

^{14}C activity in atmospheric CO_2 and biological samples around the Nuclear Power Plant Krško, Slovenia

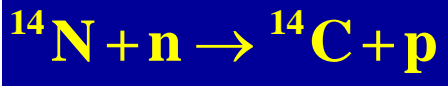
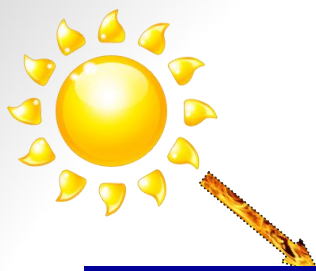
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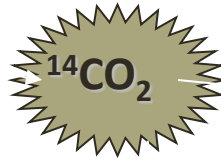
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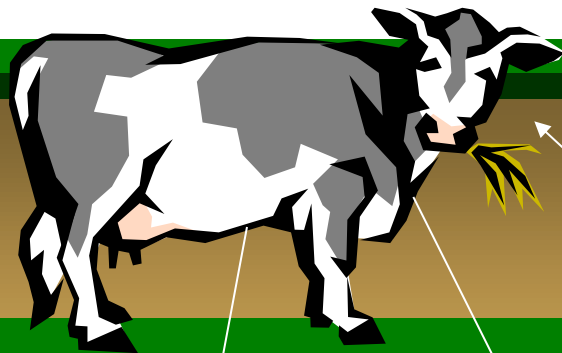




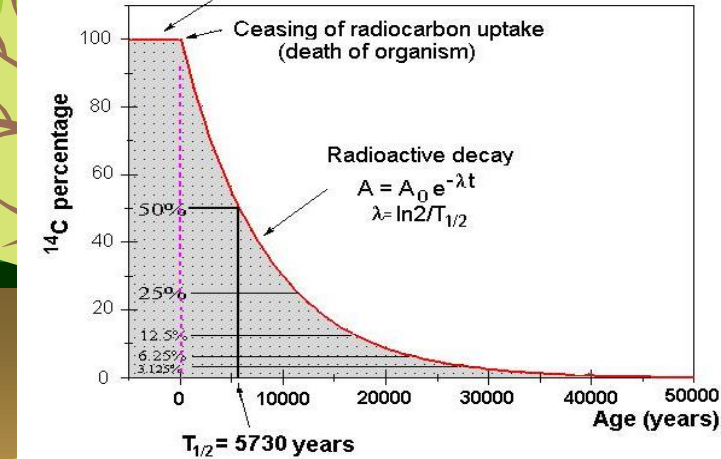
O_2



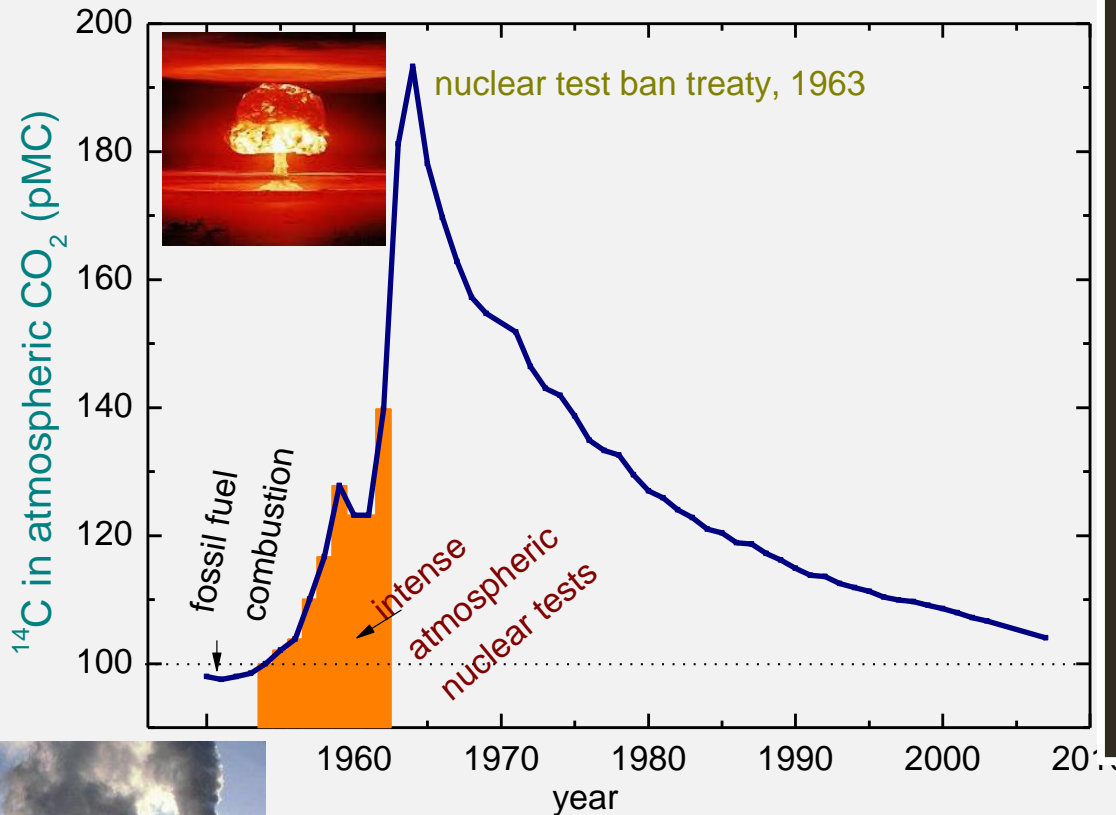
Carbon on Earth
 ^{12}C : 98.89 %
 ^{13}C : 1.1 %
 ^{14}C : 1.18×10^{-12} %



Decayed ^{14}C balanced by its constant uptake



Anthropogenic ^{14}C



Anthropogenic activities disturbed the natural distribution of ^{14}C in the atmosphere through fossil fuel combustion (increasing of ^{12}C compared to ^{14}C) and atmospheric bomb tests (doubling the natural atmospheric ^{14}C activity in 1960-ties).

The „bomb-peak“ has served as an invaluable tracer to get insight into the global carbon cycle on the decadal time scale.

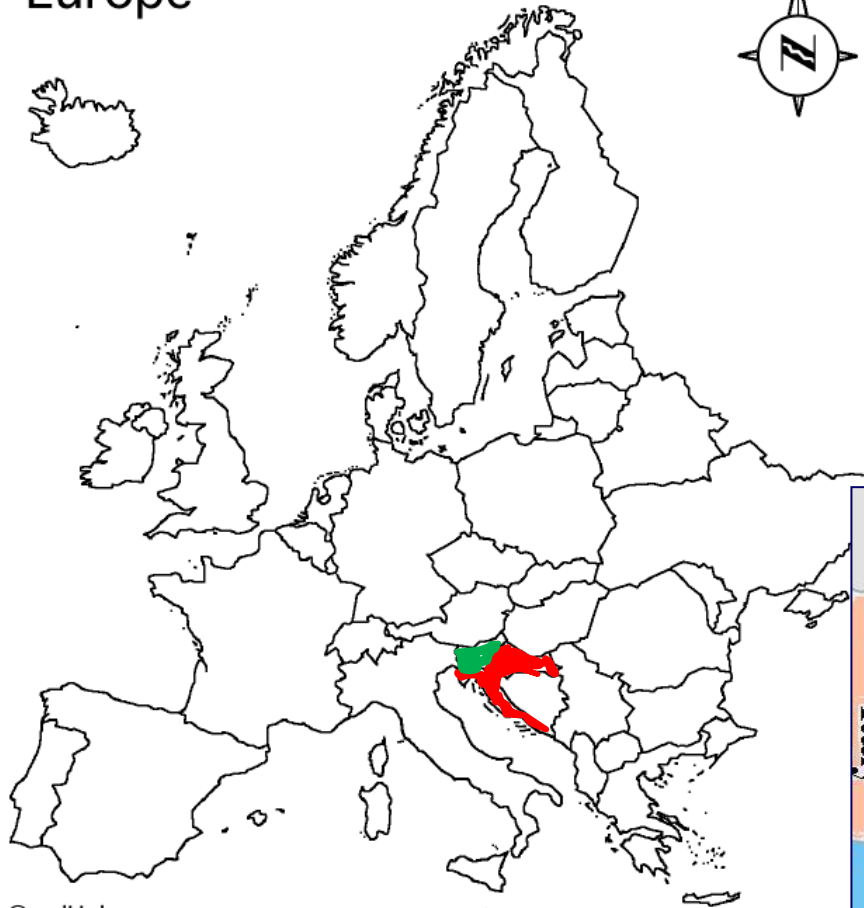


Carbon-14 can be produced in:

- $^{13}\text{C}(\text{n},\gamma)^{14}\text{C}$ and $^{17}\text{O}(\text{n},\alpha)^{14}\text{C}$ with thermal neutrons
- $^{15}\text{N}(\text{n},\text{d})^{14}\text{C}$ and $^{16}\text{O}(\text{n},^3\text{He})^{14}\text{C}$ with fast neutrons

In PWR ^{14}C is produced by neutron activation with oxygen ^{17}O or nitrogen ^{14}N in fuel, moderator and coolant of the reactor. It is emitted into the environment in the form of **CO_2** , which **enters the natural carbon cycle** in the vicinity of power stations. Through food chain (ingestion) it can contribute to the additional irradiation of the population, resulting thus to the enhancement of the effective dose of the population.

Europe

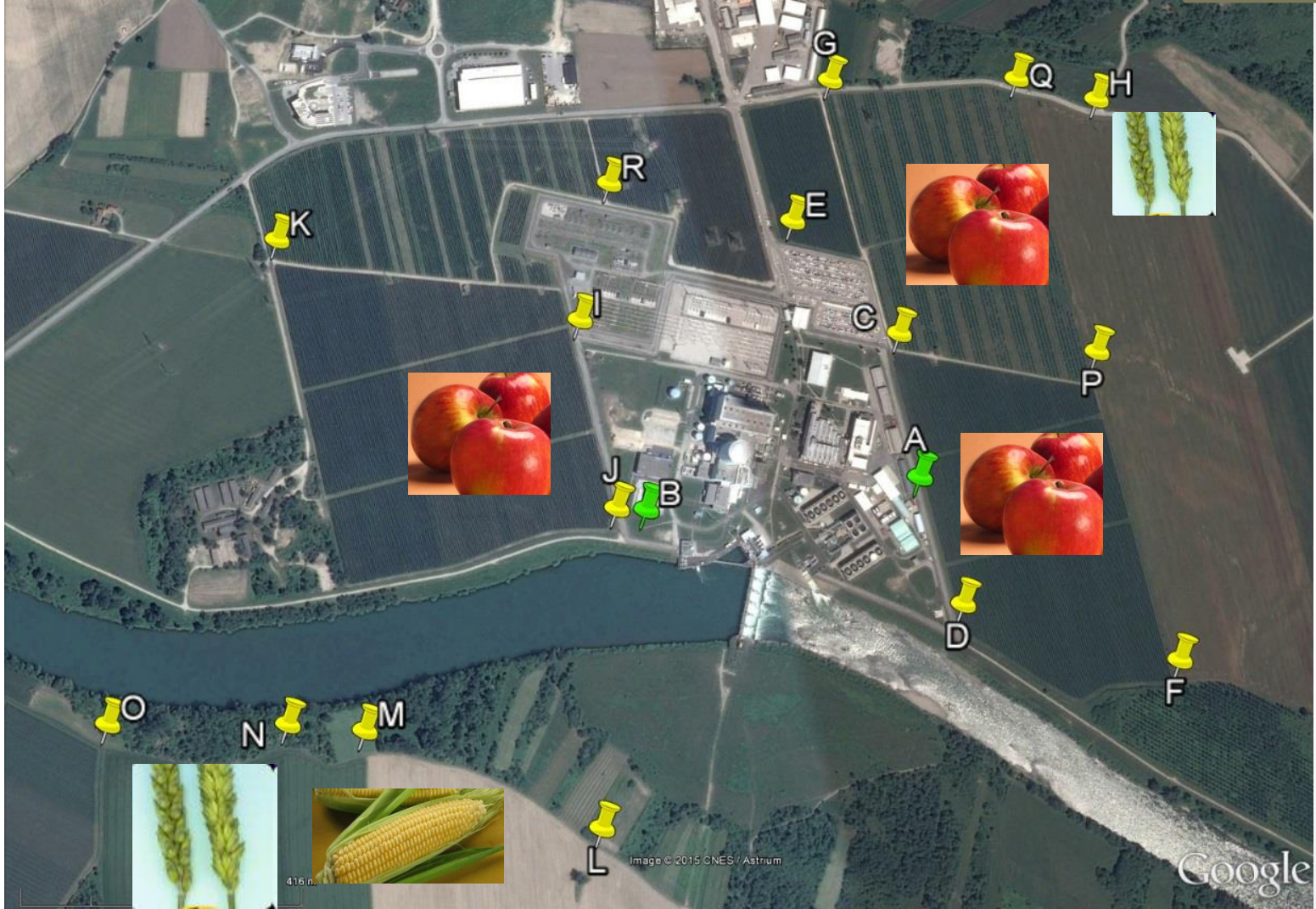


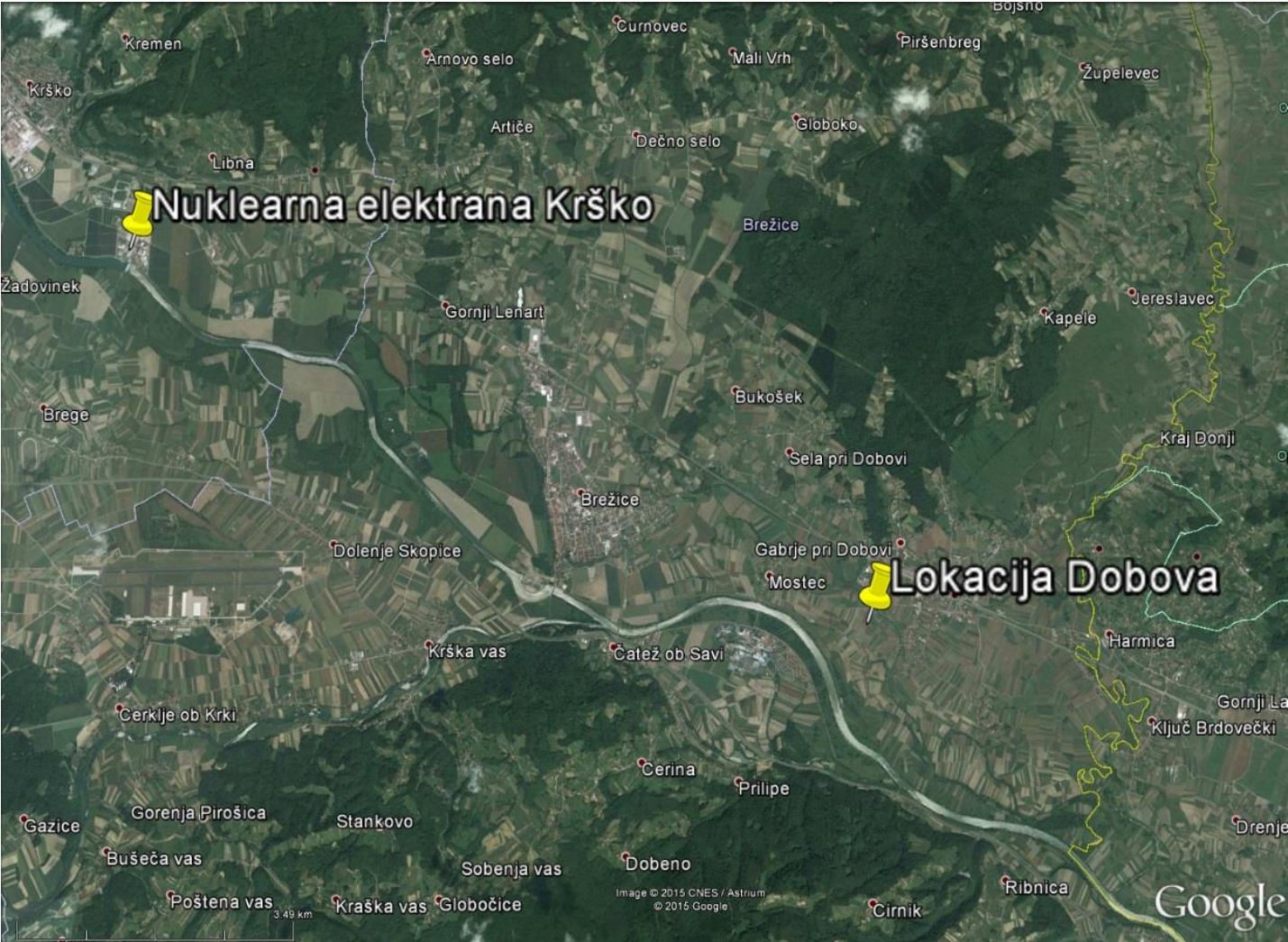
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Figure 1. Sampling sites Krško and Dobova.







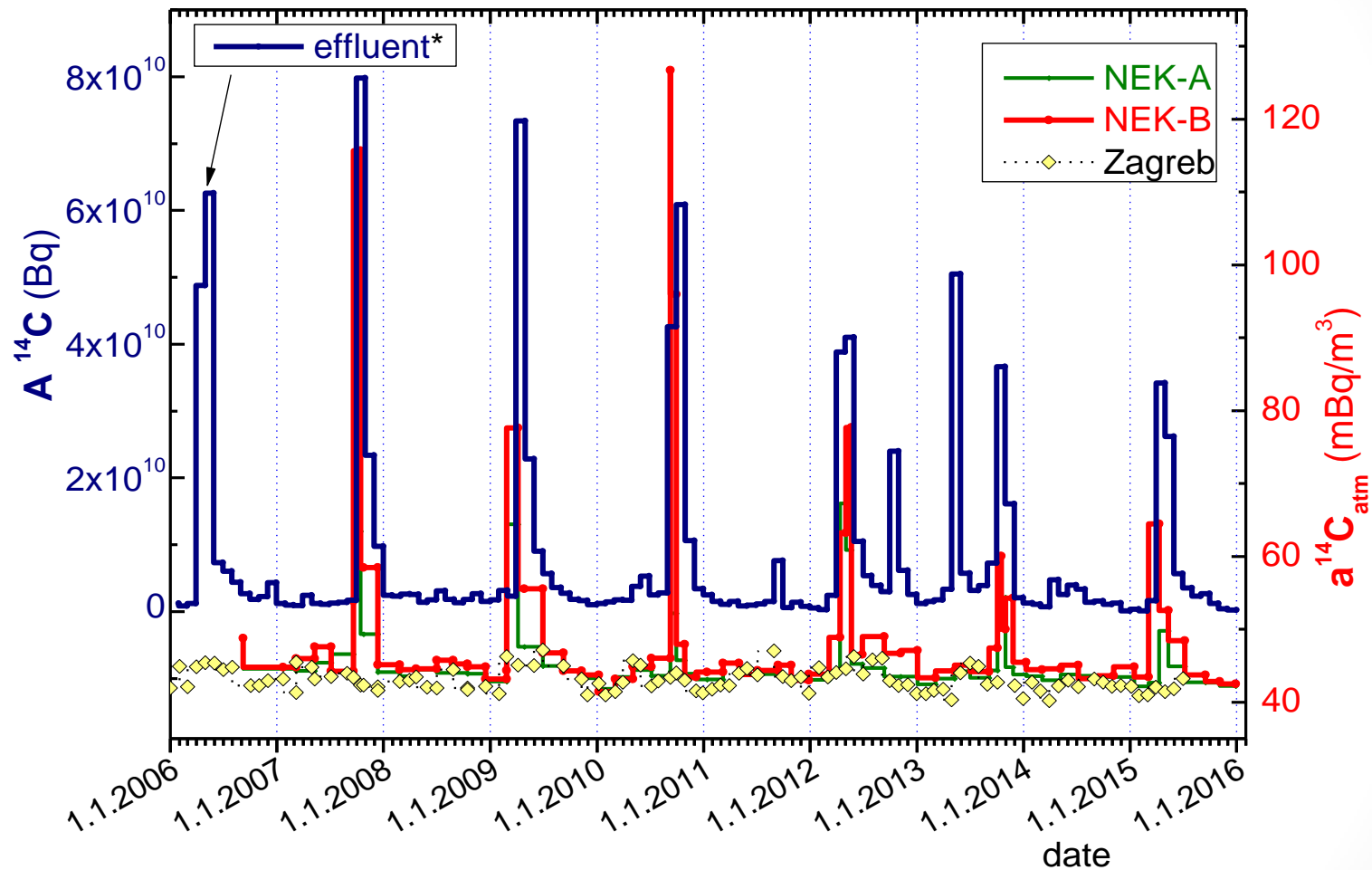
Atmospheric CO₂



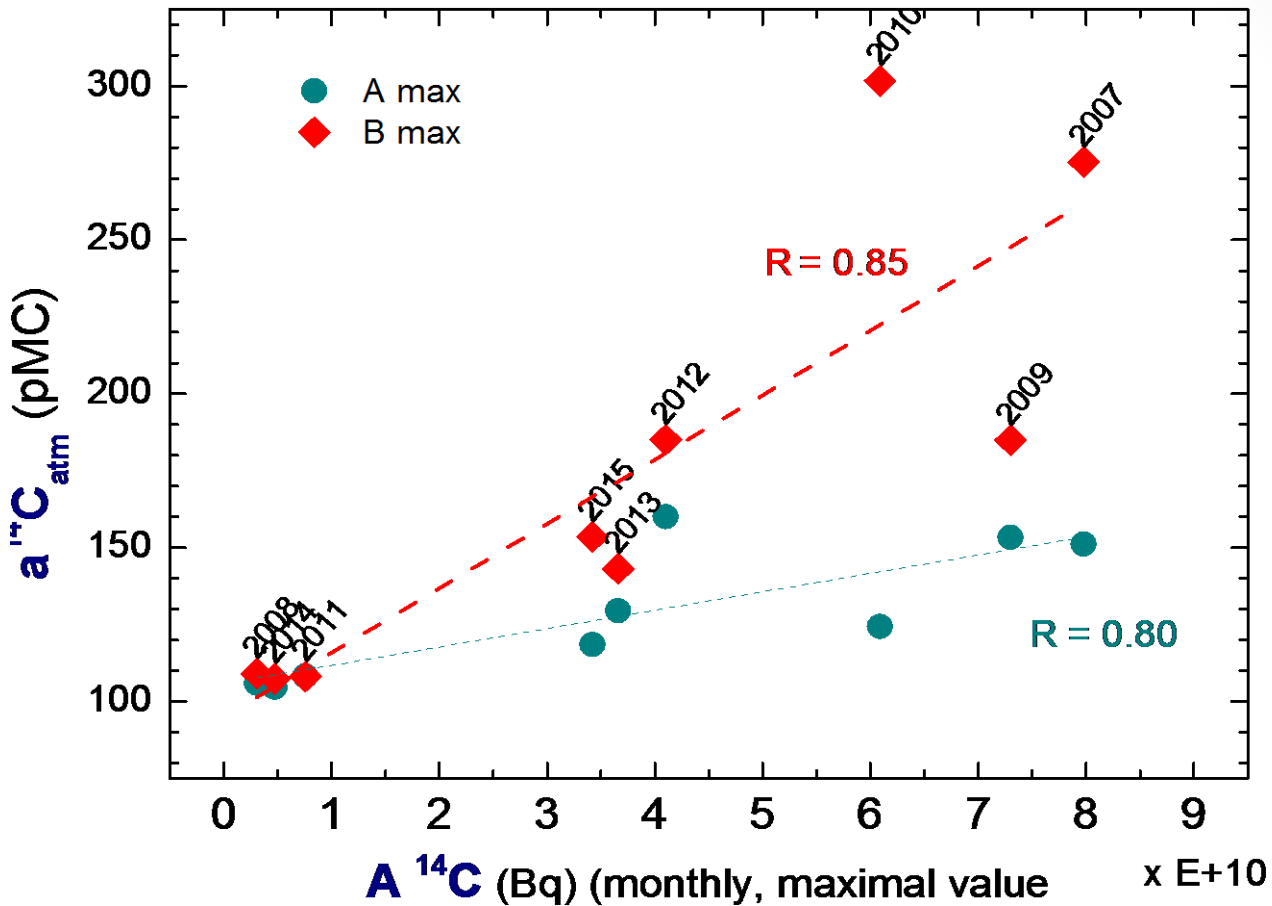
Tray with saturated NaOH
(location **B**)

- + Absorption of atmospheric CO₂ on saturated NaOH during 2-month periods forming Na₂CO₃ (shorter period exceptionally during the refueling process);
- + Na₂CO₃ reacts with HCl and obtained CO₂ is transformed to benzene;
- + Measurement of ¹⁴C activity in liquid scintillation counter (LSC) *Quantulus 1220*.

Atmospheric CO₂



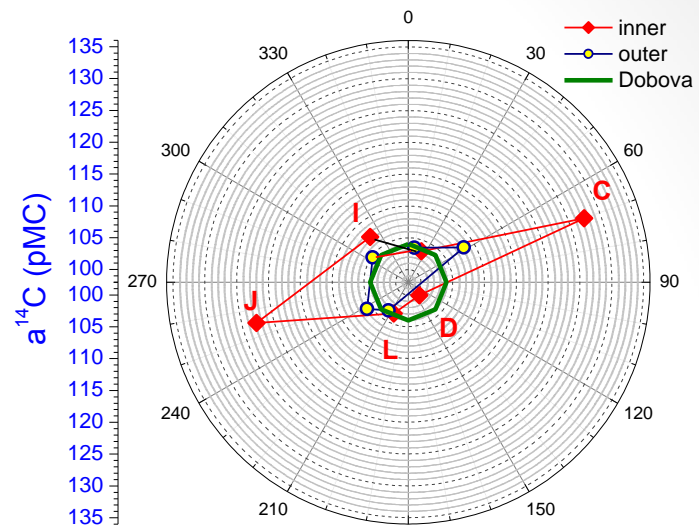
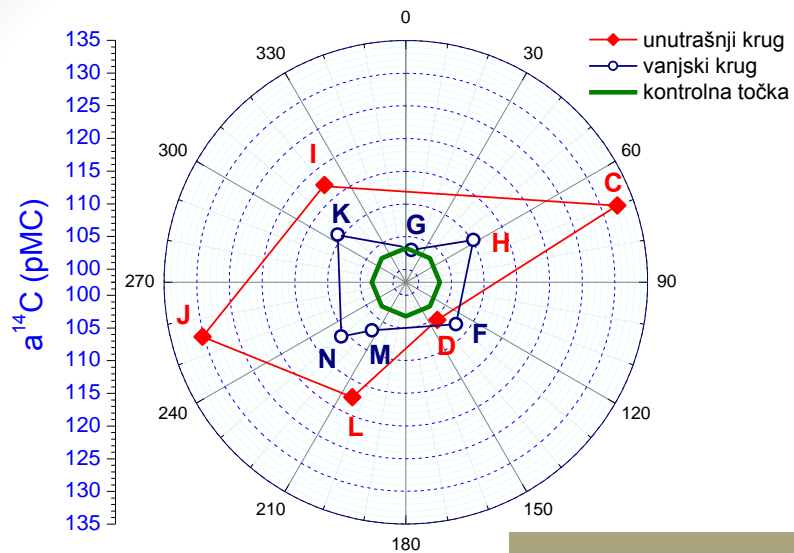
* measured at J. Stefan Inst., Ljubljana, Slovenia



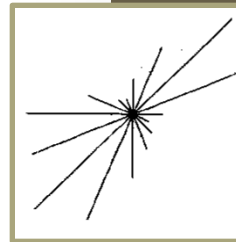
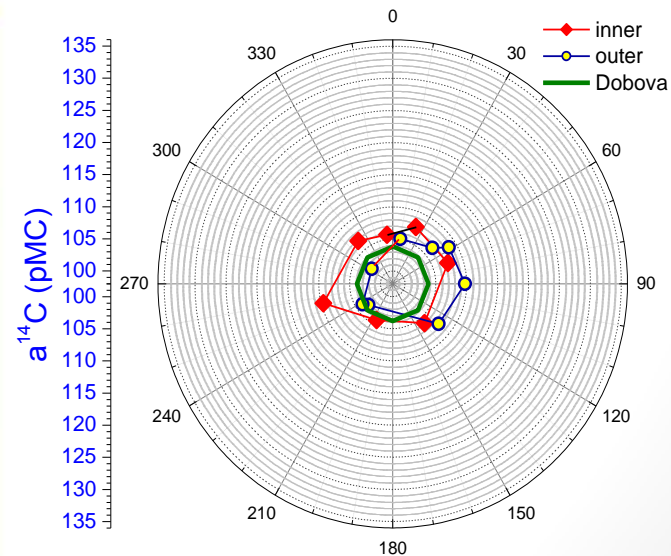
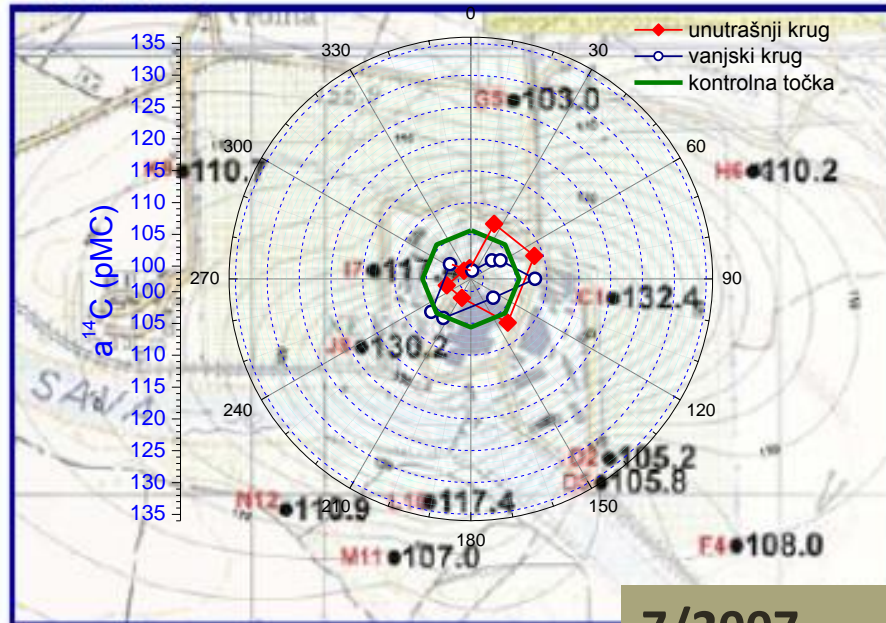
^{14}C activity in atmospheric CO_2 at locations **A** and **B** (maximal values), correlated with the highest ^{14}C activity in monthly gaseous effluents released during the outage periods. Atmospheric ^{14}C activity at the location **B** is always slightly higher than that at the location **A**.

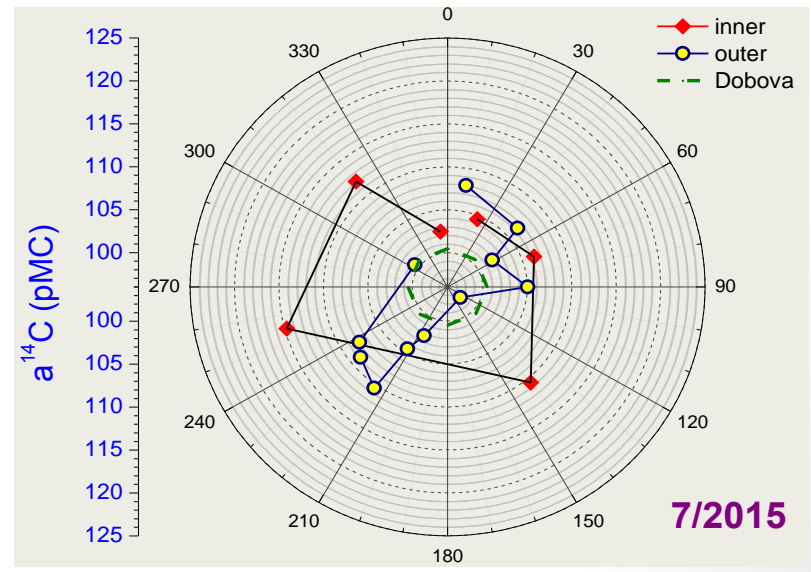
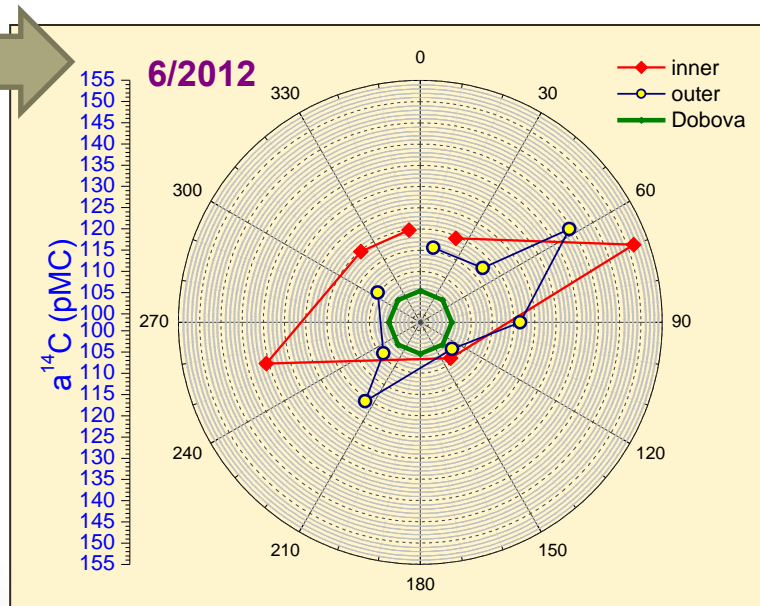
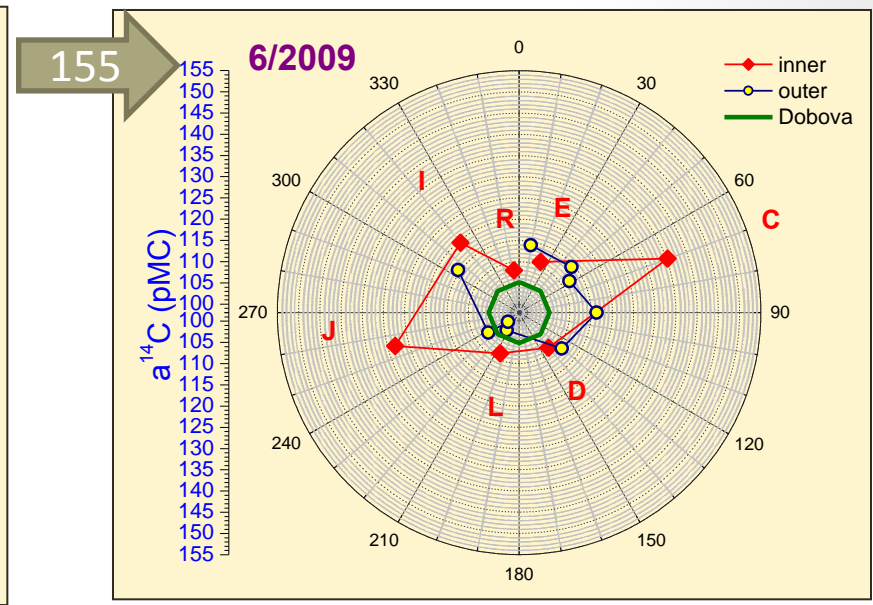
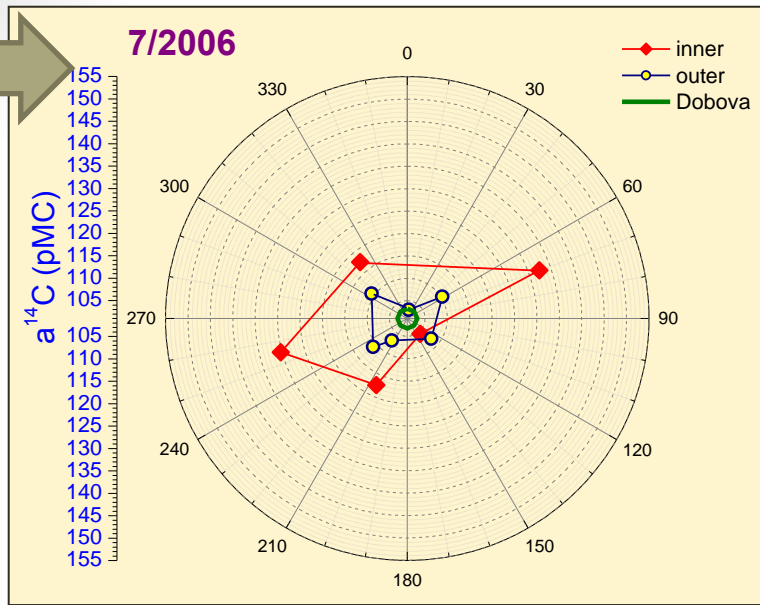
The higher the ^{14}C activity of gaseous effluent, the higher the atmospheric ^{14}C activity.

^{14}C in biological samples, spatial distribution



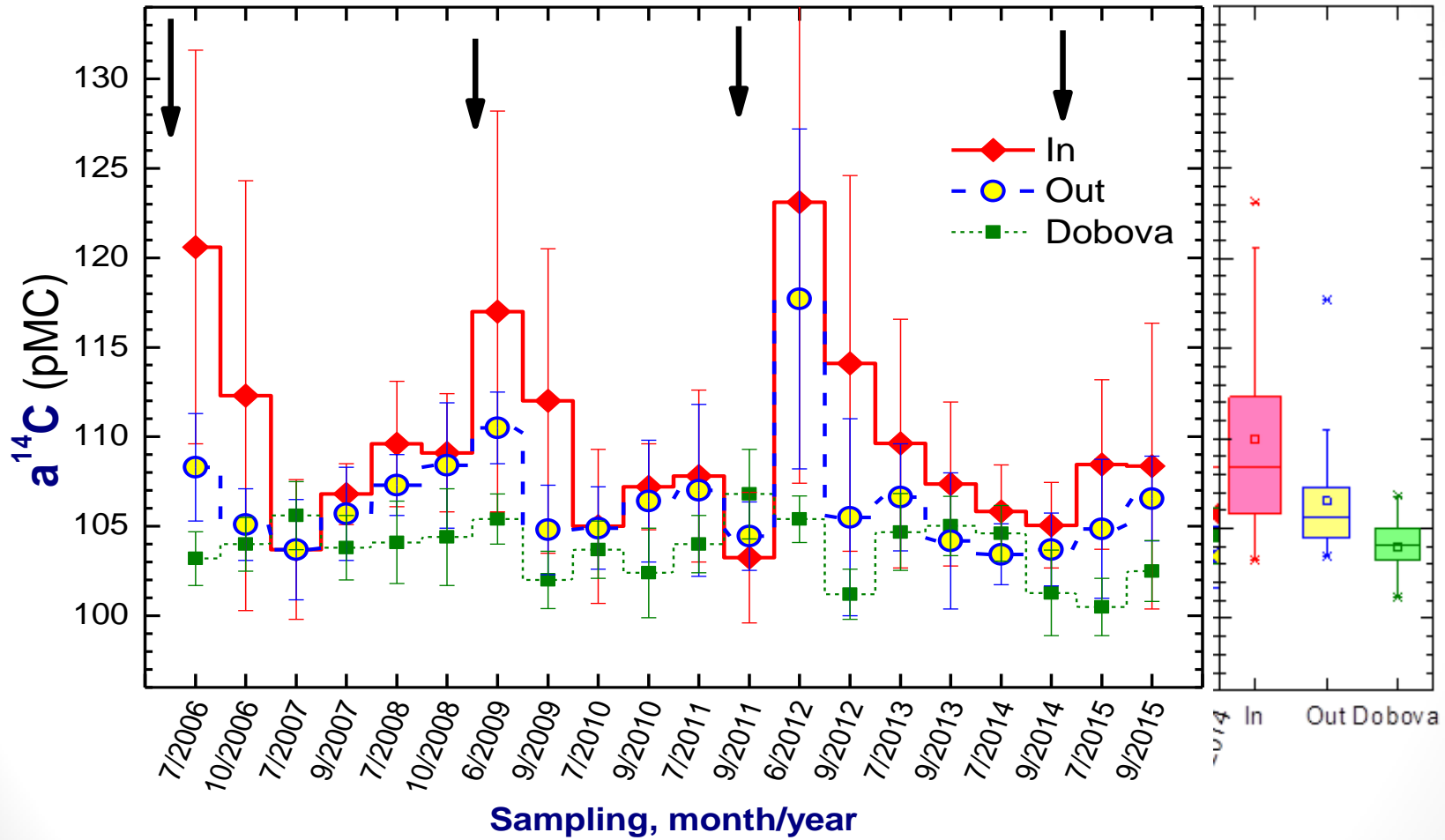
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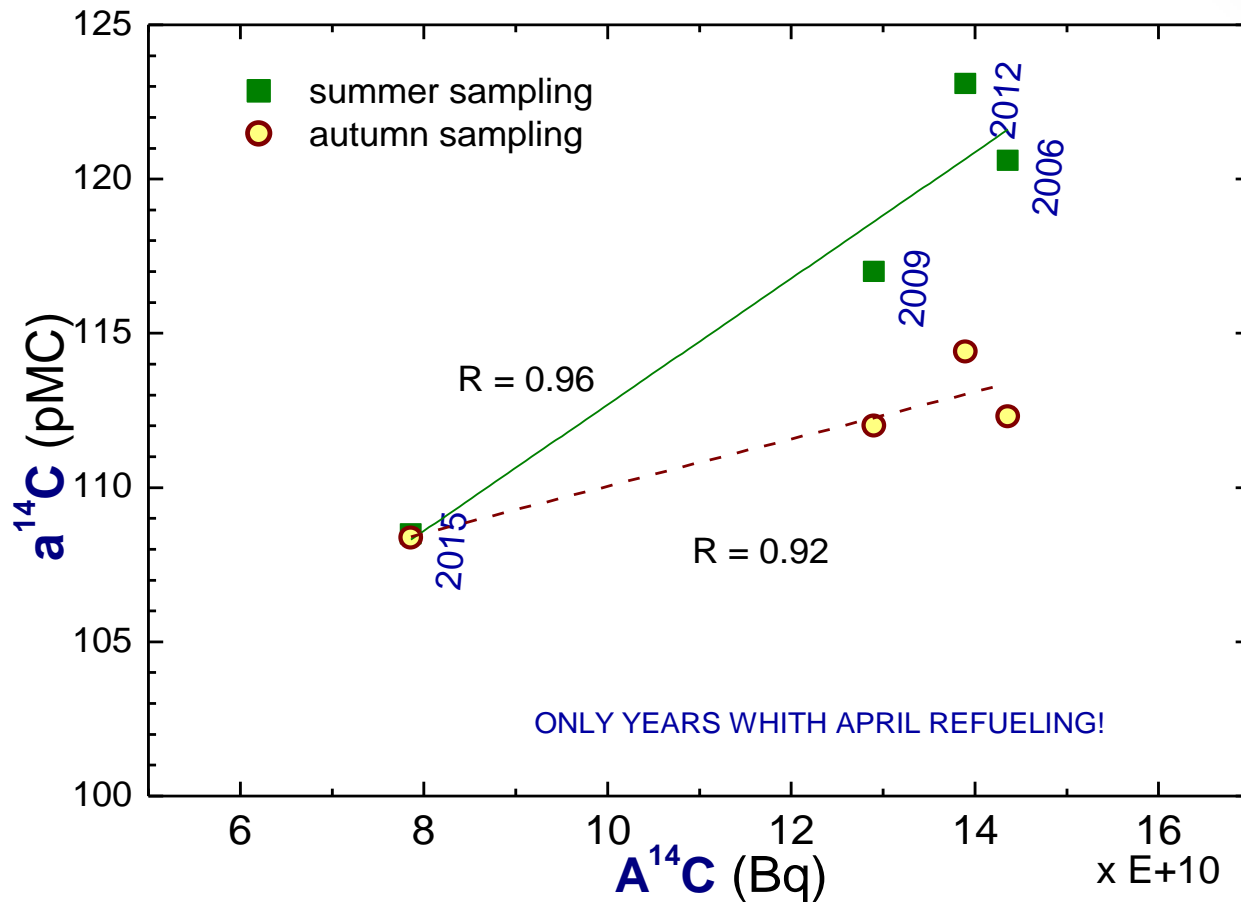




Summer sampling, after refueling in April

Seasonal average values





Dependence of the mean ^{14}C activity ($a^{14}C$) of samples from the inner circle sampled in the summer campaign (■) and in the autumn sampling campaign (○) on total released ^{14}C activity in gaseous effluents, $A^{14}C$.

Only years with the spring (April) outage periods .

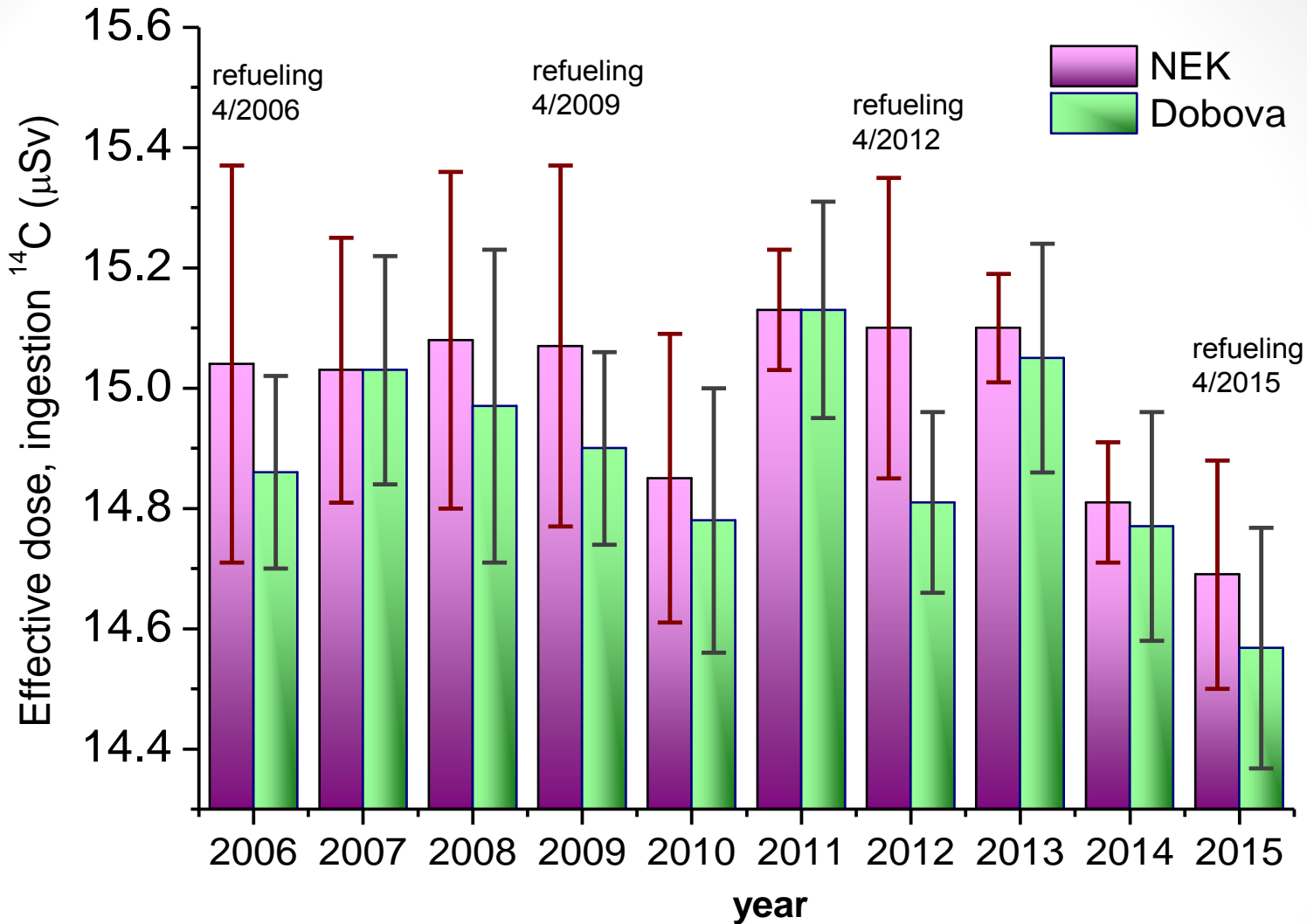
to assess the radiation dose rate (by consumption/ingestion):

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

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

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

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



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 refueling of the nuclear power plant
- 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 refueling outage - intake of ^{14}C from gaseous effluents during the vegetation period
- The maximum increase of total annual dose to local population due to the release of ^{14}C from NEK in the years of spring refueling was estimated to be negligible and within the errors of the estimate