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Radiocaesium contamination of beef in Croatia after the Chernobyl accident

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Abstract

Long-term investigations of radiocaesium activity concentrations in beef in the Republic of Croatia are presented. The radiocaesium levels in beef decreased exponentially and the effective ecological half-life of ^{137}Cs was estimated to be 0.57 ± 0.06 years for 1986–1990 period and 5.21 ± 0.27 years for the 1991–2005 period. For 1986–1990 period, the effective ecological half-life of ^{134}Cs in was estimated to be about 0.69 ± 0.05 while ^{134}Cs activity concentrations after year 1990 were below the detection limit of the instruments.

The ^{134}Cs:^{137}Cs activity ratio in beef has been found to be similar to the ratio that has been observed in other foodstuffs and environmental samples.

Radioecological sensitivity for beef meat, i.e., the transfer coefficient from fallout to sample was estimated to be 1.15×10^{-2} Bq y kg^{-1}/(Bq m^{-2}).

For an adult member of Croatian population annual effective doses received by ^{134}Cs and ^{137}Cs intake due to consumption of beef are small, as per caput effective dose for the overall 1986–2005 period was estimated to be 24.6 μSv. Consequently, after the Chernobyl accident beef consumption was not a critical pathway for the transfer of radiocaesium from fallout to humans in Croatia.

Keywords: Beef; Chernobyl accident; Dose; Radiocaesium; Radioecological sensitivity

1. Introduction

Nuclear tests conducted in the atmosphere and releases of radioactive material from nuclear facilities are the main causes of the man-made radioactive contamination of human environment. Once released to the atmosphere, long-range atmospheric transport processes can cause a widespread distribution of such radioactive matter, although it may, like in the case of Chernobyl nuclear accident, originate in a single point on the surface of earth.

The resulting fallout, consisting of short and long-lived radionuclides, eventually affects humans, either directly or indirectly by entering the food chain through the plants and animals. In both cases it causes a health hazard to the population through the direct irradiation and internal contamination after consumption of contaminated foodstuffs.

Among man-made radioactive nuclides, those of the radiocaesium and radiostrontium, particularly ^{137}Cs and ^{90}Sr, are regarded as a great potential hazard to living beings. Namely, these fission products have unique combinations of relatively long half-lives (30.14 and 29.12 years, respectively) and chemical and metabolic properties resembling those of the potassium and calcium, respectively. Once entered the body of mammals, radiocaesium and radiostrontium are being excreted through milk, faeces and urine. Meat and milk, containing both potassium and calcium are therefore recognized as sensitive indicators for presence of fission products in the environment. In addition milk, as the very important foodstuff in dietary habits, is potentially a major source of radioactive contamination. Consequently, investigations of radiocaesium and radiostrontium in dairy milk (Franić et al., 1998, 2004) take

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significant part in an extended monitoring program of radioactive contamination of human environment in Croatia (Popović, 1966–1978; Bauman et al., 1979–1992; Kovač et al., 1993–1998; Marović et al., 1999–2006). However, the regular investigations of radioactive contamination of beef meat started in the year of the Chernobyl accident, i.e. in 1986.

Regarding cattle, lessons learned from the Chernobyl aftermath are that the detailed knowledge of decreasing behaviour of radiocaesium activity concentrations in meat of animals bound for human consumption and effective decontamination measures (Unsworth et al., 1989; Petäjä et al., 1992; Franić et al., 1993; Ratnikov et al. 1998) are of utmost importance for estimation and reduction of total ingestion doses.

In Croatia, annual average for beef consumption is about 12 kg per person (Central Bureau of Statistics, 2000–2006), which cannot be met by production in Croatia. To satisfy those needs substantial amounts of beef are imported, mainly from EU countries. For comparison, annual average pork and poultry consumptions are about 15 and 20 kg per person respectively (Central Bureau of Statistics, 2000–2006).

It should be noted that relatively recent occurrence of cattle disease known as bovine spongiform encephalopathy (BSE) had caused great fluctuations in production and consumption of beef meat all over the Europe. The more detailed food habits for Croatian population regarding beef consumption, with special respect to BSE, are in more details presented by Mijić et al. (2005).

2. Materials and methods

According to national monitoring programme beef samples have been once a year, usually in late spring or early summer, commercially obtained on markets in the cities of Zagreb and Osijek and occasionally in the cities of Gospić and Split.

From each site were obtained 5 or more samples, 1–2 kg each. Meat samples were cut into small pieces in order to obtain the composite sample and then dried in an oven. Dried meat was then ashed in a muffle furnace at 450 °C for 24 h. The ^{137}Cs and ^{134}Cs activity concentrations in beef are reported as wet weight.

Fallout samples were collected monthly in the city of Zagreb at the location of the Institute for Medical Research and Occupational Health (45° 50′ 7.3″ N, 15° 58′ 58.7″ E). The funnels, which were used for rainwater collection, had a 1 m^2 catchment area. Precipitation height was measured by Hellman pluviometer. Rainwater was evaporated to volume of 1 L in order to enrich the ^{137}Cs and ^{134}Cs activity concentrations.

Gamma-ray spectrometry systems based on a low-level ORTEC Ge(Li) detector (FWHM 1.87 keV at 1.33 MeV ^{60}Co and relative efficacy of 15.4% at 1.33 MeV) and ORTEC HPGe detector (FWHM 1.75 keV at 1.33 MeV ^{60}Co and relative efficacy of 21% at 1.33 MeV) coupled to a computerized data acquisition system were used to determine radiocaesium and ^{40}K levels in the samples from their gamma-ray spectra. Ash from the fish samples was measured in cylindrical plastic containers of appropriate volume, which were placed directly on the detector.

Fallout samples were measured in Marinelli beakers.

Counting times depended on sample activities, ranging from 10,000 to 250,000 s, typically being 80,000 s.

Quality assurance and intercalibration measurements were performed through participation in an International Atomic Energy Agency (IAEA), World Health Organization (WHO) and Joint Research Centre (JRC) international intercalibration programs, which also include the regular performance of blank and background as well as quality control measurements.

Radiocaesium activity concentrations in beef samples in this paper were reported as averages of sampling locations, implicitly implying similar characteristics and microclimate conditions in which the livestock used to live, that is not necessarily true. However, relative error usually did not exceed 25%, except in the year of Chernobyl accident due to high variability.

3. Results and discussion

3.1. ^{137}Cs activity concentrations in beef

The radioactive fallout resulting from the large-scale nuclear weapon tests in the atmosphere conducted in the 1960s, followed by similar, but smaller scale tests by the Chinese and French in the 1970s and afterwards, was the dominant route for the introduction of artificial radionuclides in the environment until the nuclear accident at Chernobyl on 26 April 1986.

Severe radioactive fallout from highly radioactive air plumes that originated from the damaged Chernobyl nuclear reactor was spread and transported all over Europe. Fortunately, due to the prevailing meteorological conditions at the time after the accident, that influenced the formation and spreading direction of Chernobyl plumes, Croatia was only on the Northwestern region partially affected by the edge of one of the plumes (United Nations Scientific Committee on the Effects of Atomic Radiation, 1988).

The highest observed ^{137}Cs activity concentrations in fallout in the post-Chernobyl period were recorded in May 1986, resulting in about 6400 Bqm^{-2} for the surface deposit by fallout (Bauman et al., 1979–1992). The radioactive material introduced to the atmosphere by Chernobyl accident was by global dispersion processes distributed throughout the troposphere, causing the considerable increase of radiocaesium activity concentrations in the European environment in years to come. However, ^{137}Cs showed a significant exponential decrease over time due to natural removal processes and radioactive decay. Also, no new releases of ^{137}Cs occurred after the Chernobyl reactor accident either from nuclear facilities or nuclear weapons testing. Therefore, in 2005 total ^{137}Cs surface deposit by fallout was only 2.8 Bqm^{-2}.

The highest ^{137}Cs activity concentration in beef, being 55.7 ± 53.2 Bq kg^{-1} was recorded in 1986. It should be noted that such high variability of ^{137}Cs activity concentrations in environmental samples was characteristic for immediate post-Chernobyl period (Bauman et al., 1979–1992). For comparison, in 1986, reported ^{137}Cs activity concentrations in beef in Austria was 137 Bq kg^{-1} (Schwaiger et al., 2004).

In 2004 for ^{137}Cs activity concentration in beef was recorded minimal value of only 0.12 ± 0.01 Bq kg^{-1} while in 2005 ^{137}Cs it was just slightly higher, being 0.17 ± 0.06 Bq kg^{-1}.