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Radiological investigation of wood used for combustion

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The aim of this study was evaluation of public radiological risk due to the use of wood fuel in combustion power plants. ^{137}Cs and ^{90}Sr concentrations were measured in wood fuel and its combustion products from the local markets and manufacturers. The measurement results were used to assess the effective dose for the critical group members in order to estimate the radiological effect of the effluents from combustion power plant stacks on habitants living in the surroundings of such plants. Evaluation of ^{137}Cs concentration in the wood fuel that can be imported without alarm at border radiation gates was performed using modelling.

A number of wood fuel samples were analyzed. The activity concentration of ^{137}Cs in wood fuel products as well as in ashes was determined using gamma spectrometers with high purity germanium detectors. Wood fuels were burned at 400 °C until constant weight. ^{90}Sr activity concentration in ashes was determined with a liquid scintillation counter after radiochemical separation. A conservative dose assessment model was applied to evaluate the effective dose from the radioactive effluents to critical group members. The modelling of dose rate for wood contaminated by ^{137}Cs was performed using the Visiplan suite 4.0 3D ALARA planning tool.

The results of radiological investigation showed that the maximum value of ^{137}Cs activity concentration in the wood fuel of Lithuanian origin did not exceed 18 Bq/kg. The highest ^{137}Cs activity concentration – 160 Bq/kg – was detected in pellets imported from Ukraine. ^{137}Cs activity concentrations in wood fuel combustion products from Lithuania and Ukraine were 2 340 ± 220 Bq/kg and 9 800 ± 700 Bq/kg, respectively. The activity concentration of ^{90}Sr was lower than that of ^{137}Cs. The evaluation of the effective dose for the critical group members showed that the exposure due to ^{137}Cs and ^{90}Sr emission from the stacks of wood combustion power plants did not exceed 10 μSv per year, even if the plant used mostly contaminated wood fuel. The modelling revealed that wood fuel products containing higher than 3.2 Bq/g activity concentrations of ^{137}Cs may give alarm at the borders with the alarm level of 0.2 μGy/h, whereas wood fuel with a lower activity concentration of ^{137}Cs can pass the European border. Combustion products of such wood fuel may give ^{137}Cs activity concentrations higher than the exemption level (10 Bq/g).

Key words: ^{137}Cs and ^{90}Sr, wood fuel, exposure, exemption level, emission

INTRODUCTION

In recent years, the use of renewable energy sources has become increasingly significant as one of the solutions to the problem of worldwide energy resources. At present, one of the most popular renewable energy sources is biofuel. In Lithuania's energy sector, one of main sources of biofuel is wood fuel as 31% of the country is covered by forests. Wood as a fuel can be used directly or in processed form (briquettes, pellets and chips). Wood fuel products such as briquettes and pellets become one of the main heating materials for dwelling houses because of their high calorific capacity. From the ecological point of view, the use of wood fuel benefits the environment by reducing the emission of carbon and nitrous oxides. In addition, the resulting waste-ash can be used as fertilizers in the fields (Katinas, 2007).

However, various degrees of radioactive contamination in wood are observed due to the release of artificial radionuclides into the atmosphere during nuclear weapon tests and after the Chernobyl nuclear power plant accident. The territory

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of Lithuania, as of most Europe, was slightly polluted, and the level of ^{137}Cs increased up 40 kBq/m^2 after the Chernobyl accident (Butkus, 1995). Over 70% of the total contamination deposited in the territory of Ukraine, Belarus, Russia and Sweden. Ground deposition levels of ^{137}Cs activity reached hundreds or even thousands of kBq/m^2 in some regions of these countries (Balanov, 2007). ^{90}Sr activity concentration emitted to the environment during the Chernobyl accident was lower and the land was less contaminated; however, in the European part of the former USSR almost 90% of all ^{90}Sr released after the accident was deposited (7 PBq) (Aarkrog, 1994).

Radiological measurements of Lithuanian wood products and ashes conducted at the Radiation Protection Centre over the last 10 years confirm that contamination with radionuclides is negligible, and the highest detected values found in the wood were up to 4 ± 1 Bq/kg (^{137}Cs) (Pilkyte, 2006), and in the wood ashes up to 150 Bq/kg (Programos…, 2008). The results of measurements have shown that there is no need for special regulations in Lithuania as regards radioactivity in wood and wood combustion products; however, the activity concentration of ^{137}Cs and ^{90}Sr is regulated as exemption levels (HN73, 2001; Effects…, 1998) and ^{137}Cs levels in building materials (HN85, 2003; Exposures…, 1997). Legislation on handling ^{137}Cs-contaminated ashes was issued by Finland and Sweden (The Radioactivity…, 2003; Regulations…, 2005). In Finland, the regulation is based on the action level for the radiation dose on the public due to gamma radiation originating from construction materials used in houses, and the action level is 1 mSv per year (The Radioactivity…, 2003). The same action level is set for workers handling with ashes. The activity index in ashes is set for the radionuclides ^{232}Th, ^{226}Ra, ^{40}K and ^{137}Cs. Regulations for ash incorporated in concrete are foreseen. If the activity concentration of ^{137}Cs in the ash is less than 1 000 Bq/kg, the maximum amount of ash incorporated should be less than 120 kg/m^3. Requirements for the environmental monitoring in the territory of a combustion plant and the subsequent use of ashes for fertilizing purposes or for the manufacturing of construction materials are regulated in Sweden (Regulations…, 2005). In the combustion plants that produce more than 30 tons of dry matter of ash per year, measures for protection against leaching are foreseen. Recycling of contaminated ashes onto woodlands is permissible if the content of ^{137}Cs is less than 10 kBq/kg (for dry mass).

As biofuel power plants become more and more popular, and wood fuel products become wide-use products, detailed radiological investigations were done by the Radiation Protection Centre in 2009. The aim of this study was radiological public risk evaluation due to the use of wood fuel in combustion power plants. Results of experiments aimed at evaluating the activity concentration of ^{137}Cs and ^{90}Sr in wood fuel and its combustion products and the impact of effluents of the combustion power plant stacks on habitants living in the surroundings of power plants are reported in the paper. Assessment of the effective dose for members of a critical group and calculations of the dose rate that may give alarm at a border gate were also performed.

The dose rate when a wagon with wood fuel contaminated with ^{137}Cs passes the detector gates was calculated using the Visiplan suite 4.0 3D ALARA planning tool software (Vernmeersch, 2005). The latter experiment is of special importance, since wood fuel in Lithuania is produced also from imported wood and Lithuanian borders constitute part of the European Union borders.

MATERIALS AND METHODS

Samples of wood fuel products (chips, briquettes and pellets) were randomly selected from 15 operating wood fuel production plants and from different bio-fuel suppliers. Also, samples of wood fuel imported from Poland, Ukraine, Russia (Kaliningrad region) and Belarus were taken and analyzed as well. A wood origin country was determined from the information provided by the manufacturer or indicated on the label.

The activity concentration of radionuclides in the samples refers to dry weight and ashes. Wood fuel samples were homogenized, and part (1–1.5 kg) of samples were burned at 400 °C until the constant weight. Wood fuel and ashes were put in the measurement vessels for gamma spectrometry analysis.

The activity concentration of ^{137}Cs in samples of wood fuel products and ashes was determined using the IEC 1452 : 1995 method (IEC, 1995). Two gamma spectrometers with high-purity germanium detectors were used. The relative efficiency of the detectors was 27.3% and 25%. The spectra were analyzed using the Genie2000 spectra analysis program version G2K-CPCE1 V3.1A. The detectors were calibrated employing LabSOCS mathematical calibration software for specific measurement of the geometry and density of wood fuel products and their ash samples. ^{90}Sr activity concentration in the wood fuel was determined after radiochemical separation by counting the Cherenkov radiation of high-energy electrons (2.27 MeV) radiated by ^{90}Y in a Quantulus liquid scintillation counter (Suomela, 1993, LAND, 2005). Expanded uncertainty was calculated at the 95% confidence level. Both methods are accredited according to ISO 17025 : 2005 requirements.

The dry weight / ash ratio was determined during the combustion process and calculated as a ratio of ash weight and the weight of dry wood fuel before ashing.

A conservative dose assessment model was applied to evaluate the effective dose of radioactive effluents on members of the critical group living in the surroundings of biofuel plants by the methods given in (Hedvall, 1996).

Wood fuel ashes are composed of about 75% of fly and 25% of bottom ashes, and fly ashes generally have a higher activity concentration than bottom ones (Hedvall, 1996). Accordingly, the conservative model of dose assessment due to immersion and due to inhalation for critical group members was adopted. Based on the assumption that the total stack emission is 1 kg/h, according to investigations done in Sweden (Hedvall, 1996), the screening model for atmospheric dispersion can be represented by the following equation:

$$C_A = \frac{P_p F Q_i}{u_a}, \quad (1)$$

where C_A is the ground level air concentration at a downwind distance (Bq/m^3), P_p is the fraction of the time during the year when the wind blows towards the receptor of interest; usually, 1/4 is used; u_a is the geometric mean of the wind speed at the height of release, representative of one year (in Lithuania it is 4 m s^{-1}), F is the Gaussian diffusion factor appropriate for the height of release H, the downwind distance x being considered (m^{-2}) (Generic…, 2001). Different effective stack heights (20, 60 and 100 m) were chosen, using the diffusion factor for neutral atmospheric stratification; Q_i is the annual average discharge rate for radionuclide i (Bq/s).

The annual effective dose from immersion in the atmospheric discharge plume E_{im} (Sv/a) was calculated using the equation:

$$E_{\text{im}} = C_A DF_{\text{im}} O_f, \quad (2)$$

where C_A is the annual average concentration of nuclide i in the air (Bq/m^3) calculated using eq. 1, DF_{im} is the effective dose coefficient for immersion: for ^{137}Cs – 8.7 · 10^{-7} Sv/a per Bq/m^3, for ^{90}Sr – 3.1 · 10^{-9} Sv/a per Bq/m^3 (Generic…, 2001); O_f is the fraction of the year for which the hypothetical critical group member is exposed to this particular pathway, which is equal to 1 (Generic…, 2001).

The annual effective dose from inhalation E_{inh} (Sv/a) is

$$E_{\text{inh}} = C_A R_{\text{inh}} DF_{\text{inh}}, \quad (3)$$

where C_A is the radionuclide concentration in the air (Bq/m^3), calculated using eq. 1, R_{inh} is the inhalation rate (m^3/a), DF_{inh} is the inhalation dose coefficient (Sv/Bq): for ^{137}Cs – 4.6 · 10^{-9} Sv/Bq, for ^{90}Sr – 1.6 · 10^{-7} Sv/Bq (Generic…, 2001).

The annual effective dose for critical group members was evaluated, assuming that a power plant works 8760 h/a and a member of the critical group is standing for 24 h/day at a spot where the ground concentration is at its maximum.

The dose rate was calculated using Visiplan 40 3D ALARA software which allows fast three-dimensional calculations. The software was developed by the Belgian Nuclear Research Centre (SCK CEN). This software considers the transport of radiation through intervening shielding in the line of sight path from the source to a dose point. The method used in Visiplan is based on the point-kernel calculation with a build-up correction (Vermeersch, 2005). A model of the wagon was created for calculations. Powdery materials are transported in closed (3 mm wall thickness) wagons. The dimensions of a typical wagon used in the Baltic States and in the Commonwealth of Independent States are 13.8 m in length, 2.76 m in width and 2.8 m in height. The density of wood fuel is assumed to be 0.72 g/cm^3. Detector gates for the railway are at 1 m distance from the side of a wagon. Wagon after wagon pass through the detectors. Wood fuel pellets contaminated with ^{137}Cs are shielded by the wagon metal walls which reduces the dose rate. The activity concentrations used for calculations were as follows: the average activity concentration in Lithuanian wood fuel samples, the highest activity concentration measured in imported wood fuel products, and the exemption level (10 Bq/g). The dose rate at a distance of 1 m was calculated for this type of wagon. Dose rate distribution at the plane of detectors was assessed and the relationship between dose rate and activity was estimated.

RESULTS AND DISCUSSION

Radiological measurements of wood fuel products (briquettes and pellets) as well as of raw material were carried out considering the type of wood fuel production process and the country of origin. The influence of other factors related to the level of wood fuel contamination with radionuclides, such as soil contamination, site characteristics, kind of wood, age of a tree, uptake by roots, etc. is too complex and thus was not considered (Soukhova, 2003). The values of ^{137}Cs activity concentration in the wood fuel products and their ashes are presented in Table 1.

The results of radiological investigation of Lithuanian wood fuel products showed that the maximum values of ^{137}Cs activity concentration in samples of wood pellets and wood briquettes were 14 ± 1 Bq/kg and 1.4 ± 0.4 Bq/kg, respectively. A slightly higher ^{137}Cs activity concentration was measured in wood pellets made in Ukraine. The maximum value of the ^{137}Cs activity concentration was 156 ± 9 Bq/kg for dry weight. According to the information from Lithuanian wood fuel producers, wood pellets can be made of wood with or without bark. Pellets that are made from wood with bark have a dark colour and are cheaper. Such type of wood pellets is often imported to Lithuania from Ukraine. Some countries import only white-coloured pellets made only from wood trunk without bark. It is a known fact that ^{137}Cs activity concentration is higher in the bark than in the trunk as the root absorption of ^{137}Cs is very small comparing with the aerial deposition on the plant surface (Barci-Funel, 1995; Yamagata, 1969). It follows that the wood fuels that are prepared using only wood trunk have less quantity of ^{137}Cs compared to those which are made from different parts of trees.

The measurements for the wood fuel ashes showed that in burned wood fuel made in Lithuania activity concentrations of ^{37}Cs was not higher 7 201 ± 567 Bq/kg. The highest activity concentration was detected in the ash sample of pellets from Ukraine – 9 800 ± 700 Bq/kg. Using the methodology

Table 1. ^{137}Cs activity concentration in wood fuel and ashes. Results are given with the confidence interval of 95%

Sample type	Country of origin	^{137}Cs activity concentration, Bq/kg	Dry/ash ratio	^{137}Cs activity concentration in ash, Bq/kg
Wood briquettes	Lithuania	1.4 ± 0.4	95	126 ± 18
		<2	280	73 ± 15
		<4	261	157 ± 49
	Russia	1.0 ± 0.3	189	151 ± 34
	Ukraine	20 ± 3	368	5 754 ± 485
Wood briquettes with a hole	Ukraine	1.5 ± 0.5	14	21 ± 4
Wood pellets	Lithuania	14 ± 1	187	2 630 ± 121
		8 ± 1	210	1 489 ± 95
		1.0 ± 0.3	95	71 ± 17
		5.0 ± 0.4	253	1 264 ± 128
		2.0 ± 0.2	122	579 ± 51
		2.0 ± 0.6	168	333 ± 71
	Ukraine	106 ± 10	92	9 800 ± 700
		84 ± 8	37	3 466 ± 170
		37 ± 9	43	3 527 ± 274
		56 ± 4	56	3 432 ± 150
		156 ± 9	40	6 502 ± 501
	Belarus	30 ± 2	78	2 433 ± 162
	Belarus–Lithuania	12 ± 1	157	1 952 ± 20
	Poland	4.0 ± 0.4	110	579 ± 68
Wood chips (pine and fir)	Lithuania	1.0 ± 0.6	370	468 ± 104
		28 ± 7	268	7 201 ± 567
Wood chips	Lithuania	<0.9	227	62 ± 20
Wood chips (pine and fir)	Belarus	32 ± 2	170	2 626 ± 118
		3.0 ± 1.0	370	2 545 ± 1961
Mixed raw material	Belarus–Lithuania	16 ± 1	130	1 813 ± 140
		16 ± 2	86	1 432 ± 155
Wood chips (larch)	Russia (Kaliningrad)	2.0 ± 0.3	304	525 ± 87

adopted in Sweden this value is higher than exemption level (Regulations…, 2005).

A detailed radiological monitoring of ^{137}Cs in wood pellets was performed at one of the biggest Lithuanian factories (where wood of Lithuanian origin and wood imported from Belarus are used) taking daily integrated samples (each sample was composed of 24 samples taken on a 60-minute basis). Measurements of 122 such integrated samples were done in the period from June 23, 2009 till October 21, 2009. The results of radiological investigation showed that ^{137}Cs activity concentration ranged from 5 up to 40 Bq/kg of dry material with the average of 16 ± 1.4, and no higher activity was detected (Fig. 1).

The dry weight / ash ratio of wood fuel was estimated. It was found that even for the same type of wood fuel the concentration factor varied significantly – from 1 : 14 to 1 : 370. The variation of the concentration factor in different kinds of wood fuel is shown in Table 1. The dry weight / ash ratio highly depends on the raw material and processes used for wood fuel production and as well as on the burning process. During the study, it was noted that the volume of ashes was higher for samples with a low dry weight / ash ratio (the quantity of sample remained constant). Therefore, the significant difference between dry weight / ash ratios of the same type samples could be caused by soil which is mixed with wood in the wood fuel production process. The analysis of the results shows that it is impossible to calculate the ^{137}Cs activity concentration in ash directly from the ^{137}Cs activity in the wood fuel. Nevertheless, in conformity with measurement results (Table 1), wood pellets containing more than 100 Bq/kg of ^{137}Cs dry matter could be considered as a possible source of radioactive waste from the combustion process (^{137}Cs activity concentration in ash can reach the exemption level of 10 Bq/g (HN73, 2001)).

Determination of ^{90}Sr was performed in ashes of wood samples with the highest ^{137}Cs activity concentrations in dry matter (Table 2).

The activity concentration of ^{90}Sr in most cases was lower than the corresponding ^{137}Cs activity concentrations and did not exceed the exemption level (HN73, 2001)]. This fact can be explained by the ^{137}Cs / ^{90}Sr ratio produced during nuclear weapon tests in 1945–1980 (approximately 3 : 2) and during the Chernobyl accident (approximately 10 : 1) (Ilyin, 1987; Nedveckaite, 2004). The high ^{137}Cs activity in the wood fuel of Ukraine can be explained by the very high content of ^{137}Cs

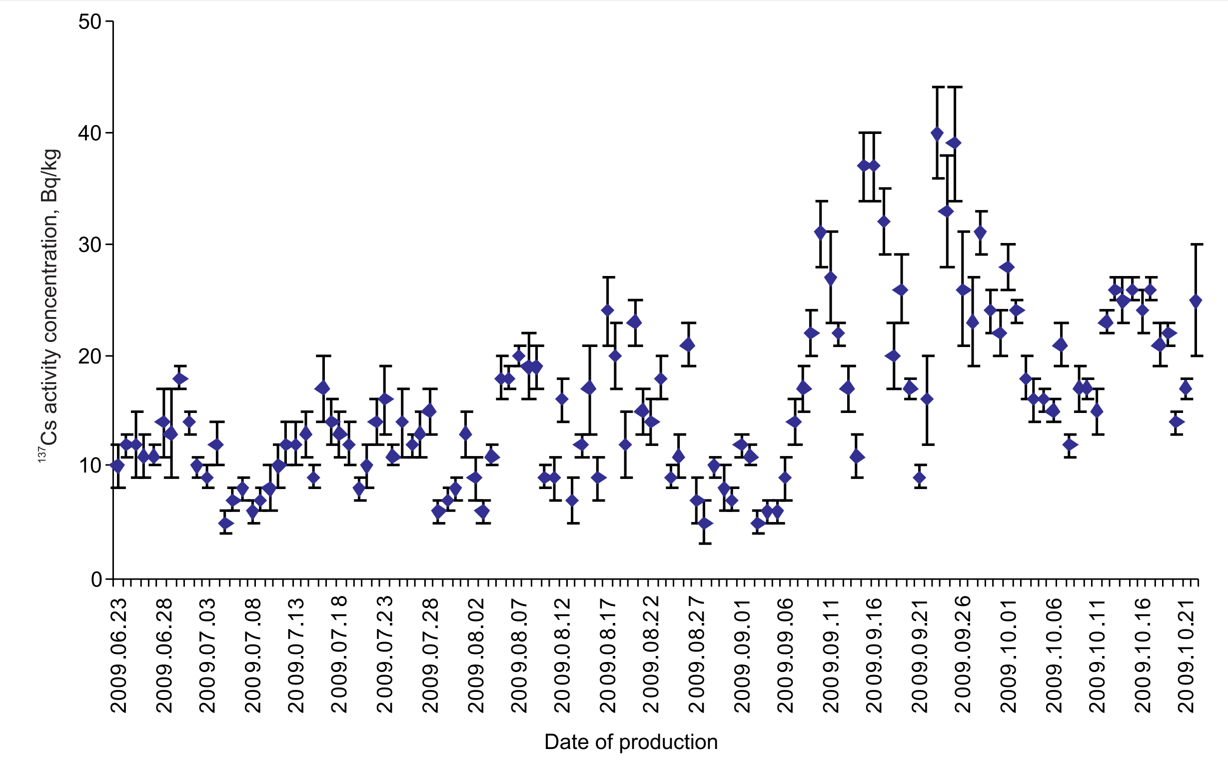

Fig. 1. ^{137}Cs activity concentrations in daily integrated samples of wood pellets collected from a Lithuanian wood fuel factory

Table 2. **The ratio of ^{90}Sr and ^{137}Cs activity concentrations in wood fuel ashes. Results are given with a confidence interval of 95%**

Sample	Country of origin	^{137}Cs / ^{90}Sr	Activity concentration in ash, Bq/kg		^{90}Sr activity concentration in wood fuel, Bq/kg *
			^{137}Cs	^{90}Sr	
Wood briquettes	Lithuania	2	1489 ± 95	712 ± 106	3.4 ± 0.5
Wood pellets		0.3	157 ± 49	469 ± 73	1.8 ± 0.3
Raw material (chips)		5	7 201 ± 567	1 508 ± 230	5.6 ± 0.9
Raw material (chips)	Belarus	4	2 626 ± 118	634 ± 98	3.7 ± 0.6
Wood pellets		4	5 754 ± 485	554 ± 82	7.1 ± 1.1
		13	6 502 ± 501	485 ± 72	12.1 ± 1.8
Wood pellets	Ukraine	7	3 432 ± 150	475 ± 70	8.5 ± 1.3
		14	9 800 ± 700	715 ± 107	7.7 ± 1.2
		11	3 527 ± 274	326 ± 48	7.6 ± 1.1
Wood briquettes		14	5 754 ± 485	410 ± 63	1.1 ± 0.2
Wood pellets		30	3 466 ± 170	114 ± 18	3.1 ± 0.5
Wood briquettes	Kaliningrad region (Russia)	0.6	151 ± 34	274 ± 43	1.4 ± 0.2
Raw material (cuttings)		1	525 ± 87	474 ± 79	1.6 ± 0.3

* ^{90}Sr activity concentration in wood fuel was recalculated from ^{90}Sr activity concentration measured in ash and ash / dry factor.

deposited on the surface of plants or on the ground ((Barci-Funel, 1995; Yamagata, 1969).

The annual effective dose for the critical group members was estimated from immersion and inhalation. Calculations were applied with principles of conservatism when the highest measured values of activity concentration in ashes were used: for ^{137}Cs – 9 800 Bq/kg (of Ukrainian origin) and for ^{90}Sr – 1 508 Bq/kg (of Lithuanian origin) (Table 3).

As expected, the annual effective dose was higher for release stacks of smaller height. The annual effective dose due to ^{90}Sr in wood ashes was less than that due to ^{137}Cs.

The dose for people living close to a power plant did not exceed 10 μSv per year (HN73, 2001) even in cases when the most contaminated ashes were emitted to the surroundings of the plant.

Results of dose rate calculation, used to estimate at which ^{137}Cs concentration in wood fuel transported in a metal wagon the acts at detector gates on the border are presented in Fig. 2. The calculated dose rate data are given with the confidence interval of 95%.

The ^{137}Cs activity concentration above 3.2 kBq/kg exceeds the dose rate (action level) (Lietuvos…, 2005) of 0.2 μSv/h

Table 3. **Annual effective dose for critical group members due to ^{137}Cs and ^{90}Sr effluents from power plant stack**

Release height, m	Annual effective dose due to							
	Immersion, μSv				Inhalation, nSv			
	Distance from the plant							
	100 m		1 km		100 m		1 km	
	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr	^{137}Cs	^{90}Sr
20	0.26	0.01	0.05	0.01	1.37	0.04	0.27	0.04
60	0.026	0.002	0.013	0.002	0.14	0.01	0.07	0.01
100	0.013	0.002	0.013	0.002	0.07	0.01	0.07	0.01

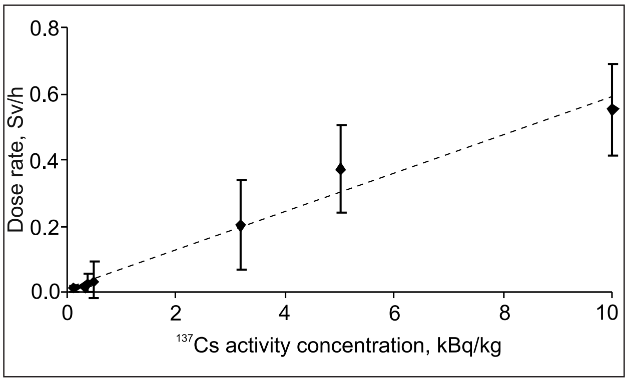

Fig. 2. Relationship between dose rate at detector gate and ^{137}Cs activity concentration in wood fuel loaded on a metal wagon

and will be detected by a detector gate. However, wood with ^{137}Cs activity concentration up to 3 200 Bq/kg can cross the border unnoticed. This may cause radioactive waste problem even when the lowest concentration factor of 14 is applied. It may give rise to the situation when the ash activity of such wood will exceed 10 000 Bq/kg for ^{137}Cs reaching the exemption level.

CONCLUSIONS

- The highest measured activity concentrations in the wood fuel of local origin were 14 ± 1 Bq/kg for ^{137}Cs and 5.6 ± 0.9 Bq/kg for ^{90}Sr. The highest activity concentrations in the imported wood fuel were 156 ± 9 Bq/kg for ^{137}Cs and 7.7 ± 1.2 Bq/kg for ^{90}Sr. These numbers show that Lithuanian wood was less contaminated compared to some imported wood from the territories that could be more affected by the Chernobyl accident.
- The dry / ash ratio for wood fuels varied in a very wide range (from 1 : 14 up to 1 : 370), which accounted for the fact that in some cases the activity concentrations of ^{137}Cs, ^{90}Sr in ashes can exceed exemption levels, even though the corresponding concentration in the wood fuel was much below exemption levels.
- The estimation of the effective dose was done using data on the most contaminated wood fuel. The results showed that the effective dose of the critical group due to ^{137}Cs and ^{90}Sr emission from the stacks of wood combustion power plants did not exceed the exemption levels (10 μSv) regulated by the Lithuanian Hygiene standard.
- A wagon loaded with wood containing ^{137}Cs activity concentration higher than 3.2 Bq/g gives a dose rate of 0.2 μSv/h and will be detected by a detector gate; however, such contaminated wood will produce ash with the activity reaching the exemption level for ^{137}Cs.

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MEDIENOS KURO RADIOLOGINIAI TYRIMAI

Santrauka

Pagrindinis tyrimų tikslas buvo įvertinti poveikį žmonėms dėl galimai radiologiškai užterštos medienos naudojimo šiluminėse elektrinėse. Tam reikėjo nustatyti ^{137}Cs ir ^{90}Sr savitąjį aktyvumą medienos kure ir jo degimo produktuose. Radiologiškai tirtas ne tik Lietuvoje pagamintas medienos kuras, bet ir įvežtinis iš Ukrainos, Rusijos (Kaliningrado srities), Lenkijos ir Baltarusijos. Tyrimų rezultatų pagrindu įvertinta apšvita gyventojams dėl radionuklidų išlakų per šiluminių elektrinių kaminus medienos kuro deginimo metu. Modeliuojant įvertinta, koks ^{137}Cs savitasis aktyvumas, esantis medienos kure, gali būti įvežtas į šalį per sienos perėjimo punkto radiologinio patikrinimo vartus.

^{137}Cs savitasis aktyvumas medienos kure ir jos deginimo produktuose matuotas gama spektrometriniu metodu naudojant didelės skiriamosios gebos germanio detektorius. Medienos kuras degintas 400 °C temperatūroje iki pastovaus svorio. ^{90}Sr savitasis aktyvumas nustatytas gautuose pelenuose jį išskyrus radiochemiškai ir aktyvumą matuojant skysčio scintiliacijos skaitikliu. Vertinant apšvitą dėl radionuklidų išlakose taikytas konservatyvus modelis su visuotinai priimtais vertinimo modeliais. Dozės galios nuo ^{137}Cs medienoje modeliavimui naudota Visiplan suite 4.0 3D ALARA programa.

Radiologinių tyrimų rezultatai parodė, kad ^{137}Cs savitasis aktyvumas Lietuvoje pagamintame medienos kure mažesnis už 18 Bq/kg. Didžiausias šio radionuklido savitasis aktyvumas nustatytas medienos kuro granulėse iš Ukrainos – 160 Bq/kg. Sudeginus medienos kurą, nustatytas didžiausias ^{137}Cs savitasis aktyvumas lietuviškos medienos kuro ir medienos kuro, pagaminto Ukrainoje, pelenuose siekė atitinkamai 2 340 ± 220 Bq/kg ir 9 800 ± 700 Bq/kg. ^{90}Sr savitasis aktyvumas tirtuose medienos mėginiuose buvo kur kas mažesnis nei ^{137}Cs. Įvertinus apšvitą, kurią gautų gyventojai šiluminių elektrinių aplinkoje, deginant labiausiai ^{137}Cs ir ^{90}Sr užterštą medienos kurą, nustatyta, kad apšvita bus ne didesnė kaip 10 μSv per metus. Modeliuojant nustatyta, kad medienos kuro produktai, kuriuose yra daugiau nei 3,2 Bq/g ^{137}Cs, būtų aptikti radiologinio patikrinimo metu sienos perėjimo punkte (vežamo krovinio dozės galia būtų didesnė kaip 0,2 μGy/h). Sudeginus šitokį medienos kurą, pelenuose ^{137}Cs savitasis aktyvumas galėtų būti didesnis už nebekontroliuojamąjį lygmenį 10 Bq/g.

Raktažodžiai: ^{137}Cs ir ^{90}Sr, medienos kuras, apšvita, nereguliuojamasis veikmuo, išlakos