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# Ingestion intakes of $^{137}$Cs by the Czech population: Comparison of different approaches

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ABSTRACT

Ingestion intakes of $^{137}$Cs of the Czech population were calculated in two different ways - either from the measured activity of $^{137}$Cs in components of food in combination with statistical data about consumption rates or from retention of $^{137}$Cs in the human body obtained by whole body counting or calculated from daily urinary excretion of $^{137}$Cs. Data from the time period since 1986 to 2015 are used. The daily ingestion intake was about 25 Bq d$^{-1}$ in 1986 and is around 0.1 Bq d$^{-1}$ at present. Both approaches of ingestion intake calculation have their advantages and disadvantages. Ingestion intake calculated from $^{137}$Cs body content was assumed to be the most accurate as it requires fewer assumptions than the calculation from food consumption. However, calculation of $^{137}$Cs intake from food consumption is an important tool for prediction doses after the release of radionuclides into environment. The best agreement exceeding the intakes from urine measurement 5 times at maximum was achieved when intakes calculated from food also included products from the natural environment. Without this, the ingestion intake could be under-predicted seriously up to 6 times, especially in the longer time after the release of $^{137}$Cs into environment. Ingestion intakes up to 11 Bq d$^{-1}$ in a group of people with significant consumption of game meat containing elevated activity of $^{137}$Cs activity were included as a special case. Various groups of foodstuffs had varying effects on the total committed effective dose from $^{137}$Cs. Dose estimates for the Czech population from $^{137}$Cs ingestion intake achieved 80 μSv in 1986 and not more than 2 μSv currently and were similar to those incurred by the population of neighbouring countries.


## 1. Introduction

Knowledge of the contamination level of environment, food chain and humans by $^{137}$Cs is important not only for estimation of doses to population, but especially as the baseline in case of a radiological accident or any inadvertent release of radionuclides into an environment. For accident cases, doses to a population are calculated with the help of models for transfer of radionuclides from a source to humans through different components of an environment. Ingestion intake of $^{137}$Cs is a key parameter, usually estimated from food chain models. In situations when activity of $^{137}$Cs is measurable in the human body, there is a unique possibility to compare predicted values with the real ones. Usually, the predicted doses and intakes are higher than the real ones as environmental transfer models use conservative parameters in order not to under predict dose in accidental situations.

In a comparison of internal doses (IAEA, 1991) based on whole body measurements (WBC) with results based on environmental transfer models for 3 locations in Belarus, 2 locations in Russia and 1 location in the Ukraine, estimates based on whole body counting (WBC) were eight to thirty times lower than those derived by environmental transfer models; the over-prediction was not only due to the food basket used but especially due to predictions about behaviour of radionuclides in environment. Balonov and Travnikova (1993) found that in the area affected by the Chernobyl accident the committed effective dose (except dose from $^{131}$I) based on body contents of radionuclides was 50%–80% lower than the committed effective dose calculated from estimated intakes. Also Schmidt (1988) points out that after the Chernobyl actual intakes were a small fraction (about 10%) of predictions derived from intervention levels set on conservative basis. In CB Scenario (VAMP, 1995), 13 models of environmental transfer of radionuclides were used for evaluation of body content of $^{137}$Cs for population in the Central Bohemia region, Czech Republic. The over-prediction was found mainly for the first months after the Chernobyl accident

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being in one model higher by factors 16 to 36. Most models over-predicted by a factor 1.5 to 4; under-prediction also occurred but only by a factor 0.4–0.9. In the Scenario S (VAMP, 1996), the data from daily intakes over-predicted the $^{137}$Cs body burden 2 to 3 times in comparison with WBC data.

Data on $^{137}$Cs retention in the human body can be obtained by whole body counting or from measurements of $^{137}$Cs content excreted daily (24 h) in urine, providing the intake of $^{137}$Cs changes only slowly. The representativeness of WBC can be rather low as it is quite difficult to cover the whole territory of interest. Determination of $^{137}$Cs in daily urine samples could be helpful in this aspect.

In the Czech Republic, the content of $^{137}$Cs in an environment and foodstuffs has been surveyed systematically since the Chernobyl accident, while $^{137}$Cs in people it has been followed since the mid-nineteen sixties.

## 2. Material and methods

### 2.1. Foodstuffs – selection of samples

Foodstuffs for $^{137}$Cs content determination have been sampled by the Radiation Monitoring Network (RMN) of the Czech Republic, both in the retail network and directly from producers (Kameník et al., 2009). Samples of foodstuffs from natural ecosystem have also been monitored. The sampling was organized in accordance with the state decree (State Office for Nuclear Safety, 2002) and carried out by the National Radiation Protection Institute, State Office for Nuclear Safety, State Veterinary Institute, Forestry and Game Management Research Institute, Central Institute for Supervising and Testing in Agriculture and Czech Agriculture and Food Inspection Authority. Main kinds of foods and their products produced preferably in the Czech territory were selected according the food basket: pork, beef, poultry meat, fruiting, leafy and root vegetables, main tree fruits of the temperate climate, early and late potatoes, raw and processed (pasteurized, sterilized and powdered) milk, main cereals (wheat, barley, oats, rye, corn, triticale). From among products of the natural ecosystem the kinds with expected high content of $^{137}$Cs were prioritized and sampled: forest gilled and boletales mushrooms, blueberries, boar, deer and other game meat, bee honey, fish. The aim was to achieve widespread and as homogeneous as possible monitoring and sampling over the Czech Republic territory for the purpose of population dose estimation. The sampling was carried out in administrative units covering all Czech territory. For meat, vegetables, and potatoes, often mixed samples composed from 2 to 5 samples purchased in different stores were measured. Since the Chernobyl accident till the present time, sampling foodstuffs has been reduced as the activities of radionuclides have decreased steadily. Several hundreds of samples from sites spread virtually homogeneously over the territory are still collected in the Czech Republic per year.

### 2.2. Foodstuffs – methods of measurement

Edible parts of sampled foodstuffs were used, where applicable. Caesium 137 activity was counted by gamma-ray spectrometry, either with or without prior sample pre-treatment. HPGe detectors of various relative efficiencies ranging from 10 to 150% were used and placed in low background shielding made of either lead or steel. Marinelli beaker geometry or 200 mL cylindrical beakers placed on - or around the detector were used for counting. Efficiency calibration curve was plotted for gel standard material and the respective counting geometry. Gamma-ray energy line 662 keV was used for the $^{137}$Cs content evaluation. Corrections to sample density were performed where applicable. Throughout the years, measurement praxis of contributing gamma-ray spectrometry laboratories has been regularly successfully tested in national (State Office for Nuclear Safety, 2002) and international intercomparisons often involving metrologicaly traceable materials (bodies as Bundesamt für Strahlenschutz, IAEA, European Commission and PROCORAD association were among the intercomparison organizers). Where the activity concentration of $^{137}$Cs in the sample was not detected, minimum significant activity (MSA) was calculated (Currie, 1968) and its values was recorded in the RMN database.

In the cases when a concentration factor was not known for the samples measured in dry condition, radionuclide activities had to be converted to the fresh weight by division by the following factors: 11.2 L kg$^{-1}$ (skimmed milk powder with less than 0.5% of fat in dry basis), 9.8 L kg$^{-1}$ (semi skimmed milk powder with 14% of fat) and or 8.2 or 8.4 L kg$^{-1}$ (whole milk powder with 26 and 28% of fat) (Kněz, 1974), 10 kg kg$^{-1}$ (fresh weight/dray weight) mushrooms, 7.7 kg kg$^{-1}$ (f.w./d.w.) blueberries. Where fat indication was missing for a given sample of powdered milk, a conversion factor for semi-skimmed milk was used.

### 2.3. Selection of individuals, representativeness

Neither the volunteers measured in the whole body counter nor those collecting daily urine samples were specially selected. Individuals measured in the whole body counter came mainly from the National Radiation Protection Institute. The group consisted of 15 men and 15 women in the age range of 22–76 years. During the long - term study, the group composition changed, but its structure (sex and age representation) changed only very slightly. Individuals collecting the daily urine samples came from the whole territory of the Czech Republic. Active and retired employees from regional branch offices of radiation protection and public health service, as well as their family members, provided the daily urine samples.

A group of people having special dietary habits in terms of increased game meat consumption, namely wild boar meat, was monitored in addition to the groups of individuals from the general population. Since the year of 1995, variable groups comprising of 7–23 hunters and their family members (males and females) were monitored for urinary excretion. *In situ* whole body counting of $^{137}$Cs was also performed with these groups since 2006. Compared to the general population, the hunters group represents individuals with increased $^{137}$Cs intake due to boar meat consumption.

The data on averaged annual consumption were taken from yearbooks of the Czech Statistical Office (CSO, 2016).

### 2.4. Humans – method of measurements in vivo, urine

Activity of $^{137}$Cs in the human body was measured in a whole body counter with a HPGe detector of relative efficiency 120% installed in a shielded room made of old steel with a wall thickness 210 mm. Since the year 2000 the counting time has been 7200 s, while before then shorter counting times were used. Before the year 1998 the minimum detectable activity (MDA) (Currie, 1968) was 40 Bq with respect to $^{137}$Cs. After an upgrade of the counting equipment in 1998, the MDA was lowered to 20 Bq with further improvement to about 15 Bq due to the extension of the counting time. For measurements of a certain group of people with special dietary habits, researchers have travelled after the group out of the laboratory. Measurements using the above mentioned HPGe detector have been performed *in situ* in an ordinary masonry building. MDA of about 150 Bq was achieved for $^{137}$Cs in the whole body for the counting time 1200 s. This MDA was sufficient for the elevated whole body retention expected in the members of the group.

Daily urine for $^{137}$Cs determination was collected in polyethylene bottles in accordance with common instruction for