REHABILITATION OF RADIOACTIVE CONTAMINATED FORESTS

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Abstract

As a result of radiation accidents and nuclear-weapon tests at the territory of the former USSR a part of the Forest Fund of 23 subjects of the Russian Federation has been contaminated by radionuclides. The contaminated forests, which are included in a structure of more than 130 forest management units (leskhozes) and more then 330 local forest management units, as a rule, are located in highly inhabited regions with traditionally intensive forestry management and high level of forest resources use.To provide radiologically safe forest management in the contaminated areas, the Federal Forest Service has developed and validated a special system of countermeasures. Use of this system makes it possible to diminish significantly the dose to personnel, to exclude the use of forest products with contamination exceeding radiological standards and to provide protection of the forest as a biogeochemical barrier to radionuclide migration from contaminated areas to human habitat.

More than 30 percents of the territory of Russia contaminated by radionuclides (in some regions-up to 50 percents) are covered by forests. Different countermeasures are to be applied at the territory of more than 330 forestries included in 133 forest management units in 23 subjects (regions, lands, republics) of Russian Federation.

The scale of radioactive contamination of the forest fund is essentially different in terms of area, density of soil contamination and composition of radionuclides. The most significant countermeasures were needed after the Chernobyl and East Ural accidents.

The area of forests managed by the Federal Forestry Service, contaminated ^{137}Cs with soil deposition above 37 GBq/km^2 (1 Ci/km^2) as a result of the Chernobyl accident is estimated at about 1 million hectares at the territory of 15 subjects of the Russian Federation (data for January 1, 1999). The main part of this territory is covered with forests. A total growing stock is about 145 million m^3 (Table 1).

TABLE 1. DATA ON THE FOREST FUND CONTAMINATED BY RADIONUCLIDES DUE TO THE CHERNOBYL ACCIDENT (JANUARY 1, 1999)

^{137}Cs soil deposition, Ci/km^2	Federal Forest Fund lands, thous. ha	Forest lands, thous. ha	Forested area, thous. ha	Growing stock, million m^3
1-5	856,3	835,2	816,9	128,4
5-15	96,6	91,9	89,6	14,1
15-40	27,5	27,5	27,1	1,7
above 40	2,2	2,0	2,0	0,3
Total contaminated	982,6	956,6	935,6	144,5

The total area of contaminated forests in the Ural region is about 647 thous. ha, including 424 thous. ha-in the Chelyabinsk region, 184 thous. ha – in the Sverdlovsk region and 39 thous. ha – in the Kurgan region, that makes about 35% of all contaminated territory. In the separate regions a part of forest lands comprise from 27% to 60% of contaminated territory. The radioactive forest contamination is registered at the territory of 15 forest management units in these three regions.

The territory of the forest fund within the East-Ural Radioactive Track (further EURT) is mostly contaminated by ^{137}Cs and ^{90}Sr, and the latter obviously dominates on the vast bulk of lands managed by Rosleshoz. Only in the Kasly forest management unit 57,4 thousands hectares contaminated by ^{90}Sr were revealed during mapping in 1995-1999. The soil deposition of ^{90}Sr in separate quarters reaches 35 Ci/km^2, but the main part of forests is contaminated much less (with ^{137}Cs soil deposition up to 2 Ci/km^2 and ^{90}Sr soil deposition up to 3 Ci/km^2).

The radioactive contaminated forests are mostly located in densely inhabited regions with traditionally intensive forestry management and high level of forest resources use. At the same time, an application of technical, agricultural and biological measures in most conditions is economically unreasonable.

TABLE 2. VOLUME OF FINAL FELLING IN 1998 FOR THE ENTITIES OF THE RUSSIAN FEDERATION, CONTAMINATED BY RADIONUCLIDES DUE TO THE CHERNOBYL ACCIDENT (THOUS. m^3)

Entity of the Russian Federation	Allowable cut		Actual harvested volume		Using of allowable cut (%)	
	Coniferous	Total	Coniferous	Total	Coniferous	Total
Leningrad Forest Management Body (FMB)	3523.4	7702.1	1987.2	3312.8	57	40
Bryansk FMB	323.2	1348.1	185.4	388.5	57	29
Kaluga FMB	204.3	1700.5	121.0	258.9	59	15
Orel FMB	0.0	28.2	0.0	1.6	0.0	6
Ryazan' FMB	411.3	1333.0	309.0	441.5	75	33
Smolensk FMB	408.8	1912.4	157.2	325.5	38	17
Tula FMB	0.0	0.0	0.0	0.0	0.0	0.0
Republic Mordovia FMB	76.7	715.5	57.6	188.4	75	26
Belgorod FMB	0.0	0.0	0.0	0.0	0.0	0.0
Voronezh FMB	0.0	0.0	0.0	0.0	0.0	0.0
Kursk FMB	0.0	0.0	0.0	0.0	0.0	0.0
Lipetsk FMB	0.0	0.0	0.0	0.0	0.0	0.0
Tambov FMB	26.0	116.9	24.9	48.5	96	41
Penza FMB	212.8	1131.8	190.5	435.1	90	38
Ulyanovsk FMB	312.6	1422.4	253.8	670.9	81	47
Total:	5499.1	17410.9	3286.6	6071.7		

The studies of the Chernobyl accident consequences conducted by Russian, Ukrainian and Belorussian scientists have revealed, that the forestry workers directly working in the forest receive doses by a factor of 2-2.5 higher, than general population, and belong to the group of elevated radiation risk. The role of forests in forming of the population dose increases with time elapsed from the moment of the accident. For example, according to the Nuclear Safety Institute data [1], contribution of mushrooms and berries in the internal dose in rural inhabitants of the Chernobyl accident area changed from 10-15% in 1987 to 40-50% in 1996.

More than 6 million m^3 of timber were harvested (in the process of final harvesting) only in the "Chernobyl regions" of Russia in 1998 (Table 2). Up to 30% of timber is harvested by way of intermediate use. Not less than 10 million m^3 of timber (more than a half of which is coniferous) are earmarked to be harvested in 2000 in forests contaminated by radionuclides due to Chernobyl accident.

In total, approximately12-15% of annually harvested timber is produced in the subjects of the Russian Federation contaminated by radionuclides in different years. In most cases this timber corresponds to the established standards. But in some special conditions of the forest growing, a part of timber is contaminated by radionuclides over the permissible standards even at the rather low radionuclide soil deposition and cannot be used for house constructions (Table 3).

TABLE 3. LIMITING LEVELS OF ^{137}Cs SOIL DEPOSITION IN DIFFERENT FOREST TYPES, UNDER WHICH SALE OF STANDING TIMBER FOR HOUSE CONSTRUCTION IS ALLOWABLE

Soil humidity	Tree species	^{137}Cs soil deposition, Ci/km^2 Soil enrichment (humufication)			
		Poorest -À	Rather poor -B	Rather rich-C	Rich oak forest -D
Very dry-0	pine birch	not assessed		74 74	not assessed
Dry-1	pine birch	not assessed		24 12	not assessed
Fresh -2	pine birch	8 4	10 5	18 9	37 18
Wet-3	pine birch	not assessed		8 4	not assessed
Rather wet-4	pine birch	not assessed		7 3	not assessed
Very wet-5 (bog)	pine birch	not assessed		6 2	not assessed

According to published data and observations results, from 10-15% to 30-35% of radionuclides have migrated in the mineral soil layer by the present time. The main fraction of radionuclides is accumulated in the upper 5 cm layer (Fig. 1).

The total content of mobile forms of radionuclides in soil does not exceed 4-5%, therefore even at the most unfavorable conditions, 90-95% of radionuclides are captured in the forest litter and soil. It is established that about 4-6% of the total reserve of radionuclides in the forest biogeocenoses have been transferred in different organs and tissues of vegetation, mushrooms and animals by 1999. The root pathway of radionuclides migration to vegetation began to dominate comparing to the atmospheric one approximately in 2-3 years after the Chernobyl accident.

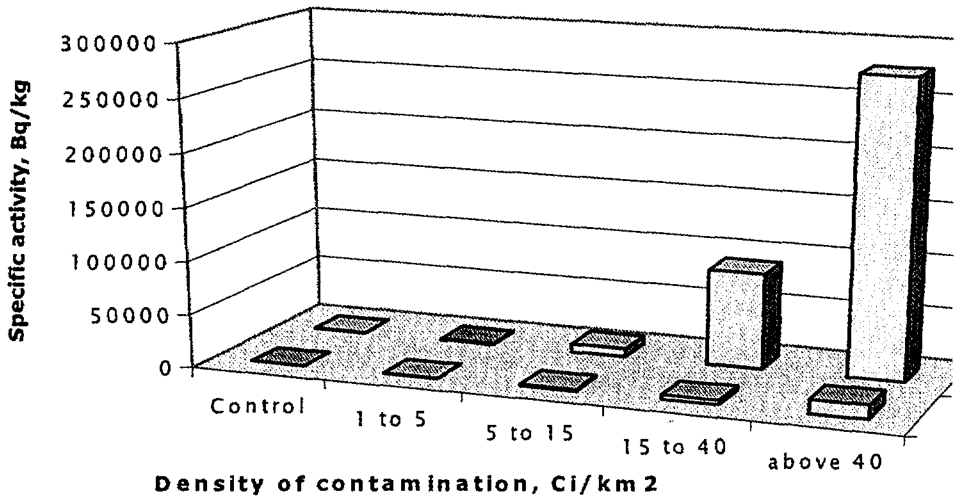

FIG.1. Contents of ^{137}Cs in the forest litter and soil in accordance with the density of soil contamination (average data for 1994-1999).

At the relative stabilization of migration processes in the contaminated forest ecosystems, the concentration of radionuclides will change according to the law of radioactive decay per the proximate 15-20 years.

To sum up the results of studying radionuclides migration in the forest ecosystems at the remedial stage of the Chernobyl accident, it should be noted, that increasing humidity and reducing soil humus contents results in increasing transition of ^{137}Cs both in grassy, shrubs and wood plants.

Results of the key plots observations expressed in the standardized transfer factors relating to the forest growing conditions allow to conclude, that at the root uptake of radionuclides the barked wood is the least contaminated part of the tree, further the concentration increases in the small branches, leaves (needles), bark and bast respectively. The bast tissues are most contaminated by ^{137}Cs due to the root uptake, but accounting the atmosphere pathway, bark (especially outer bark) frequently contains more radionuclides, than bust (Fig. 2).

Among the wood species growing under identical conditions and density of soil contamination, the greatest transfer of ^{137}Cs into organs and tissues is observed for birch and aspen. Coniferous species (pine and fur-tree) are characterized by the lowest uptake of ^{137}Cs from soil.

The main principles of radioecological classification of forest types were developed in Russia [2]. The classification is stipulated by the following attributes: type of forest growing conditions, structure of plantings, distinction of wood species in intensity of radionuclide absorption from soil and their accumulation by organs and tissues, radiosensitivity of wood species and their ability to detain and keep radionuclides from the atmosphere. The radioecological classification of forest types is a component of the forestry counter-measures system application at the early, intermediate and recovering stages of the radiation accident.

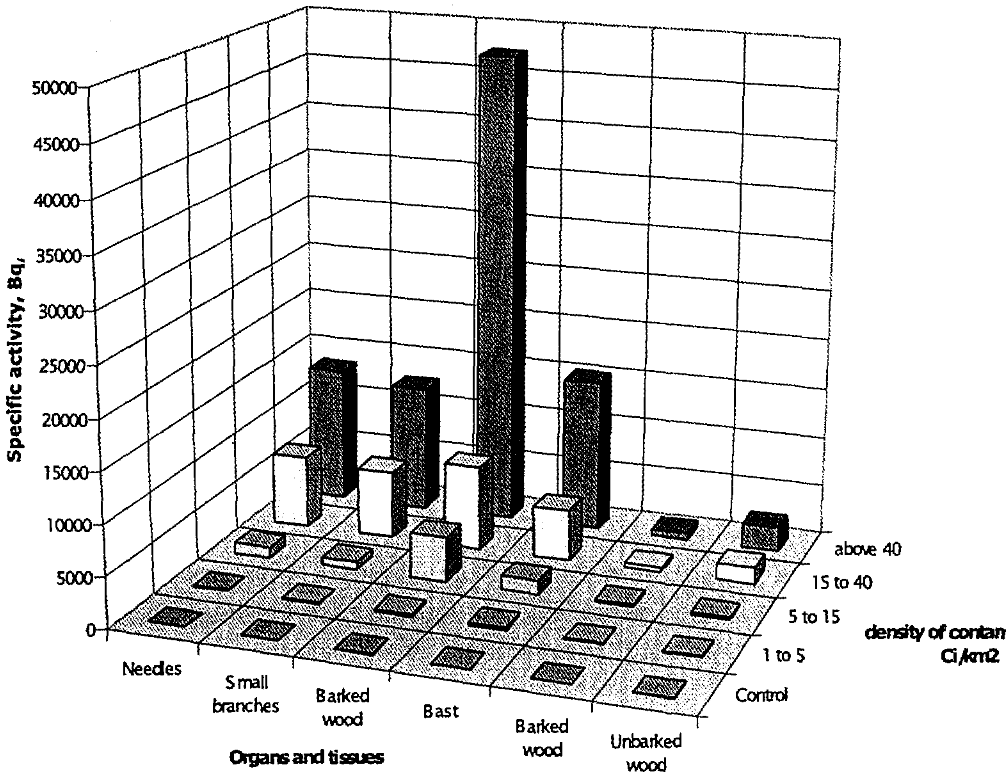

FIG. 2. Concentration of ^{137}Cs in different organs and tissues of pine (average data for 1994-1999).

To provide radiologically safe forest management in the contaminated areas, the Federal Forest Service has developed and validated a special system of countermeasures to govern the state forest resources accounting for a factor of radioactive contamination.

The term "protective measures in forest management" or "forest countermeasures" implies a range of administrative-structural, technological, sanitary, and other measures and activities intended to reduce or exclude additional irradiation doses (above the background and technogenic radiation level for the given territory) to the forestry personnel and population in the areas exposed to radioactive contamination due to nuclear accidents [3-5].

Organizational and technical countermeasures include regulation of forestry activity according to zones of radioactive contamination, system of radiation monitoring, system of timber certification in terms of radionuclides content, setting of standards for the forest products and working conditions. These measures are mandatory during long period of time and require essential financial expenditures comparing to the forest in the non-contaminated areas. The efficiency of these measures is rather high.

Technological countermeasures are applied to forests located in all the zones of radioactive contamination. They include: (1) Regulation of the forest use in different zones of radioactive contamination; (2) Development and use of technologies demanding minimum personnel; (3) Radiation monitoring and introduction of special measures to provide safe working conditions; (4) Radiation monitoring and special measures for forest-fire prevention under conditions of radioactive contamination [6] and others. The efficiency of the technological countermeasures is determined by the reduction of collective and individual dose burdens to the forest service personnel and the local population. Also, it is important to maintain biological sustainability of the forests and the overall ecological situation. This group of countermeasures is helpful for restoration of the agricultural and industrial activities in the region. It saves jobs and provides conditions for normal forest industrial activity.

The application of technological countermeasures requires the most significant additional financial expenses.

The limiting countermeasures (ban of forest use for industrial and recreation purposes, for collection of mushrooms and berries, for hunting, etc.) are used during different stages of the nuclear accident and could be used on a short or long term basis. They are used most often, do not require large additional expense, and are rather effective in terms of reduction of the dose of the local population. However, limiting measures cause significant economical damage to the forest industry due to stopping the forestry activity.

Informational countermeasures include scientific research; professional education and personnel training; information service to the forest managing bodies and local population in terms of radiological situation in the forests. These countermeasures should be used during all the stages of the accidental situation and complement forest management. Unfortunately, it is difficult to estimate the overall efficiency of informational countermeasures.

Social and economic countermeasures include improvement of working and living conditions and medical service for the forest personnel.

Preventive countermeasures are used in the vicinity of the nuclear installations during their routine exploitation to protect the environment in case of the hypothetical nuclear accident. The basic requirement to forestry activity in these forests is formation of plantings capable to sustain a sharp change of radiation situation in case of possible accident, to prevent degradation of the forest environment, to soften ecological consequences of the accident in the given region, and also to ensure performance of necessary protective measures and probably fast rehabilitation of the contaminated territory in accordance with the requirements of radiation safety.

Taking into account limited financial and material resources and application of strict dose limits for the population exposure and standards of the radionuclides content in the forest products, the radiation monitoring is of special importance. Providing the effective radiation monitoring becomes the basic and determining protective measure. To solve this task a service of radiation monitoring has been created by the state bodies of forestry management. The radiation monitoring of living standing timber, secondary forest resources and forest food products in terms of correspondence to permissible levels of ^{90}Sr and ^{137}Cs concentrations is an integral part of the radiation control. The development of such standards for timber and secondary forest resources was executed under the initiative of the Federal Forestry Service of Russia (Sanitary rules SP 2.6.1.759-99 [7] and their previous editions).

The long-term experience has shown, that the forestry activity should not be completely stopped in the contaminated forest ecosystems irrespective of the level of irradiation. Even in the most contaminated zones from which the population was removed an optimum complex of forestry measures is necessary to be carried out. First of all, these are measures for fires prevention and forest protection implemented according to the rules of radiation safety [8]. From several hundred up to several thousand wood fires annually occur only in four areas of Belorussia, Russia and Ukraine most contaminated by radionuclides. The radionuclides concentration in ash and incombustible materials can reach $n*10^{-6}$-$n*10^{-4}$ Ci/kg [3]. The consequences of such forest fires can worsen both environmental conditions in wide regions and living conditions for some hundred thousand people. A specific radioactivity and volume of burning products of forest combustible materials is to be considered while carrying out preventive measures, detection and extinguishing of forest fires in the contaminated forests.

A basis for practical application of the countermeasures in contaminated forests are principles modern radiation protection in case of intervention recommended by IAEA: substantiation and optimization. Thus, development of optimal strategy of the countermeasures at the regional level is supposed to be necessary. Providing the principles of sustainable forest management and keeping forestry functions, the strategy will allow to considerably decrease the levels of irradiation of the population and persons professionally connected to the forest.

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DISCUSSION AFTER THE PRESENTATION OF A.V. PANFILOV

K. Mück (Austria): According to calculations performed by me for a deposition level of about 500 kBq/m^2, the inhaling of aerosols from a large forest fire by people living in nearby villages would result in an excess dose of only a few microsieverts. In my view, therefore, the radiation hazards associated with forest fires may be exaggerated.

A.V. Panfilov (Russian Federation): Opinions differ about this in Ukraine, Russia and Belarus. It is an open question.