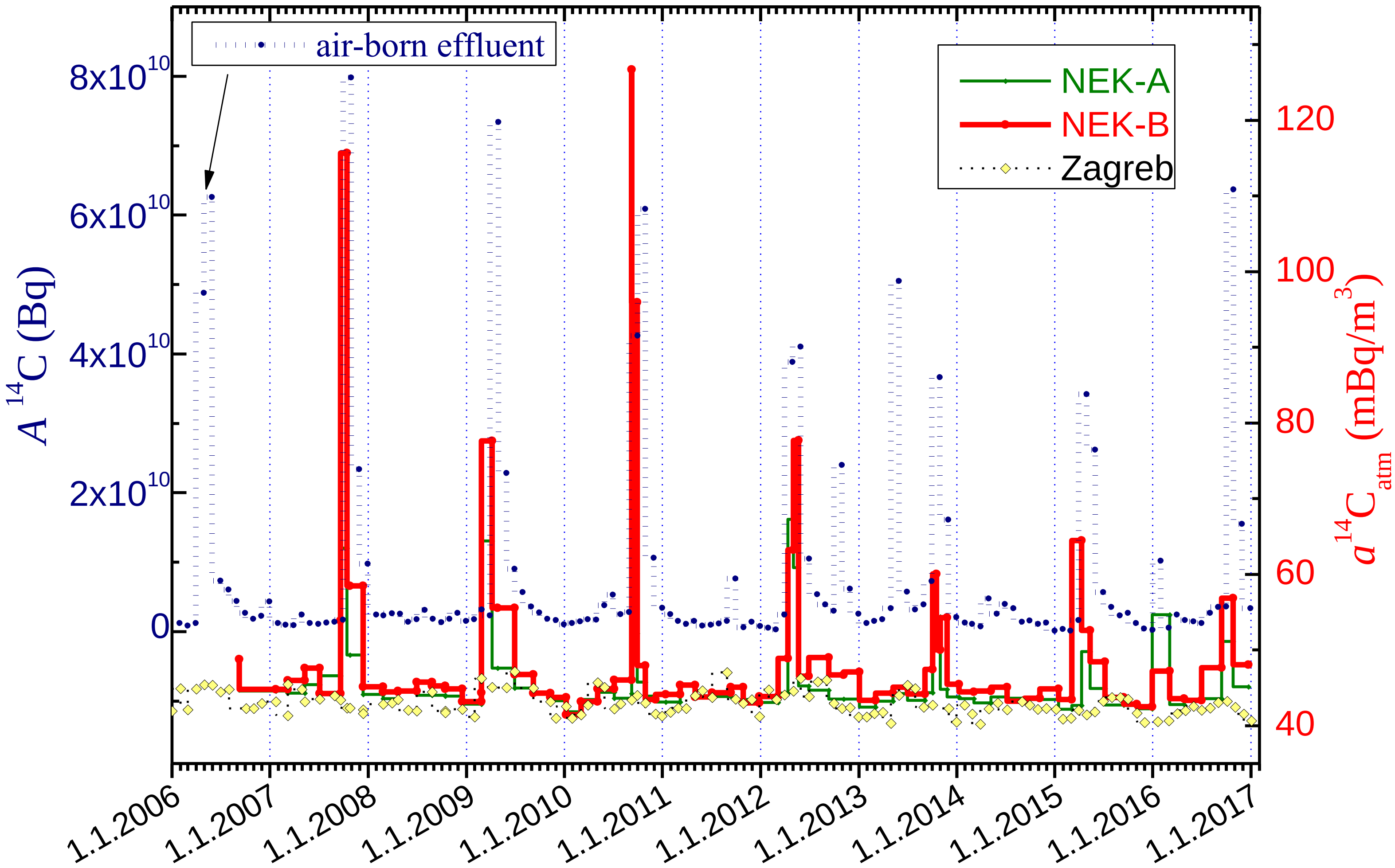
- Atmospheric CO_2 absorbed as Na_2CO_3 → conversion to benzene
- Biological samples → dried → carbonized → combusted to CO_2 → absorption in Carbosorb®E + Permafluor®E cocktails.
- Measurement of ^{14}C activity by liquid scintillation counter (LSC) Quantulus 1220

Methods described in:

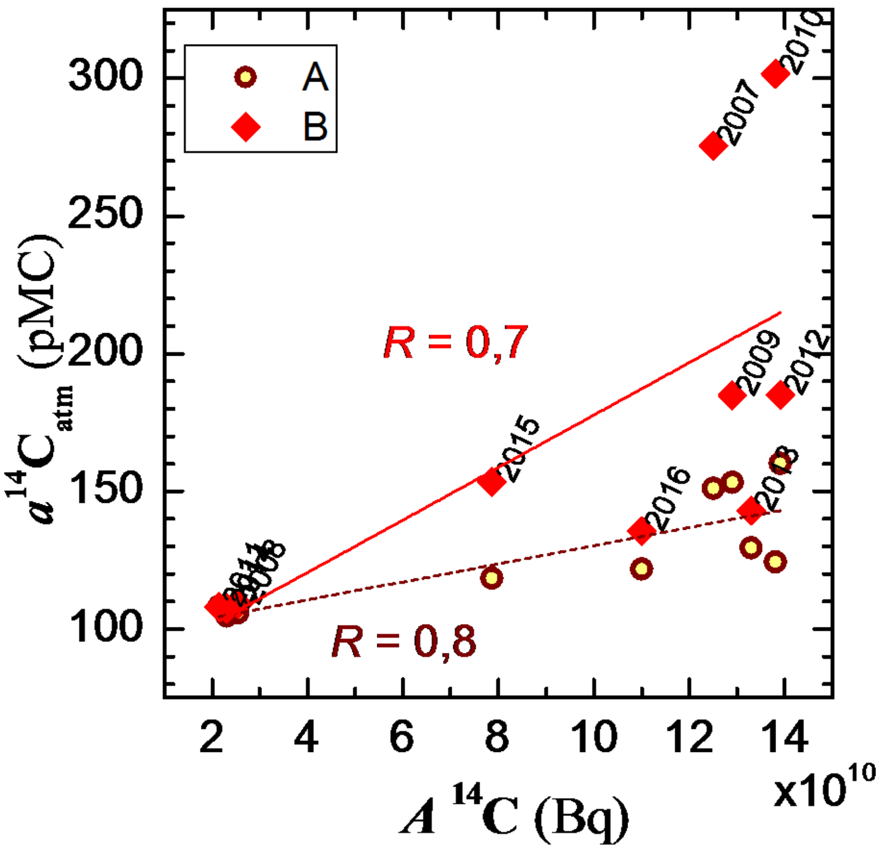
- Horvatinčić, Nada; Barešić, Jadranka; Krajcar Bronić, Ines; Obelić, Bogomil. Measurement of Low ^{14}C Activities in Liquid Scintillation Counter in the Zagreb Radiocarbon Laboratory. *Radiocarbon* **46** (2004) 105-116.
- Krajcar Bronić, Ines; Horvatinčić, Nada; Barešić, Jadranka; Obelić, Bogomil. Measurement of ^{14}C activity by liquid scintillation counting. *Applied radiation and isotopes* **67** (2009) 800-804.

RESULTS

atmospheric CO_2



* Measured at the Jožef Stefan Institute, Ljubljana, Slovenia



Deviations from the correlation line at higher annual activities A^{14}C may be explained by mismatch of periods of collection of the atmospheric CO_2 and periods of the highest effluent activities

Highest monthly ^{14}C activity in the atmospheric CO_2, $a^{14}C_{atm}$, at locations A and B within NEK-a vs. total annual ^{14}C activity in air-born effluents (A^{14}C).

The higher the ^{14}C activity of gaseous effluent, the higher the atmospheric ^{14}C activity

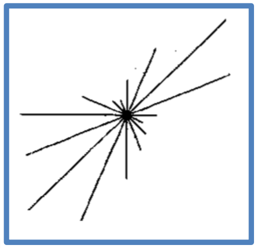
The highest measured $a^{14}C_{atm}$ of atm. CO_2 in the refuelling period gives a rough estimation of the ^{14}C activity released in gaseous effluents

RESULTS

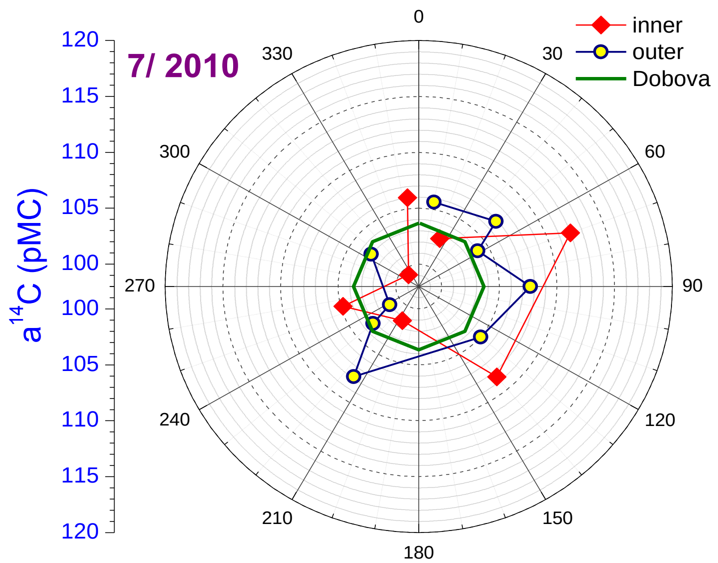
Biological material

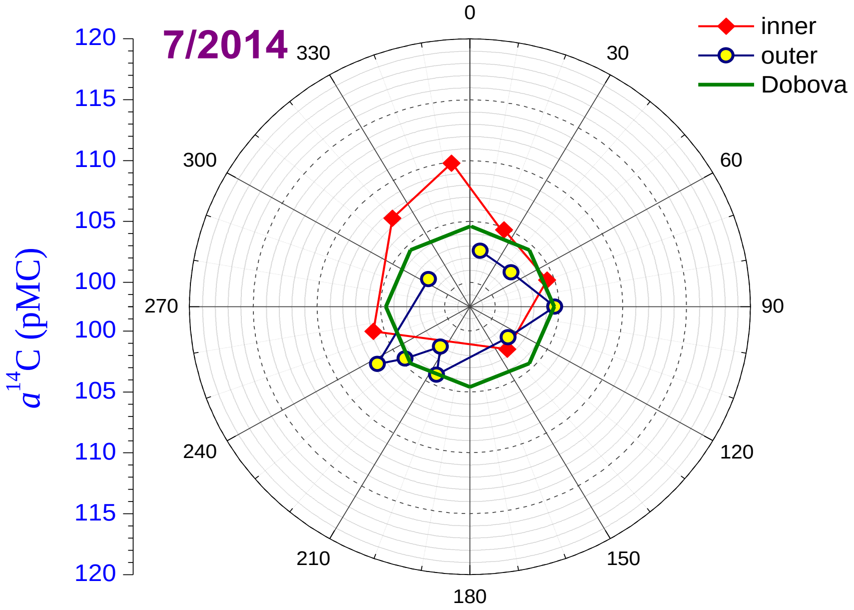
Distribution of ^{14}C activities in plants can best be observed by so-called polar diagrams.

Spatial distribution of $a^{14}C$ is determined by the prevailing winds (SW-NE).



Summer sampling if there was no spring refuelling in the same year



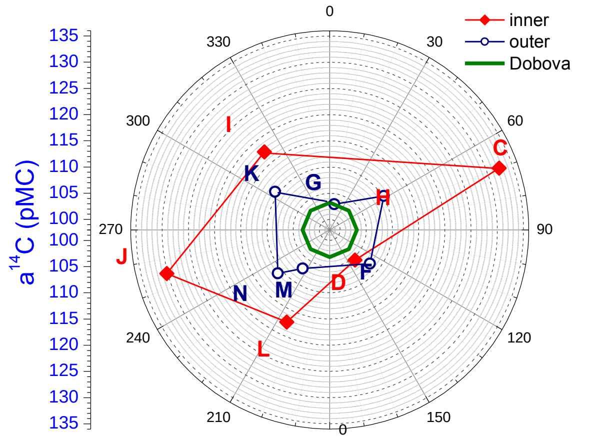


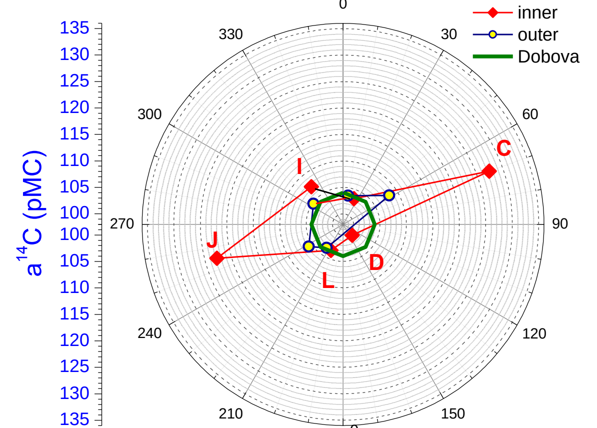
7/2010
Refuelling 4/2009 and 10/2010

7/2014
Refuelling 10/2013

Sampling after spring (April) refuelling

2006





2009

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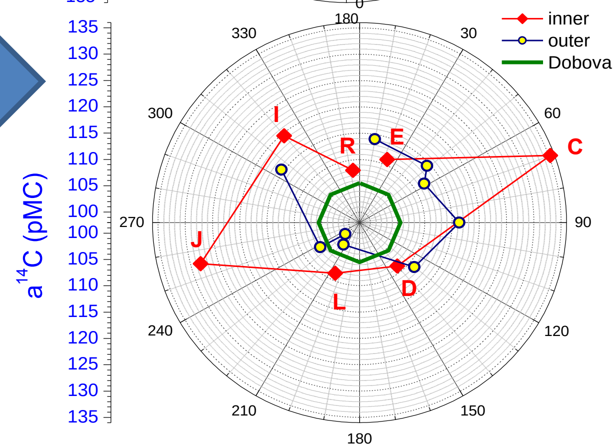

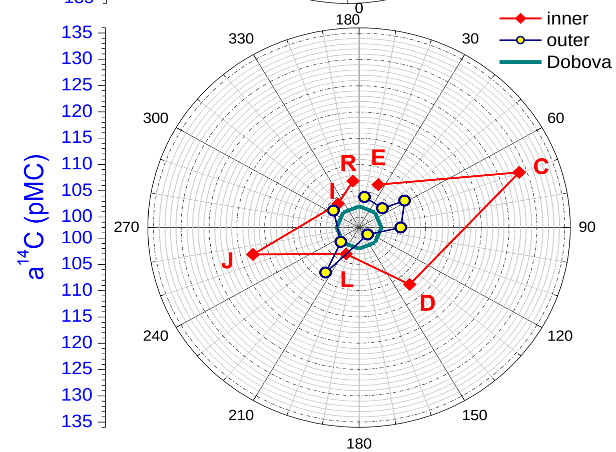

2012

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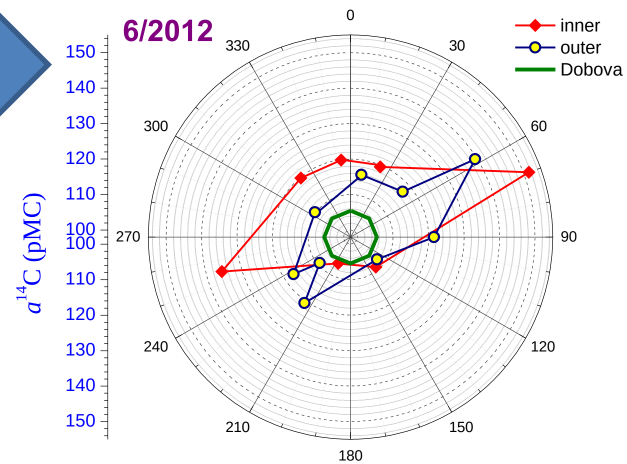
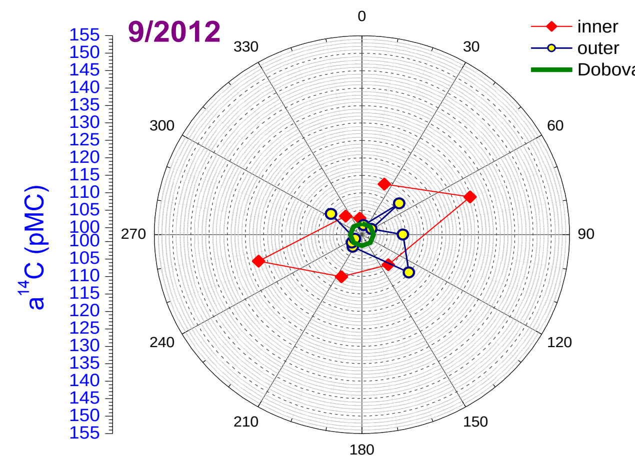
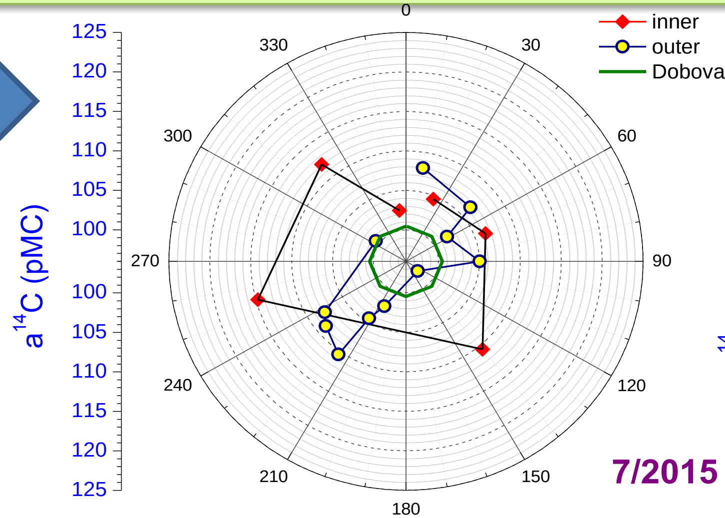


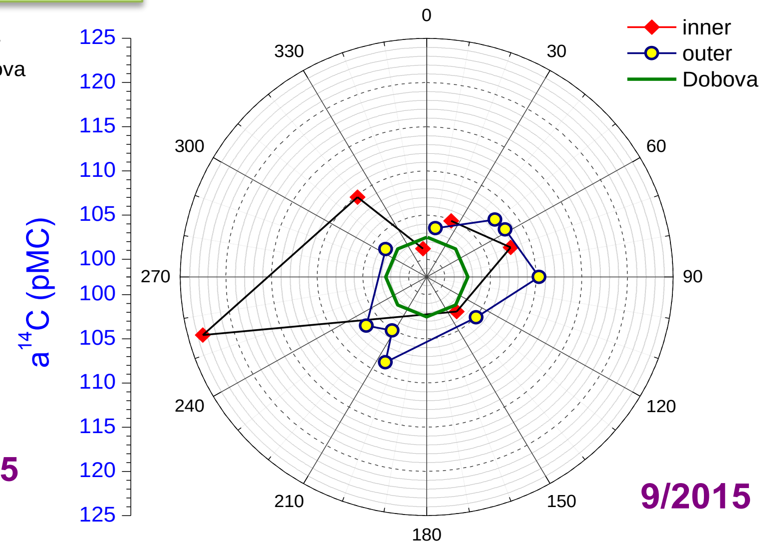


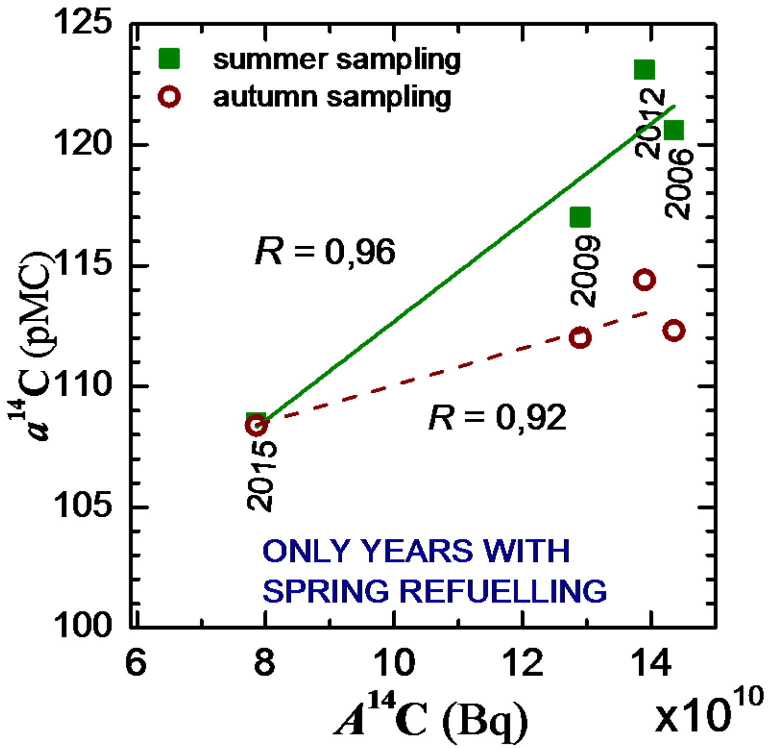
Spring refuelling - 2015

115

2015

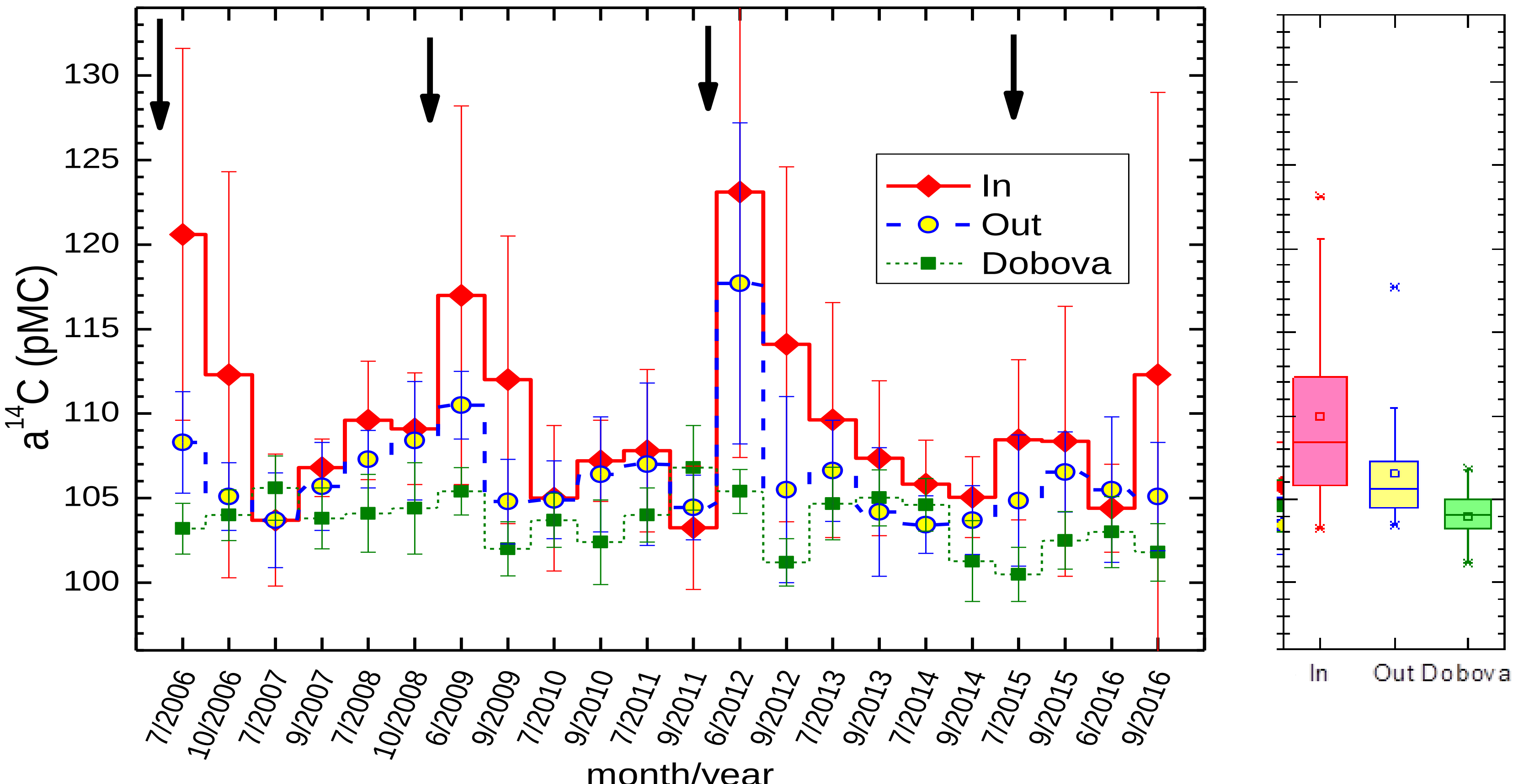






- higher $a^{14}C$ in samples taken in summer than in the autumn samples, because during spring plants use CO_2 from the atmosphere immediately after the refuelling
- good correlation between the released $A^{14}C$ and the mean $a^{14}C$ of the inner locations

↓ Spring refuelling – before the vegetation period – significantly affects distribution of ^{14}C activitis in plants in summer sampling, somewhat less in autumn sampling.
Autumn refuelling – after the vegetation period – does not influence plant ^{14}C activity in the next year.
In years without a refuelling – $a^{14}C$ in the outer circle of NEK similar to the $a^{14}C$ at the control location Dobova, in the inner circle higher $a^{14}C$ values



Comparison of the average plants $a^{14}C$ values in the inner circle (C, D, E, I, J, R), in the outer circle (F, G, H, K, L, M, N, O, P, Q) around NEK, at the control location Dobova, and the atmospheric $a^{14}C$ in Zagreb

	Average $a^{14}C$ (pMC) 2006 – 2016
Inner circle	**109.7 ± 4.1**
Outer circle	**106.4 ± 1.9**
Control location - Dobova	**103.6 ± 1.0**
Zagreb (atm. CO_2)	**102.3 ± 1.2**

to asses the effective dose (by consumption/ingestion):

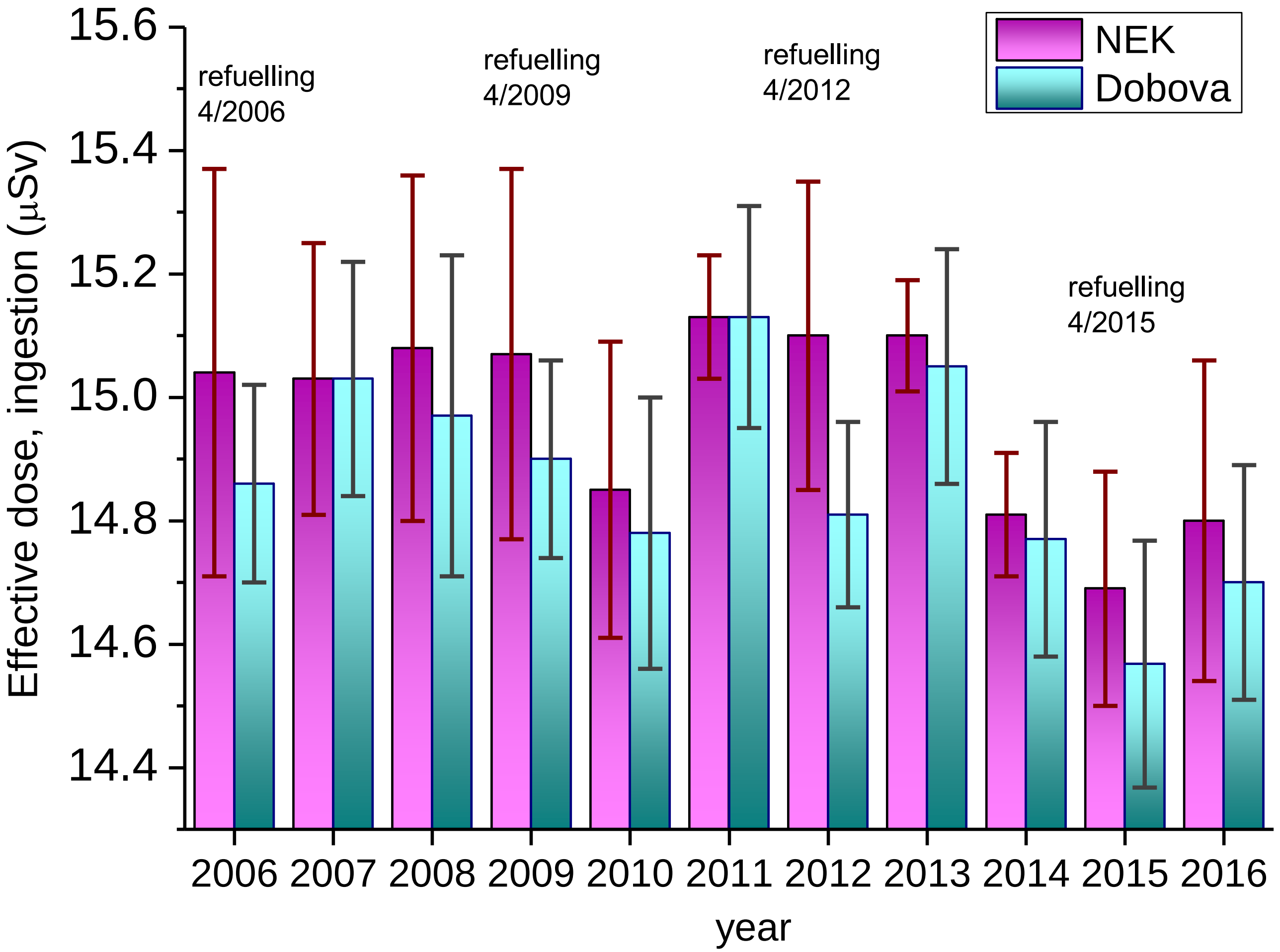
- activity conc. in foodstaffs, **$a^{14}C$ [Bq/kgC]**
- relevant consumption rates – daily uptake of C by food: 0.3 kg (ICRP, 1996)
- ICRP ingestion dose coefficients are needed
  e = 5.8×10^{-10} Sv/Bq

$$E = e \times a^{14}C \times m \times t$$

however, obtaining the consumption data for particular areas may not be simple;

luckily – the specific ^{14}C activity in all types of (terrestrial) foodstaff is the same

Consumption model: 2 months NEK + 10 months Dobova



Comparison of annual effective doses due to ingestion of ^{14}C for population in the close environment of NEK and at the control point Dobova. No significant difference is observed.

CONCLUSIONS

- Increase of ^{14}C activity in atmospheric CO_2 and in plants was observed during and immediately after the refuelling of the nuclear power plant
- The influence is short-term and spatially limited
- Spatial distribution depends on the local wind rose and the distance from the exhaust of the plant ventilation system
- Higher activities in plants collected after the spring refuelling outage - intake of ^{14}C from gaseous effluents during the vegetation period
- Correlation between the total released $A^{14}C$ in air-born effluents and measured $a^{14}C$ in both atm CO_2 and in plants has been observed

CONCLUSIONS

- The maximum increase of total annual dose to local population due to the release of ^{14}C from NEK (even in the years of spring refuelling) was estimated to be negligible and within the errors of the estimate