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Fire Hazard Assessment for the Forests Located in the Radiation-Contaminated Areas of Bryansk Region of the Russian Federation

Moscow-Bryansk
2011

Contents

1. The current state of problem

As a result of radiation disasters, accidents and incidents at nuclear fuel cycle enterprises, significant parts of forests in the Russian Federation have been subject to radioactive contamination. The largest-scale pollution, covering the territory of 19 subjects of Russian Federation, is related to the consequences of the Chernobyl disaster.

As a result of terrestrial radiation survey of forest fund soils, it was revealed that the forest fund (previously under the supervision of the Federal Forestry Agency) with an area of 982.6 thousand hectares has been radioactively contaminated as a consequence of the accident at the Chernobyl Nuclear Power Plant (NPP).

In Kaluga region, the area of contaminated forest fund is 162.0 thousand hectares. About 25 % of it has a density of soil contamination with cesium-137 above 5 Ci/km^2. Deciduous forests constitute 89 thousand hectares of plantings affected with radioactive contamination, and radioactively contaminated coniferous forests consist of 50 % of small stands, among which there is a great danger of fires.

In Tula region, 77 thousand hectares of forest fund territory are contaminated with cesium-137, previously under the supervision of the Ministry of Natural Resources (MNR of Russia), which is more than 86 % of all forest area contaminated in the region. The main part of forests contaminated with radionuclides is located in the area with density of soil contamination with cesium-137 from 1 to 5 Ci/km^2. About 15 % of the forest fund is located in the area with a density of soil contamination with cesium-137 from 5 to 15 Ci/km^2. More than half of contaminated forests are represented by middle-aged, premature and mature plantings, and among them the economically valuable hardwoods are dominating (22 thousand hectares).

Orel and Ryazan regions are also noted to have forest areas with soil contamination with cesium-137 with a density from 5 to 15 Ci/km^2, but most of contaminated forests belong to the area with a density of soil contamination with cesium-137 from 1 to 5 Ci/km^2. The contaminated forests of Orel region are represented by middle-aged hardwood and softwood trees, which also have important field-safeguarding and erosion preventive functions in the forest-steppe zone. In Ryazan region, 30 % of contaminated forests are represented by commercially valuable hardwoods.

Forests of Penza region are also contaminated on a considerable area (143.0 thousand hectares). The contamination of soils with cesium-137 with a density from 1 to 5 Ci/km^2 is noted at 10 forestry enterprises in parts of 39 forest districts.

This territory is dominated by deciduous species, but over a third part of the contaminated forests is coniferous forests, mostly flammable small stands.

In Leningrad region, all contaminated forests belong to the zone of residence with privileged socioeconomic status. Radioactive contamination of mosaic character is marked on an area of 85.7 thousand hectares. Forest lands make up 72 % of all the territory exposed to radioactive contamination during Chernobyl disaster. More than half of contaminated plants are conifers.

Forest land of the Ulyanovsk region with an area of 64.2 thousand hectares contaminated with cesium-137 belongs to the zone of residence with privileged socioeconomic status. They occupy 63 % of all contaminated areas of this region. They are represented mainly by softwood trees and flammable conifers.

In Voronezh region, 24.2 thousand hectares of forest land are contaminated with a density of 1 to 5 Ci/km^2 in 18 forest districts of 9 forestry enterprises. The large mosaic structure of radioactive fallout is typical there. In contaminated forests, the middle-aged stands of commercially valuable hardwood (mainly) and conifers predominate.

In Kursk region, radioactive contamination with a density from 1 to 5 Ci/km^2 found on the territory of 21.3 thousand hectares in 10 forest districts of 5 forestry enterprises. There are also areas with minor economic use, belonging to the area with a density of soil contamination with cesium-137 from 5 to 15 Ci/km^2. Contaminated forests in this area consist of 75 % of stands with a predominance of hardwood and softwood (pine) species, mostly middle-aged.

In Belgorod and Lipetsk regions, in the zone with preferential social and economic status, there are 15.4 thousand hectares of forest land, respectively, in 23 forest districts of 5 forestry enterprises and in 19 forest districts of 6 forestry enterprises. A large mosaic structure of radioactive contamination is registered there. Contaminated forests in groups of several quarters are located within the administrative regions and equally represented by conifer, hardwood and softwood plantings.

Large mosaic structure of radioactive contamination is also characteristic of the Smolensk region. Radioactive contamination, with the density corresponding to the zone with preferential social and economic status, is registered on the part of territories of 9 forest districts included into 5 forestry enterprises. The total area of contaminated districts is relatively low (5.0 thousand hectares).

The 3 forest districts of 3 forestry enterprises and 4 forest districts of 4 forestry enterprises, respectively, are located in the forest fund of the Tambov region and of the Republic of Mordovia, in a small area in the zone with preferential social and economic status. One or two groups of several contaminated quarters are identified on the territory of forest fund of these forest districts. Basically, these are the broadleaved species.

Given the dynamic nature of the radionuclides redistribution in forest ecosystems, the boundaries of zones of forest fund radioactive contamination need constant refinement.

A difficult radiation situation has developed in the Ural region as a consequence of the multi-annual work of the “Mayak” industrial association.

Dumping radioactive wastes in the shallow Techa river (1949-1956), explosion of one of the high-level waste tanks (1957), wind dispersal of radionuclides (1967) from the shores of lake Karachay, which was used to store medium-level radioactive waste, current radionuclide migration from contaminated marshes and industrial water reservoirs to the Techa river, and gas-aerosol emissions from “Mayak” industrial association since 1948, have led to contamination of the territory and to radiation exposure of population in the region.

As a result of only the first three of the above radiological incidents, a part of the territory of the Chelyabinsk, Sverdlovsk and Kurgan regions (about 23 thousand square kilometers) is subject to long-term radiation contamination.

Radiation situation on the territory of forest fund within the East-Ural Radioactive Trace is formed by strontium-90 and cesium-137, with mainly pollution of forest ecosystems with strontium-90. Distribution of forest fund area of Ural region, contaminated with radionuclides due to the accident and incidents at “Mayak” industrial association (a constituent of the Russian Federation), being under the jurisdiction of the Ministry of Natural Resources of Russia, is given in Tables 1 and 2.

Table 1. Distribution of Forest Fund Area of Ural Region According to the Density of Soil Contamination with Strontium-90, thousand hectares

Region	Total contaminated	Which includes density of soil contamination with strontium-90, Ci/km^2		
	Thousand hectares	0,15-1,0	1,0-3,0	Above 3
Chelyabinsk	160,38	127,66	22,82	9,9
Sverdlovsk	16,97	12,8	4,1	0,07
Kurgan	15,1	11,8	3,3	
Total	192,45	152,26	30,22	9,97

Table 2. Distribution of Forest Fund Area of Ural Region According to the Density of Soil Contamination with Cesium-137, thousand hectares

Region	Total contaminated	Which includes density of soil contamination with cesium-137, Ci/km^2			
	Thousand hectares	1...5	5...15	15... 40	Above 40
Chelyabinsk	18,55	18,47	-	-	0,08
Kurgan	0,76	0,68	0,08	-	-
Total	19,31	19,15	0,08	-	0,08

In the forests of Chelyabinsk region, on the territory of the East-Ural and Karachay Radioactive Traces, soil contamination with strontium-90 is found on an area of 160.38 thousand hectares, and with cesium-137 on 18.55 thousand hectares. Forest funds of four forest enterprises are subject to radioactive contamination: Argayashsky, Kaslinsky, Kunashaksky and Kyshtymsky. Out of 20 forest districts of these forestry enterprises, the territory of nine is contaminated both with strontium-90 and cesium-137. 80 % of forest areas contaminated with strontium-90 and 99.5 % contaminated with cesium-137 are included in the zones with 0.15 to 1 Ci/km^2 and with 1 to 5 Ci/km^2, respectively.

The forests of Sverdlovsk region contaminated with radionuclides (16.97 thousand hectares) are located on the territory of the East Ural Radioactive Trace. The main dose forming radionuclide here is strontium-90. Most contaminated are the four forest districts of the Kamensk-Ural forestry enterprise; moreover, 95.8 % of contaminated territory belongs to the zone with a contamination density of 0.15 to 1 Ci/km^2. On 0.07 thousand hectares of forest fund on the territory of Kamensky and Pokrovsky forest districts there is an even higher density of soil contamination (over 3 Ci/km^2).

The forest fund of the Kurgan region, contaminated with strontium-90, covers an area of 15.1 thousand hectares. All radioactively contaminated forests are located in the floodplain of the Techa River on the territory of Kataysk and Dolmatovsk forestry enterprises. All forest areas contaminated with strontium-90, and with cesium-137, refer, respectively, to the zones of 0.15 to 1 Ci/km^2 and of 1 to 5 Ci/km^2. During radiation survey, an accumulated soil contamination with cesium-137 with a density between 5 to 15, and strontium-90 between 0.15 to 1 Ci/km^2, was revealed in 136 sections of Kataysk forest district of Kataysk forestry enterprise on the area of 82 ha.

In accordance with the Federal Law № 200-FZ of 04.12.2006, the forests that used to be under the supervision of agricultural enterprises are combined with forests that used to be under the public administration of FFA. Information on the radiation situation in the forests of former agricultural enterprises of constituents of the Russian Federation, whose territories are exposed to radioactive contamination, is virtually nonexistent. The area of these forests according to preliminary data may be more than 0.5 million hectares.

Radiation situation prevailing in the forests as a result of radiation accidents varies greatly depending on the composition of radionuclides deposited. In areas of contamination of Chernobyl origin the forests are mainly polluted with cesium-137. Parameters like density of soil contamination, equivalent dose rate, levels of radionuclide content in forest resources - all these parameters are specific for the Chernobyl Trace.

Almost all forests contaminated with radionuclides are located in areas with high population density, where they have high ecological, social and economic importance. Radiation contamination has violated the existing regimes of forests use and reduced their recreational and resource function. However, it is not possible to completely discontinue the use of forests and it is important to undertake scheduled preventive and protective activities because of their traditionally-established economic, social- economic and territorial-infrastructural roles, environmental functions and the need to maintain biological and fire stability of forest sites, hydrological, anti-erosion and protective role of forests.

The indicators of ecological risks in the natural environment here are the density of radioactive contamination of soil by individual radionuclides (Ci/km^2), the exposure dose rate at 1 m from its surface (µR/h, µSv/h) and the radionuclides levels in forest resources that exceed hygienic standards. The objects of permanent radiation monitoring in areas with a density of soil contamination with cesium-137 of more than 1 Ci/km^2 and strontium-90 of more than 0.15 Ci/km^2 are: soil, debris layer, wood, minor, food, medicinal, forage and technical resources of forest, which imply a high content of radionuclides. Intensity of radiation dose is also controlled.

The most important tasks in dealing with forests, contaminated with radionuclides, are restoring their socio-economic importance in the infrastructure of radionuclides contaminated areas and retrieval into economic turnover.

Taking into account the inclusion of radioisotopes into biological cycle of substances and radionuclides delivery to vegetation, the self-cleaning of contaminated forests occurs only through natural radioactive decay of radionuclides. Therefore, the forest fund exposed to radioactive contamination will be for many decades included into the territories with radiation-ecological danger.

2. Forest Fund of Bryansk region

The area of land, on which the forests in Bryansk region are located, is 1236.9 thousand hectares, including land covered by forests - 1149.2 thousand hectares. A significant part of forests, 665.4 thousand hectares or 54 % of the total area, is allocated to protective forests. Commercial forests occupy 571.5 hectares, or 46 %.

The share of coniferous forests is 48 %, hardwood 6 %, and softwood 46 % of the forested area. Age structure is characterized by a predominance of middle-aged stands – 48 %. The share of young stands is 18 %, ripening stands – 17 %, ripe and overripe – 17%. The average age of stands is 49 years.

The area of artificial stands is 303 thousand hectares. Together with open forest communities they occupy 29 % of forested land. According to forest site regionalization, Bryansk region belongs to the mixed coniferous-broad leaved forests zone. Forests are characterized by high productivity. Total stand volume is 226 million m^3.

The forest fund of the Bryansk region is the most contaminated as a result of the Chernobyl disaster. The forest area with a density of soil contamination with cesium-137 above 5 Ci/km^2 occupies more than 100 thousand hectares. In areas with density of soil contamination with cesium-137 above of 5 Ci/km^2, about 40 % of forests were contaminated. Some forest districts in the south-western part of the region are entirely located in these zones. More than 16 % of contaminated forest lands were in the area with density of soil contamination with cesium-137 from 15 to 40 and over 40 Ci/km^2; in some forest quarters the density of soil contamination with cesium-137 reached 200 Ci/km^2.

Most (45 %) of contaminated forests of Bryansk region is made up of economically valuable coniferous stands of different ages, which are dominated by middle-aged and young stands. This results in a high fire danger of radiation contaminated forests.

Soil contamination above 15 Ci/km^2 persists on the territory of Bryansk region.

Among 4'343 population centers, included into the zones of radioactive contamination by decision of the Government of the Russian Federation, in 4'020 the average annual effective dose (AAED) does not exceed 1 mSv/year. In 321 population centers in Bryansk region and 2 population centers in Kaluga region the AAED exceeded the legal level - 1 mSv. The maximum levels of AAED reach: Tula region - 0.69 mSv/year, Orel region - 0.54 mSv/year, Kaluga region - 1.1 mSv/year, Bryansk region - 9.4 mSv/year.

The area of radionuclides contaminated forest fund in the Russian Federation, which is under the jurisdiction of the Federal Forest Administration

(FFA), exceeds 170.5 thousand hectares in Bryansk region. In addition, 140.6 thousand hectares of forests from former agricultural organizations managed by constituents of the Russian Federation are contaminated with radionuclides. In general, over 25 % of forest land is affected by radiation in the Bryansk region.

Most of these forests are located in areas of compulsory evacuation and relocation, in which forestry activities are suspended in accordance with radiation safety standards. Timber resources in areas of highest radioactive contamination (more than 15 Ci/km^2) exceed 6.3 million m^3, of which over 0.6 million m^3 of ripe and overripe wood.

Due to accumulation of dead wood, the sanitary state of forests has deteriorated in the Bryansk region. In the Zlykovsky and Klintsovsky experimental forestry enterprises, dead wood forms huge massifs among the stands that have not reached the age of maturity; the volume of dead wood constitutes 930 thousand m^3, and is annually growing by tens of thousands of cubic meters.

During the period of high fire danger, by the decision of the Bryansk regional administration of 30.04.2009 № 216-P, citizens’ visits and vehicles access to the forests is temporarily forbidden. Below are details on occurrence of forest fires and performance of fire-prevention measures (see Table. 3)

Table 3. Indicators of Forest Fires Occurrence Forest Administration in Bryansk Region, 2003-2009

Year	Quantity of fires	Area (ha)	Average area of one fire
2003	133	54.48	0.41
2004	59	21.52	0.36
2005	157	122	0.78
2006	263	229.24	1.25
2007	145	122.0	0.84
2008	241	336.0	1.39
2009	399	751	1.9

3. General Laws of Radioactive Contamination Impact on Forest Ecosystems

Among the factors of anthropogenic impact upon the environment, a special position is taken by the radiation factor, the ecological importance of which is constantly growing due to the increasing use of nuclear energy.

Radiation is marked by its persistent impact on living organisms; therefor, the ability of radioactive substances to migrate and accumulate in various elements of the environment constitutes a significant impact on the components of biosphere; as a result, living organisms are under the influence of not only external, but also of internal radiation.

The following factors define the degree of radiation damage to organisms in forest ecosystems: value of absorbed dose; radiation sensitivity of species; age, stage of growth and development of species; type of forest vegetation; weather conditions; and other.

Fluctuations in radiosensitivity of individual representatives of vegetation can be up to a factor 500. The highest radiosensitive has tree layer, especially of conifers.

Depending on the absorbed dose value, the radiobiological effects may be different with woody plants. When the absorbed dose is 80-100Gy or more, a complete die-away of aerial organs of conifers happens. The impact of the absorbed dose of 2000-5000 rad is characterized by partial desiccation of pine needles, absence or reduction of growth, morphological abnormalities in the needles and shoots, and completely suppressed reproductive ability.

Deciduous woody plants are 5-10 times more radioresistant than conifers. Total loss of hardwoods occurs at the absorbed dose of 500-800 Gy. At the absorbed dose of 5000-10000 rad, the reduction of growth, yellowing of leaves, formation of abnormal reproductive organs, morphological changes of young shoots, and reduced seed germination are observed.

Herbaceous plants and most shrubs are more radioresistant compared to woody plants. In particular, herbaceous plants are (on average) 10 times more resistant than woody ones.

Lower plants (mosses, lichens, algae) are exceptionally resistant to radiation: their vital activity depression is observed at doses tens to hundreds times higher.

Soil microflora is the most radiation-resistant component in ecosystems. At doses fatal for higher plants and animals, soil microflora usually remains unaffected.

In addition to external contamination, all components of forest cenosis also undergo internal contamination by radionuclides from soil to plants. In animal and human bodies the radionuclides enter through the food chains. In this context, the capacity of hardy-shrub species and herbaceous plants to accumulate long-lived fission products needs to be paid attention, necessitating regulation of radionuclide content in forest resources. It should be noted that radiation regulation of forest resources, as a source material, allows obtaining radiation safe products at all stages of processing.

The large capacity of radionuclides absorption by forest ecosystems and their inclusion into the biological cycle of substances turn forest into a powerful biochemical barrier to radionuclide migration. A significant part of radionuclides consisting of solid aerosols is mostly retained in trees crowns after the fallout from atmosphere. Then their vertical and horizontal migration begins, during its first phase the important transport media are precipitation and wind. Precipitation moves radionuclides from the upper to the lower part of the crown, and then – under the forest canopy. Wind transports radionuclides from the crown of one tree to another, under the canopy and to the surrounding area, with highest intensity at the initial, relatively short period, especially in the absence of rain.

An important role in radionuclides moving under the forest canopy is played by processes of biological migration: abscission of leaves, pine needles, small branches and other contaminated parts of trees. As a result of this migration, in deciduous forests a year after the fission products fallout, their share in trees crowns is reduced several times and, consequently, the pollution of debris layer and soil increases. In coniferous forests the self-cleaning of tree crowns is going 3-4 times slower. After this period, which is the most dangerous, the radioactive substances move into the debris layer and soil, where they are firmly fixed.

With the course of time, soil becomes a long standing, permanent source of radionuclide supply into the forest products due to the intake of radionuclides by plants through the root path. This process becomes the main pathway for timber contamination. Then, with vegetation, radionuclides enter animal and human food. The risk level of forest land contamination is determined not only by the quantity of radionuclides, but also by the composition of their radioisotope mixture in soil, for the reason that their physicochemical properties constitute the main factor determining radionuclides’ behavior in the soil, their biological activity in the system "soil - plant" and the ability to migrate through the food chain.

Long-lived radionuclides are of particular biological hazard, including, cesium-137 and strontium-90, which are chemical analogues of potassium and calcium, respectively, with high biological activity and mobility.

Cesium-137, getting onto the aerial parts of hardy-shrub species, quickly enters the wood, while the supply of strontium-90 by foliar way is tens and hundreds times slower. However, strontium-90 is the most mobile and easily incoming radionuclide through soil into woody plants. In opposite, cesium-137 is strongly sorbed by soil and for this reason proceeds into woody plants in relatively smaller quantities.

These radionuclides are produced in relatively large quantities during fission reactions in nuclear reactors and have a long (about 30 years) half-life, high rates of transfer into plants and intensive incorporation into biological processes. Therefore, radiation safety measures and peculiarities of forest management in contaminated areas are calculated for these two radionuclides according to their contribution to total exposure dose. Thus, as a result of disaster at Chernobyl nuclear power plant, the main dose forming radionuclide in contaminated forests proved to be cesium-137.

Accumulation of radionuclides in different groups of plants is marked with specific and other taxonomic differences. Mosses and lichens have the greatest ability to concentrate them. In some types of mushrooms concentration of cesium-137 can be as high as in lichens and mosses. Compared with mushrooms, transfer factors of radionuclides from soil to forest berries are considerably lower.

In different woods (with the same density of soil contamination and growth conditions), the basic forest forming species accumulate radionuclides in descending order as follows: softwood trees, hardwoods, conifers. Radionuclides accumulation in the tree layer is more intense in young stands than in middle-aged, pre-mature and mature forest stands; the trees of better growth class accumulate cesium-137 more intensively than ones with suppressed growth factors. In hydromorphic conditions, this process runs more actively compared to automorphic site conditions. All tree species have the highest content of radionuclides in vegetative organs (leaves or pine needles, and shoots), and the lowest levels in the wood. The content of radionuclides in cortex is also many times higher than their specific activity in the wood. The above-noted objective laws are important in managing forestry in contaminated areas.

The natural way of self-purification of contaminated forest areas is only through the radioactive decay of radionuclides contained. The risk of re-entry of radionuclides from the afforested areas, which could cause secondary pollution of non-forested areas, is minimal, except for situations related to forest fires.

Two periods may be discriminated how radioactive emissions impact on forests. The beginning of the first period is characterized by aerial (foliar) primary radiation contamination of aboveground forest vegetation. During this period takes place acute radiation injury of assimilating organs and buds. The major contribution to radiation burden is made by short-lived radionuclides.

Radiation injury of woody plants, depending on the absorbed dose, is expressed in the dying-away of aerial organs, morphological changes of needles, leaves, shoots, disruption of protein and lipid metabolism in assimilating organs, etc.

After decay of short-lived radionuclides, for a period of 2-3 years, a normalization of growth processes in partially damaged plant is observed. Long-lived radionuclides transfer into the soil and enter plants by the root path. This time is ranked as the end of the first period and stabilization of radiation environment.

The second period – the post-accident period – lasts for decades and is characterized by the contamination of the territory with long-lived radionuclides, especially, with cesium-137 and strontium-90. The main factor determining the level of contamination of forest products during this period is the root uptake into vegetation.

Summarizing the mechanisms discussed above, radiation levels in highest contaminated areas are so high that normal work is not possible and any work must be monitored by a radiation protection service. This makes both forest cleaning for fire prevention as well as firefighting almost impossible. Due to the radiation risks for forest workers, important parts of the forests in Bryansk have not been cultivated for 25 years now.

Maintenance of the forests is important to reduce radiological risks. Incidences have shown that radioactive contamination from forest fires can be transported over long distances. Therefore, not only inhabitants of the contaminated area are at risk of radiation exposure, but also people who live far away. E.g. after intensive forest fires in Bryansk in 2002 for example, the radiocaesium value was thirty times higher for a few days in Vilnius (Lithuania). If such elevated levels would remain for an extended period (e.g. several weeks during intensive summer forest fires), this could potentially lead to a measurable addition to the annual dose.

4. Radioactive Contamination on the Territory of Bryansk Region. Measurements Accomplished.

The highest radiation-contaminated area of Bryansk region is its south-western part.

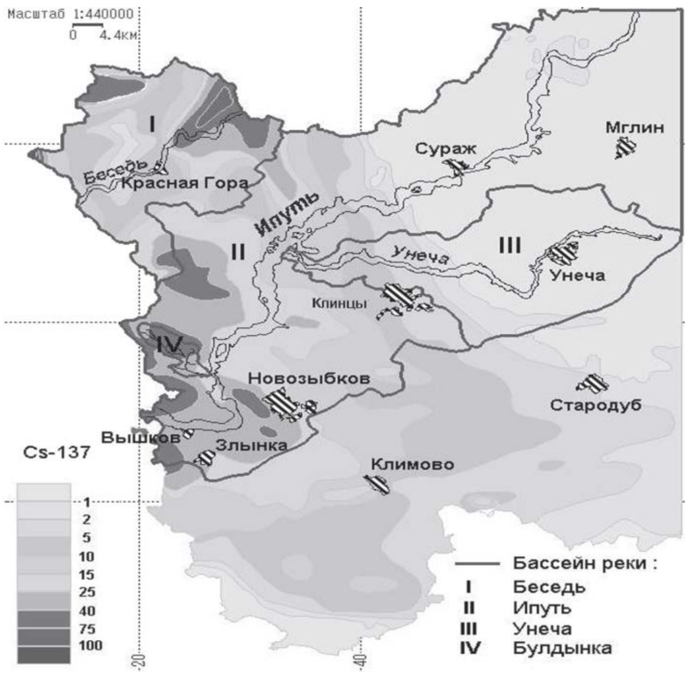

Figure 1. Cs-137 Contamination of the Western Part of Bryansk Region

In the frame of this report, an expeditionary group conducted researches in 4 population centers (Ushcherpie and Martyanovka of Klintsovsky district, Krasnaya Gora village of Krasnogorsky district; Tvorishino of Gordeevsky district) affected by the Chernobyl disaster and exposure dose rates (EDR) of gamma radiation was measured. In addition, sampling was conducted in the Zlynkovsky and Klintsovsky forestry districts, where the forest fund is one of the most polluted.

Measurements showed that on the territory of the Bryansk region contaminated by the Chernobyl disaster, in population centers with a contamination density with cesium-137 of more than 15 Ci/km^2 the EDR values ranged from 27 to 48 μR/h (Ushcherpie village, Klintsovsky district); in areas with contamination density with cesium-137 of 5-15 Ci/km^2 the EDR values ranged from 12 to 34 μR/h (Tvorishino village in Gordeevsky district, Krasnaya Gora village in Krasnogorsky district); and in areas with a density of cesium-137 contamination of 1-5 Ci/km^2 the EDR values ranged from 11 to 27 μR/h (Martyanovka village, Klintsovsky district)[1]. The total number of EDR measurements performed is 1'876.

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1 In a zone with an activity of 1 Ci / km^2, the average annual dose through external radiation is 1 millisievert per year, and accordingly in zones with 15-40 Ci / km^2, the dose can be up to 40 millisievert per year (international accepted maximum value for the annual dose for the normal population is 1.0 mSv/year). Additional doses can be received through internal radiation via food and water, and depending on food consumption patterns, these additional doses can exceed the dose received from external radiation.

On the territory of these population centers, as well as in forests of Zlynkovsky and Klintsovsky forest districts, 524 samples of soil and vegetation (parts of tree plantings and debris layer) were collected and analyzed for Cs-137.

The results of expedition group work are confirmed by official data.

In the European territories of Russia (ETR) contaminated by Chernobyl, near 1.6 Bq/m^2 of cesium-137 fell out during the 11 months of 2010, which corresponds to the global fallout over the same period of 2008. It is about 5.8 times over the average on the ETR. In some population centers located in contaminated areas, cesium-137 fallout was well above the average. The highest cesium-137 fallout over the period, as in previous years, was observed in Krasnaya Gora village of Bryansk region - 8.2 Bq/m^2 during the 9 months of 2009 (10.6 Bq/m^2 in the same period of 2008, for the whole of 2008 - 13.8 Bq/m^2).

In accordance with the results of forests survey of the Bryansk region, it was found out that 171.3 thousand hectares of forest area are contaminated by radionuclides as a consequence of Chernobyl nuclear power plant disaster (according to contamination degree): 1-5 Ci/km^2 - 102.6 thousand hectares, 5-15 Ci/km^2 - 39.7 thousand hectares, 15-40 Ci/km^2 - 26.8 thousand hectares, more than 40 Ci/km^2 - 2.2 thousand hectares), which substantially limits all kinds of forest management in them.

The radiation survey in Zlynkovsky and Klintsovsky forest districts showed that ionizing radiation dose in snow is 1.5-2 times lower than in absence of snow, as the water in the snow layer provides radiation shielding and dissipates the radiation.

Gamma-radiation intensity also depends on the density of soil contamination, and the parallel reduction of its intensity connected to the speed of vertical migration of cesium-137 into the soil (soil profile) and natural decay of dose-forming radionuclides.

Contemporary radiological levels in the forests of Bryansk region are most easily traced by measuring levels of cesium-137 specific activity (SA) in the structural parts of the main forest forming tree species (wood in cortex, wood without cortex, leaves and pine needles, birch, aspen, spruce).

Leaves and needles are the component of forest ecosystems, which actively accumulate cesium-137. This fact determines the high levels of radioactive contamination of debris layer in coniferous and deciduous forests of Bryansk region, even at low densities of radioactive contamination of soil in forest fund. When the density of soil contamination surpasses 10 Ci/km^2 and more, birch and aspen wood stripped of bark, and in areas contaminated with more than 15 Ci/km^2 (which is the case in most forests in the Bryansk region) pine and spruce wood stripped of bark, as a rule, has higher than allowable levels for housing construction (370 Bq/kg).

Levels of cesium-137 in timber of main forest forming species, and also in minor forest resources in areas with contamination levels of 15-40 Ci/km^2 on the territory of Bryansk region, allow the use of wood harvested there, but only with significant restrictions, provided for in the regulation "Permissible Levels of Cesium-137 and Strontium-90 in Wood and Minor Forest Resources Released in Stands in the Forest Areas Contaminated with Radionuclides, and Forestry Products (Sanitary Regulations - SR 2.6. 1.759-99)".

High levels of cesium-137 specific activity in leaves and needles of main forest forming species in areas with contamination levels of 15-40 Ci/km^2 on the territory of Bryansk region cause very high levels of radioactive contamination of debris layer, with average values of 12'900-36'000 Bq/kg.

High levels of cesium-137 specific activity in leaves and needles of main forest forming species in areas with contamination levels of 40 or more Ci/km^2 on the territory of Bryansk region cause very high levels of radioactive contamination of debris layer, with average values of 28'500-48'000 Bq/kg and more.

Debris layers for all types of tree formations and site conditions have transition coefficients (TC) for cesium-137 about 10 times higher than the TC for cesium-137 into the timber of the said forest forming species. The radionuclides are increasingly integrated into the wood of the trees, and today can be found in the uppermost layers of wood (5 – 8 cm), and cesium-137 also quickly accumulates in the leaves and needles. Due to the ongoing incorporation, every year more than ten thousand m^3 of wood becomes unusable for commercial use.

As a result of restrictions for forestry activities in the Zlynkovsky and Klintsovsky areas, according to our expert estimates, about 1 million m^3 of dead wood is accumulated. This volume is increasing annually by tens of thousands m^3, resulting in a deterioration of the sanitary state and turning these areas into the zones of increased anthropogenic hazard. Therefore, at present time it is a very urgent issue to involve the cleanest wood from south-western districts of region into economic activities (the most contaminated by radionuclides are the forests of Klintsovsky and Zlynkovsky experimental forestry enterprises), while ensuring radiation safety of both workers and consumers of wood. Timber production from this raw material involves additional costs: recycling of contaminated waste; radiation monitoring of personnel, premises and products.

According to our calculations, the most economical option for timber production is the use of wood from radiation-contaminated areas with a contamination density under 15 Ci/km^2, the least cost-effective option – the wood with contamination density over 15 Ci/km^2 (useful output of lumber decreases as a wood top layer of 1-2 cm needs to be removed). The most appropriate period for wood harvesting is in winter time, as the radiation levels at sites decreases by a factor of 1.5-2, however, it increases the production costs of timber. It is also necessary to take into account the quantity demanded and distribution channels of marketable products from such wood.

A need to address the problem of use of wood in these areas is caused by negative dynamics of radionuclides accumulation there and by the deeper penetration of cesium-137 into tree trunks in recent years that characterizes the economically justified wood production in areas with a contamination density of 15-40 Ci/km^2 only until 2010 (upon that it will be subject to a 100 % disposal).

5. Dynamics of Health and Demographic Indicators on the Southwest Territories of Bryansk Region

Radioactive contamination of varying intensity has affected 17 districts of the Bryansk region. Significant contamination is present on 8 territories of the region.

The resident population in the region as of 1 January 2005 amounted to 1'346.5 thousand people, including 271.5 thousand in the south-western territories. Since 1986, the resident population of the Bryansk region decreased by 8.3 %, in the south-western territories by 17.9 %. The decrease in population is mainly caused by a reduced birth rate. Migration flow of population does not cover natural losses.

From 1986 to 1991 the main reason for population outflow was the Chernobyl disaster. Already in 1986, a negative migration balance (excess of departures over arrivals in region) was noted. The deficit between the Bryansk region and other regions of Russia amounted to 5.9 thousand people, between the region and the republics of the USSR to 18 thousand people. Since the beginning of economic reforms, the situation changed dramatically. In 1992, inflow into the region from other regions of Russia exceeded outflows, and the positive migration balance amounted to 3.8 thousand people. A significant increase in population due to its arrival from neighboring countries was observed until 1995.

In 2004, 10'984 people were involved in migration process on the south-western territories, i.e. 21.6% of total migration in the region. In 2003 this figure was 20.5%. The migration balance in these areas in 2004 was 488 people (2003 - 528 people).

The determining factor for population decline in the region is the natural decline of population, which was first observed in 1991, and in areas affected by radioactive contamination it was observed already before the accident (except for the cities Klintsy and Novozybkov, both Krasnogorsk district). The highest level of natural decline was registered in the Bryansk region in 2002 - 10.4 per 1000 of people, and in the south-western territories in 2003 - 11.6. In the Klintsovsky district it was 17.5, in the Zlynkovsky district 15.4 per 1000 people; these were the highest numbers in the region in 2003. Especially pronounced losses in resident population, for the last 18 years, were in the following regions: Krasnogorsk -37.0 %; Klintsovsky -35.3 %; Novozybkov -30.8 %.

In 2004, in the south-western territories the natural decrease was in total 3'043 people, or 11.1 per 1000 people, which is 13.3 % more than the average for the region. This indicator is the highest in the Klintsovsky, Starodubsky, and Zlynkovsky districts.

In 2004, the birth rate in the south-western territories was 9.0 per 1000 people, which is 2.2 % lower than the regional rate (9.2). Higher birth rates in radiation areas in 1988-2002 are explained by some rejuvenation of population due to high migration rates in those years. In addition, social and psychological adaptation of population to the existing conditions of life took place. The highest birth rate in 2004 is noted in the Novozybkovsky district (10.7) and in the Zlynkovsky district (9.8 per 1000 people).

If a low birth rate is increasingly associated with social and economic instability, the total mortality rate is largely associated, in addition to these factors, with population age. The share of persons at retirement age at the beginning of 2005 amounted to 23.3 % of the total population in region, and in the south-western territories to 25.5 %.

In 2004, the number of deaths per 1000 of people in region was 19.0, while in 1986 the number was 11.3; on the territories affected by radioactive contamination this indicator was 20.1 in 2004 (in the region - 19.0), which is 1.6 times higher than in 1986 (12.3). The highest mortality rate in 2004 was recorded in the Klintsovsky district - 26.2; the Zlynkovsky district - 24.8; the Starodubsky district - 23.4; the Klimovsky district - 21.8; the Krasnogorsky district – 20.6; and the Gordeevsky district - 20.5.

In 2004 (as in recent years), the main causes of population mortality in regions affected by the Chernobyl disaster are: diseases of circulatory system – 67.5 % (in region – 64.7 %), and on the second place - injuries, poisonings and other consequences of external causes – 11.6 % (in region – 13.0 %), and the third place - tumors – 9.2 % (in region – 10.9 %).

Mortality from diseases of circulatory system in the region tends to increase in comparison with 1990; in 2004 it grew by 64.6 % in region, in the south-western territories this indicator varies, but in comparison with 1990 it increased by 74.8 %.

The death rate from cancer in the south-western territories during the last three years is reduced, in 2004 it was 184.7 per 100 thousand people, which is 10.4 % below the average regional rate (206.1).

The death rate from injuries, poisonings and other external causes for the period 2002-2004 varies both in the region and in the south-western territories; in 2004 this indicator in the south-western territories (232.7) is below the regional number (247.0) by 5.8 %.

The infant mortality rate in the Bryansk region for the past 20 years decreased by 30.8 %, but it is not possible to say that there have been significant positive changes - periods of recession of infant mortality alternated with growth periods. In the south-western territories, to the contrary, there has been an increase in infant mortality rates - in 2004 by 14.7 % compared to 1986. In addition, it should be noted that the reduction in absolute number of deaths of children under one year old is largely influenced by the decline of birth rate (in the south-western territories for the period 1986-2004 by 1.7 times). In 2004, in the south-western territories, the infant mortality rate amounted to 15.6 per 1000 live births, which is 6.8 % higher than in 2003 (14.6) and 31.1 % higher than the regional average - 11.9. The stillbirth rate varies in the south-western territories, in 2004 it was 9.6 per 1000 total births or 12.9 % higher than in the region (8.5). Perinatal mortality also varies in the south-western territories, in 2004 it was 13.6 per 1000 total births, which is 3.0 % higher than in the region (13.2).

Given the current demographic situation on the south-western territories and in the regions as a whole (low birth rate and high level of total mortality, reduction of migration growth), there is a stable natural population decline.

The forecast for the coming years sees an increased population reduction as a consequence of exposure of background radiation on human health in conjunction with socio-economic factors.

6. Status of Forest Fire Protection System

Emerging in the last years is an increase in the number of forest fires, showing the need to strengthen preventive measures that do not require, as a rule, large financial costs, but reduce the risk of emergence and spread of forest fires. Special attention should be paid to strengthening fire prevention education through electronic media and enforcement of fire safety rules, as well as scaling up of planned burning of vegetation to reduce forest fuel reserves.

The most acute problem is the persistent deficit of financial, material and technical resources provided for protection of forests. Lack of these resources is exacerbated by delays in payments, making it extremely difficult to timely prepare forces and means of fire fighting for the beginning of the fire season. An important condition for stabilization of forest fire services is the assignment of costs for forest protection to the category of secure items in the federal budget. An urgent solution is required for the issue of partial financing of forest protection from the budgets of the constituents of the Russian Federation.

In 2002, the Russian Federation State Duma Committee on Safety held a meeting, which addressed the issue of fire safety system for forests and peatlands in the Russian Federation. The discussion was attended by deputies of the State Duma, representatives of executive authorities of constituents of the Federation, Ministry of Emergency Situations, Ministry of Natural Resources, and the Hydrometeorological Center of Russia. Speakers noted that Russia's forests have global ecological importance and are a crucial factor to regulate and stabilize the environment.

Back in 2002, in the course of implementation of state fire control by the State Fire Service of the Ministry of Emergency of Russia, significant deficiencies in the organization and carrying out of measures to prevent forests and peat fires were found out. Human and material resources belonging to forest protection services, municipal structures and forest user are not fully involved; involvement of internal affairs officers to patrol fire hazardous locations is not organized at appropriate level; financing of work for extinguishing of forest and peat fires is not resolved efficiently; landfills of household wastes are poorly controlled; not organized is the control on the fulfillment of decisions on implementation of fire safety measures aimed at preventing the spread of burning forests and peat on the territory of population centers, horticultural societies and suburban cooperatives.

In this regard, the Committee on Safety suggested to consider the possibility to review the recently formed approach to the issue of authority and responsibility in the maintenance of fire safety of the Ministry of Natural Resources of the Russian Federation, Ministry of Emergency Situations, government authorities Federation constituents and local self-government, and also forest users, independent of ownership and their allocation by federal laws, as well as to establish a unified system of fire detection and extinguishing as a part of a unified state system of prevention and liquidation of emergency situations in the Russian Federation.

The Committee recommended the Ministry of Emergency Situations and the Ministry of Natural Resources of Russia, together with the authorities of the Federation constituents, to develop a program and ensure creation of a special reserve and auxiliary equipment, communications equipment and personal protective equipment, fuel and lubricants of the State Forest Guard Service and the State Fire Service, to provide for an increase in the volume of deliveries, including using possibilities of conversion and reduction of the Armed Forces of Russia, as well as to prepare proposals for amendments and additions to the Criminal Code in terms of strengthening criminal liability for environmental crimes. In this regard, the Committee proposed to consider possibility of amending the Forestry Code, Land Code, the Federal Law "On Local Self-Government in the Russian Federation" and the Federal Law "On Fire Safety", which specify the powers of public authorities of the constituents of the Russian Federation, local self-government, the State Forest Guard Service of the Ministry of Natural Resources and the State Fire Service of the Emergency Ministry of Russia.

Preparations for the next fire season at sites may be studied by the example of the disastrous situation in the 2010 summer fires.

For example, in recent years, federal budget provided funding of forestry enterprises at the level of 25 % of the budgeted amounts. This level does not allow even to pay salaries to forestry enterprises workers in full volume. As the forest service do not possess sources of own working capital, this results in debts increase on social payments and growth of penalties from the tax authorities.

In this situation, the summer 2010 forest fires turn into a real tragedy. On the board of directors of the State Forest Service of the Natural Resources Committee, it was decided that from April 2010, due to a lack of financing, forest enterprises will move to a shortened working week, i.e. they will work one day out of seven. And this happens at the beginning of the fire season. Forest enterprises move to one-day working week, equipment is not ready, reserves of fuel and lubricants are impossible to create, people cannot be stationed at the fire-chemical stations as there is no guarantee of labor payment. Labor protection issues (protective clothing, food, vaccination against tick-borne encephalitis, professional instruction) also remained unresolved.

How much money is spent on fighting fires and what are these losses in financial estimation? No one will call exact figures. Prevention, armament, equipment, fire towers, aircrafts, fuel, spare parts, protective clothing, salary to those involved in firefighting, burned property, dead people, ecological consequences – if all the above is calculated, the amount of money will be huge. Many people have unserious attitudes to forests. But the biggest problem is that a burning forest is nobody’s forest, the state’s forest, but for prevention “real” money are needed. But in any case, the cost of fire suppression is immeasurably less than its damage to nature. Trees are one thing. But did anyone account for all the dead nests, rare plants, animals? How do we count the psychological damage when a person, instead of beautiful nature, sees scorched earth?

The Moscow region in 2002 spent 123 million rubles (CHF 5.85 million at that time) for fire extinguishing.

The question arises that is often asked by forest workers: is it not better to spend this money on effective forest protection? After all, its absence is the most important reason that fires are not detected at early stages; fires have time to ignite and large forces are needed to extinguish them, with assistance of expensive equipment and a lot of people. Forest rangers get small salaries for immediate protection of forests - a few hundred rubles, which is difficult to live with. All the rest of the salary they receive through various side-jobs: improvement of cutting, sanitary felling and so on. Due to these second jobs, foresters rarely appear in their assigned territories, thus, there is nobody to detect occurring wildfires. In Moscow region there are almost 2'400 foresters, each of which has an assigned forest area of several square kilometers. If part of the money allocated to firefighting was spent on foresters salaries in order to perform their direct duties (forest protection from fires and forestry violations), each of them could get decent wages during the fire season. That is foresters could devote all their working time to protection of forests against fires, thereby not thinking of side-jobs. And that means, the risk of large forest fires could decrease by a factor of ten.

The main reason of fires is careless handling of fire in forests. This causes 70-90 % of forest fires. Weekend campers as well as berries and mushrooms pickers, a total number of 2-3 million persons, travel to the forests of the Moscow region, increasing the number of fires by 1.5-2 times.

After the weekend, forest services extinguish fires all week. By the next weekend, the cycle repeats again. Forest services, e.g. with 2'370 staff in the Moscow region, cannot cope with this outbreak. 1'850 foresters and forestry experts are also included there; they have somewhat different function – first of all, to restore the burned forests.

By RF Government Decree #35 of 10 January 1999, the Federal Target Program "Fire Protection of Forests for 1999-2005" was adopted. It deserves special attention, as it vividly reflects all the issues of forests fire protection.

The main developers of the program are the Ministry of Economy, Federal Forestry Service, Ministry of Agriculture and Food, Ministry of Defense, and the State Committee of the Russian Federation for Environmental Protection. The area of forest fund supervised by the organizations in 1999 are:

- Federal Forestry Service of Russia – 740.59 mln. hectares;
- Ministry of Agriculture and Food of Russian Federation – 43.3 mln. hectares;
- State Committee of Russian Federation for Environmental Protection – 16.2 mln. hectares.

The Ministry of Defense protects 4.8 million hectares of forests, located on military lands.

Within the systematic lack of financing for forestry work, the Federal Forest Service of Russia and its territorial bodies can no longer provide the necessary level of forest fire protection. As a result, the number of large forest fires with disastrous character increased, accounting for 70 % of forest area affected by fire.

7. Characteristics of Forest Fires

Forest fires are characterized by the burning object and distributional pattern. Forest fires are usually subdivided into ground (burning debris layer), crown (burning tree branches) and underground (peat, soil) fires. Ground and crown fires can occur independently from each other.

The probability for large fires is much higher in coniferous forest than in deciduous ones. Fire-propagation rates of ground fires against the wind is 6 to 10 times lower than with the wind. At night the fire propagation rate is less than at daytime.

Fire-propagation rates of catastrophic fires:

- Crown - over 100 m/min;
- Ground - over 3 m/min;
- Underground - more than 2 m/day.

Ground fires in deciduous forest happen in the spring more often if there is a dry layer of fallen leaves and herbaceous plants from last year but no green grass yet able to hold the fire.

At a wind speed of more than 6 m/s, a ground fire may become a crown fire. Crown fires arise from ground fires. When crowns burn, there is always continued burning at ground level. Ground fire turns into a crown fire on forest areas, where there is a plenty of undergrowth, brush-wood, and dead branches at the bottom of stands.

Underground fire occurs on peat soils or on debris layer with a depth over 20 cm.

Independent ground fires spread along the lower storey of forests (ground cover, undergrowth, fallen trees) at low speed (up to 0.5 m/min.), covering the lower parts of tree trunks and roots protruding to the surface.

Running ground fires burn live and dead ground cover, fallen trees, natural seeding plants, coniferous young growth and undergrowth, but due to more favorable conditions (dry forest, windy weather) such fires spread with increased speed (over 0.5-1 m/min) and flame height, avoiding high humidity places.

Ground fires may be characterized by elongated shapes of conflagration with rough edge. The smoke color is light gray.

When the direction of wind changes, it is more complicated to define the shape of fire - its basic elements of front, rear and flanks. In such cases, especially when the fire takes huge sizes, it becomes possible that people are surrounded by fire in the forest. Only with the help of air reconnaissance support it is the possible to orientate oneself in surroundings of large fires.

Independent crown fires are the next stage of ground fires; flames of ground fires ignite the trees' crowns, burn pine needles, leaves, small and larger branches. The transfer of ground fire to forest canopy occurs with stormy wind, in plantations with lower crowns, in uneven-aged forest plantings, with abundant young coniferous growth (especially on mountain slopes with upslope fire propagation).

The stands after crown fire usually die completely; the charred remains of trunks are left only. During independent crown fires, the fire spreads on crowns as the ground fire edge moves.

In **crown running fire** conditions**,** which occur only in strong winds, the fire jumps in trees' crowns, being ahead of the front of the ground fire. Wind also carries burning branches and other small burning objects and sparks, which create new ground fireplaces hundreds of meters ahead of the main fire. In some cases, the fire moves this way across the rivers, wide roads, bare areas and other apparent boundaries that may localize the fire.

During leaping fires, the fire spreads in crowns with a speed of 15-25 km/h, but the average speed of fire propagation is always less, because after a “jump” there is always a delay in the fire front propagation as long as the fire passes the already burnt crowns. This happens because the “jump” is caused by the heated canopy created by the energy of ground fires. The heat flow arising downwind heats the tree crowns ahead of the fire front at a considerable distance. When at least one crown is ignited, all the other crowns are instantaneously ignited too, and the fire jumps in heated crowns, but then, outside heated areas it dies. When the ground fire approaches the new fire front, the process of canopy heating repeats itself and the next jump can occur.

Crown fires, releasing large amounts of heat, cause upward streams of combustion products and hot air, and form convection columns with a diameter of several hundred meters. Their progressive move coincides with the direction of the fire front advance. Flames insides a column may raise to a height of 100-120 meters. Convective columns increase the flow of air into the fire zone and create winds enhancing combustion.

The area in the conditions of running crown fires is extending downwind. The smoke of crown fires is dark.

Underground (peat, soil) fires occur in very dry areas with peat soils or in areas with a thick debris layer (20 cm or more). The fire spreads slowly in the peat layer – up to several meters per day. Peat and debris layers burn through the entire depth of the dry layer or to the mineral (earth) soil.

The most common soil forest fires show different stages of development. At the first stage, dry peat layers burn only under fallen trees that fall randomly. Then, soil funnel burning continues deep into the peat layer. With the wind, burning particles of peat and debris layer are transferred to adjacent areas, promoting the rise of ground fires.

Large forest fires are fires with an area of over 200 hectares in the Asian part of Russia and more than 25 hectares in the European part of Russia. Large fires are most often of mixed type, i.e. ground and crown fires at the same time.

For the occurrence of large forest fires, with transition to crown fires, a large number of sites with ground fires is necessary as well as dry hot weather (III-V classes of fire danger) and an increase of wind from moderate to strong or gale.

These conditions can merge multiple fire beds and create vast areas with massive fires with an area of hundreds of hectares, create imminent threat of fire destruction of population centers and any objects located in forest areas or nearby.

According to long-term data, forest fires in Russia occur as follows: ground fires - up to 98 % of the annual number of fires, covering 81.4 % of the affected area; crown fires – 1.5 % and covering 18.6 % of the affected area; soil fires – 0.5 % with an area of 0.02%. In some dry years, the number of soil fires increases to 2%, but in general the above indicators are stable.

Almost all massive fires occurred and occur during droughts. Droughts dry up rapidly not only superficial and underlying combustible materials in dry lands, but also the forest areas that in normal years serve as an obstacle to fire propagation (floodplains, swamps, hollows and other places with excessive humidity). In the conditions of long droughts, dead fallen wood and other large forest fuel dry up. All this leads to the fact that natural barriers preventing fire propagation disappear and the conditions for large fires occurrence is created. Therefore, with the same number of flame sources in dry years, the probability of fires increases and possibility of extinguishing them reduces. During the drought it is particularly difficult to extinguish fires in wetlands and swamp forests, where there are large stocks of organic matter ready for burning. Thus, the problem of massive fires is a problem of droughts and their forecasting.

Drought is a rainless period long enough to ensure that the moisture absorbed by plants in the root zone of the soil is exhausted. For example, a critical condition for the occurrence of large fires in the forests of Siberia and the Far East is: in springtime a 10-day period without rain, in summertime a 20-day period without rain, and in autumn a 30-40-day period without rain.

Currently, every second summer is abnormally hot in Russia. If in the nineties the increased intensity of fires was observed every three years, then in the last six years it is observed every two years. If it continues the same way, in a few years Russia will be stifled by smoke each year.

Adverse factors of forest fires and the nature of their effects are listed in Table 4, the dynamics of forest fires is presented in Table 5.

Table 4. Adverse Factors of Forest Fires

Source of emergency	Adverse Factor	Nature of Effect Demonstration of Adverse Factor
Forest fire	Thermophysical, as per GOST P 22.0.06	Flame. Heating with heat flow. Heat stroke. Atmospheric turbidity. Dangerous fumes.
	Chemical, as per GOST P 22.0.06	Pollution of air, soil, ground, hydrosphere.
Radioactive forest fire	Thermophysical	As per GOST P 22.0.06. Also, lack of oxygen in the combustion zone, expansion of particle burning, fiery whirlwinds and tornadoes.
	Chemical	As per GOST P 22.0.06
	Radiophysical	Ionizing radiation. Creation of radioactive products of combustion - open sources of ionizing radiation. Radioactive contamination of atmosphere, soil, plants, hydrosphere. Lack of oxygen in combustion zone, expansion of particle burning, fiery whirlwinds and tornadoes.

A report in due form is to be made up on each forest fire. Control parameters for each forest fire are:

- total area of extinguished forest fire, ha;
- forest areas with tree stands destroyed in a fire (fumes – as per GOST 17.6.1.01);

- forest areas with tree stands partly destroyed after a fire (burnt timber – as per to GOST 17.6.1.01);
- forest area after crown fire, ha;
- forest area after ground fire, ha;
- forest area after soil (peat) fire, ha;
- non-forest area after fire, ha;
- volume of deforestation, m^3;
- volume of damaged timber, m^3;
- mass (estimated) of radioactive combustion products in the conditions of forest fire in contaminated forests, t.

Table 5. Dynamics of Forest Fires in Russia, 1992—2003

Year	Indicators		
	Number of forest fires (thousand)	Forest area after fire (millions of hectares)	Losses (billions of rubles)
1992	25,8	0,691	
1993	18,4	0,748	
1994	20,3	0,536	
1995	26,0	0,360	
1996	32,0	1,853	
1997	31,3	0,727	1,31
1998	22,7 (24,9)	2,7 (3,1)	4,0 (5,2)
1999	31,0	0,960	1,835
2000	18,0	2,0	3,7
2001	20,9	0,868	2,9
2002	38,0	1,2	3,7 (10,0)
2003	25 561	2, 005	

A statement of President Vladimir Putin at a press conference on 20 June 2003 on forest fires is noticeable: “What the state may do to oppose this fiery wave, how long are we going to hope for the sky to help and when will the forces of the Emergency Ministry solve this problem?” The answer of the President was as follows: “You know, the thing is not only with the Emergency Ministry, there are situations, which the Ministry cannot cope with by definition, it is simply impossible. And if we have to deal with large-scale environmental, natural phenomena, even with ten Emergency Ministries gathered together – there will be no results”.

8. Environmental Effects of Forest and Peat Fires in Radiation-Contaminated Areas

Forest fires are one of the most common phenomena, accompanied by a large release of carbon black, soot and carbon dioxide (from 3 to 150 million tons per year) into the atmosphere. Thereupon, at intervals of 6-7 years their sharp rise is observed. In the last decade due to the sharp deterioration of the environment, the problem of forest fires extinguishing has become particularly acute.

The radiation factor occupies a special place among the factors of anthropogenic impact on the environment; its ecological importance is constantly growing due to the increasing use of nuclear energy. In particular, as a result of the radiation disasters at the Chernobyl nuclear power plant, “Mayak” industrial association and Siberian Chemical Combine, and also due to nuclear weapons tests at the Semipalatinsk Nuclear Test Site, a part of the forest fund in the 23 constituents of the Federation has been impacted by radioactive contamination. Radiation has long-term negative impacts upon economic activities in forests of more than 130 forestry enterprises and more than 330 forestries.

Forest fires in areas contaminated with radionuclides have also much bigger dangers. Fire in such zones becomes a reason for radionuclide migration. As a result, not only the population of this area, but also of other, more remote areas are subject to additional radiation exposure.

Table 6. The area of forest land, contaminated with cesium-137 at Chernobyl nuclear power plant disaster, thousand hectares.

Bodies for forestry management	Area of land contaminated by cesium-137				
	Total	Including density of soil contamination, Ci/km^2			
		1—5	5—15	15—40	above 40
Forestry Administrations:					
Bryansk	171,0	103,1	39,7	26,0	2,2
Kaluga	177,8	132,6	43,8	1,4	—
Orel	97,1	95,6	1,5	—	—
Ryazan	70,3	70,2	0,1	—	—
Smolensk	5,0	5,0	—	—	—
Belgorod	15,4	15,4	—	—	—
Voronezh	25,3	25,3	—	—	—
Kursk	21,3	21,2	0,1	—	—
Lipetsk	15,4	15,4	—	—	—
Tambov	1,7	1,7	—	—	—

Penza	148,4	148,4	—	—	—
Forestry Committees:					
Tula region	77,5	66,0	11,4	0,1	—
Leningrad region	85,7	85,7	—	—	—
Ulyanovsk region	69,4	69,4	—	—	—
State Forestry Committee of the Republic of Mordovia	1,3	1,3	—	—	—
Total	982,6	856,3	96,6	27,5	2,2

The recovery stage after a radiation accident has begun; its duration, considering the composition of radionuclides involved, may last tens or even hundreds of years.

Forests have the ability to securely retain radionuclides thus preventing their migration from the contaminated area. At the same, contaminated forests are sources of secondary radiation pollution of other areas due to forest fires releasing and transferring radionuclides over large distances.

Subsiding with the dust, radioactive particles are retained and accumulated over vast areas by trees, shrubs, soft debris layer. It is noted that after the disaster at the Chernobyl nuclear power plant the concentration of radioactive substances in forests was 7-10 times higher than in greenlands and marshes. Coniferous forests retain 2-3 times more radionuclides than deciduous.

During forest fires radioactive particles vaporize and rise up. Fires play a role of a pump: it pumps and raises these particles with the heated air masses and other products of combustion into the high atmosphere, up to 6-12 kilometers, and are then carried over considerable distances. In the conditions of large fires, a breakthrough of combustion products with radionuclides sometimes occurs even to the stratosphere. The lifetime of radiation smoke and aerosol clouds in the lower troposphere (up to 1.5 kilometers) is less than one week, in the upper troposphere - about a month, in the stratosphere - from 1 to 5 years. There will always be wash-out and deposition of radionuclides on new territories. Therefore, fires, especially large ones, are extremely dangerous in areas contaminated by radiation. Fires in buildings and peatland fires are dangerous, but forest fires are the most hazardous.

Due to the accumulation of dead wood the sanitary state of forest has deteriorated sharply, and fire danger has increased. In the former Zlynkovsky and Klintsovsky experimental forestry enterprises, in premature plantations, the dead forest formed huge areas (“Zaiputsky Grunt” district in Novozybkov forestry, etc...) with a volume of dead wood up to 930 thousand m^3, which is growing by tens of thousands of cubic meters annually. The timber, obtained from sanitary fellings in these forestry enterprises, is practically impossible to use, even as firewood (according to the current regulations on radionuclides content). The radiation situation in the forests of the Bryansk region currently remains difficult. The dose rate in closed forest areas with a given density of pollution is 2-3 times higher than the dose rate in open areas with an identical pollution density. In addition to external radiation, up to 80 % of the annual dose by internal exposure is accumulated by forest food products.

These areas have become areas of high environmental, radiation, chemical and possible terrorist risk and represent a great danger because of the high likelihood of large-scale fires, the consequences which may be similar to the effects of Chernobyl disaster and the spread of cesium radionuclides possibly far beyond the boundaries of existing pollution that would increase the radiation burden on the population.

Fires in contaminated forests constitute a significant radioecological danger. The most important is that fires promote intensive involvement of radionuclides into the surface layer of atmosphere, which leads to the transfer of radioactive aerosols, soot and smoke over long distances. The experimental data obtained in the simulation of forest fires demonstrates that radionuclides can rise to a height of several kilometers, and radionuclide concentration increases by 2-3 orders of magnitude. Thereupon, the air specific activity increases by 8-9 times at a distance of 10 km.

With dusts, fumes and soot up to 50 % of radioactive cesium contained in vegetation material, fallen pine needles and debris layer may come into the environment. It is of importance that the main size of particles containing radioactive substances is about half a micron (0.5, 0.4 microns), which increases their migration capability greatly.

Fire causes damage not only in an economic way, but also it causes great environmental losses – death of animals, reduction of green belts of the Earth, changes in climate, soil erosion, powerful air pollution, etc. When extinguishing fires, fluorinated surface-active agents (surfactants) are widely used, which are capable of causing serious damage to the environment, causing irreversible genetic changes in animals, and promote destruction of the ozone layer of the earth.

9. Problems in Rehabilitation of Radiation-Contaminated Forests

The total forest area of the Bryansk region is 1'200 thousand hectares with a timber reserve of 200 million cubic meters. 810.7 thousand hectares are under the supervision of the forest management in Bryansk region. The share of conifer plantations is 53 %. Periodic yield of Bryansk region forestry in 2004 amounted to 1457.0 thousand cubic meters, including coniferous – 359.8 thousand cubic meters; hardwood – 59.6 thousand cubic meters; softwood – 1'037.6 thousand cubic meters.

The Bryansk region is assigned to areas with a high degree of environmental stress, which is due to the radiation contamination from the Chernobyl accident, first of all. Most of these forests are located in areas of compulsory evacuation and relocation, in which forestry activities are suspended in accordance with radiation safety standards. Due to the impossibility of carrying out forestry activities, in recent years, in most areas of radioactive contamination 2.84 million cubic meters of commercial timber has accumulated, including 1.25 million cubic meters of coniferous trees. Sanitary state of forest has deteriorated sharply due to the accumulation of dead wood.

Contaminated forests rehabilitation by results-based method becomes now of particular relevance for the following reasons:

- 25 years have passed since the accident. As a result of terminating harvesting and silvicultural works, due to excessive accumulation of overmature wood, dead wood forest litter, wind-fallen trees, and fallen trees, these areas have become a zone of high environmental and possible terrorist risk and represent a great danger because of the high probability of large-scale fires;
- dynamics of cesium accumulation in the wood has, in recent years, a very negative trend, which greatly limit the possibilities of wood processing due to deeper penetration of cesium compounds into the tree trunks. Based on scientific calculations of experts of Russia and Belarus, economically sound timber harvesting in areas with a contamination density of 15-40 Ci/km^2 and more can be done only up to 2010, after which the timber will be virtually not usable and will be subject to 100 % disposal, requiring huge material and financial resources;
- in the conditions of market economy, providing the wood processing industry of the Bryansk region with raw materials and timber from its own forests, and without environmental depletion, becomes an important issue. An important role in resolving this task should be played by the rational use of wood from areas contaminated with radionuclides.

Not being able to fully implement silvicultural preventive measures, forestry workers are to protect such forests and extinguish occurring forest fires under high-risk conditions and with a lack of special vehicles and technical means of protection. Workers of forest protection service are socially vulnerable. Salary of foresters today makes 2000-2100 rubles per month. All this has a negative impact on the effective protection of forests from unauthorized felling. According to a research carried out in these forestry enterprises, the forestry workers directly employed in the forest and usually involved in fighting forest fires belong to a higher radiation risk group. The radiation dose of these people is more than 2 times higher than that of the other citizens permanently residing in the same area, but engaged in other professions.

When visiting the Bryansk region, Minister of Emergency Situations Sergey Shoygu expressed the idea to create a mobile unit to extinguish forest fires in contaminated forests, based in the city of Klintsy. However, until the present time the unit has not been created.

The use of aircrafts for the detection and suppression of forest fires in these forests is not possible because of the lack of funds.

At the same time, timber from the south-western areas of Bryansk, according to the results of radiometric researches, can be used for economic purposes, but with mandatory radiation monitoring. For stockpiling of timber in mandatory evacuation and relocation zones, radiation-proof highly-automated manufacturing technologies, based on mobile equipment using multi-functional machines, are developed. The annual capacity of mobile equipment is 25 thousand cubic meters. A minimum estimated need for four mobile equipment sets is about 100 million rubles. Forestry enterprises cannot purchase such equipment out of their own funds.

Within the system of the Forestry Agency of the Bryansk region, a set of radiation control laboratories are functioning (certified by the system of the State Committee for the Russian Federation for Standardization and Metrology): in the Zlynkovsky and Klintsovsky experimental forestry enterprises, the annual migration of radionuclides in forest ecosystems at 10 fixed forest areas covering all areas of radioactive pollution from 5 Ci/km^2 to 150 Ci/km^2 has been observed since 1992.

The laboratory obtained data on radionuclide contamination of timber with cesium-137 in the observed forest areas show a constant annual increase of specific activity in stands, especially, in hardwoods (aspen, birch).

All this confirms the trend of increasing radionuclide accumulation in the stands of trees, the wood from which it is advisable to use as quickly as possible, but with a permanent radiation control. Therefore, additional funds or investments are needed to solve this important task for the Bryansk forestry.

In 2003, the regional administration on behalf of former Deputy Prime Minister of the Russian Federation V.B. Khristenko, developed a draft subprogramme “Rehabilitation of forests in the highest radioactively contaminated areas of the Bryansk region for the period 2005-2010” within the Federal Target Program “Overcoming the consequences of radiation accidents for the period up to 2010”. This project was coordinated with the Ministry of Natural Resources of

Russia, the Ministry of Emergency Situations of Russia, and was included into a draft of the amended Federal Target Program “Overcoming the consequences of radiation accidents for the period up to 2010”. But the Ministry of Economic Development and Trade of the Russian Federation did not support this forest rehabilitation program, important for all Bryansk region, and it was rejected.

In November 2004, the regional administration addressed the Prime Minister of Russia, Mikhail Fradkov, with a letter on the issue of providing practical financial assistance to Bryansk foresters in their hard and noble effort to prevent large-scale fires in the areas with highest radioactive contamination and, thus, to prevent a “second Chernobyl” in Russia.

This appeal again was not supported by the ministries in charge of funding programs related to Chernobyl. It turns out that in the event of the burning of one million cubic meters of dead wood in an area with more than 40 Ci/km^2, all responsibility for the catastrophe equal to Chernobyl lies with the Zlynkovsky experimental forestry enterprise only. To eliminate consequences of a disaster is always more difficult than to prevent them. With climate rapidly warming, it is not possible to wait until large-scale fires of dead and overmature coniferous plantings occur in the Klintsovsky and Zlynkovsky experimental forestry enterprises, but it is important to urgently look for ways to solve this important problem by way of results-based methods. On behalf of the Head of the Federal Forestry Agency and in agreement with the Ministry of Economic Development and Trade of the Russian Federation, a departmental target program for the rehabilitation of forests in the south-western districts of Bryansk region was drafted, the funding for which is planned to come from the federal budget.

In accordance with current forestry regulatory and legal frameworks, the Government of the Russian Federation entrusted forest management bodies with carrying out mandatory certification of timber sold in stands, including radiation control of timber on forest fund lands. But in the context of systematic underfunding, the federal programs for minimizing the consequences of the Chernobyl disaster and the activities for forests rehabilitation in the Bryansk region may be doomed to fail.

Currently, the Federal Target Program “Overcoming the consequences of radiation accidents for the period up to 2010” does not include any funds for forestry issues. Rehabilitation of radiation-contaminated forests was finally resolved by limited funding (15-20 % of the need) from the previous Chernobyl program.

Almost all equipment in radiation control laboratories has exceeded its projected lifetime, and the two spectrometers used since 1990, have exceeded this period twice.

According to a decree of the Government of the Russian Federation, forest management bodies are entrusted with carrying out mandatory certification of timber sold in stands. But with outdated technical equipment and support by only three laboratories it becomes problematic to implement the decision. It turns out that though having their own equipment, forestry enterprises have to pay considerable sums to other organizations for the certification of forest products.

The main areas of technical assistance for the implementation of economic and social reforms in the forestry of Bryansk are considered the following national and regional priorities:

- implementation of current radiation-safe, ecologically sound measures in radioactive forests management, including certification of forest products, according to a project of fire-safety management at radioactively contaminated forests developed by the Oryol branch of “RosGiproLes” institute (Russian Research and Development Institute for Forest Management Organizations and Environment Protection Assets)
- modernization of existing production using resource-saving technologies for wood production and wood processing, and improvement of customer appeal of products by supporting relevant researches, and technological renovation of processing equipment (purchase cost of 4 mobile equipment sets - 100 million rubles);
- update the instrument base for radiation monitoring in existing laboratories, which will allow to optimally conduct certification of timber products regarding radiation.

Solving these problems with financial assistance will not only significantly improve the environment and reduce to the lowest possible level negative health, social and psychological consequences of Chernobyl disaster, but also preserve the unique forest fund, which is of great importance for the socio-economic development of the Bryansk region.

10. Medical and Biological Aspects of Forest Fires Consequences

One hectare of burning wood, as a rough estimate, produces 80 to 100 tons of smoke particles and 10-12 tons of gas mixtures such as carbon monoxide, oxides of sulfur and nitrogen. The smoke of forest fires is composed 50 % of droplets of resin and water vapor, 25 % of gaseous matters and soot, and 20 % of ashes. Carbon monoxide entering the human body can be easily connected to hemoglobin, forming carboxyhaemoglobin that dramatically violates cellular respiration. The consequences of breathing such mixture for a long time for a pregnant woman are usually unfortunate, especially for the fetus.

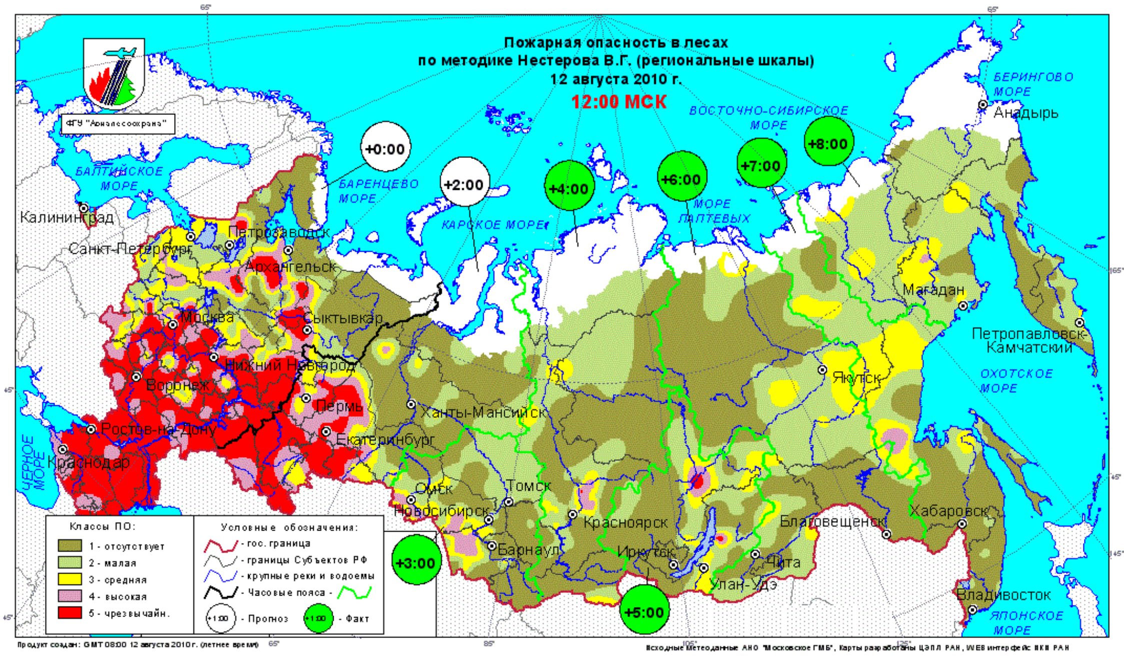

Figure 2. Fire danger in the Russian Federation as of 12.08.10

Doctors call human organs a target, which is effected by fumes and soot from fires. Every year the number of people seeking medical care with lung diseases increases.

Forest fires contribute to the spread of insect pests and wood-destroying fungi as well as degradation of soil conditions. They cause disruption of the ecological balance and lead to mass death of animals suffocating in fire. But most of all, forest fires affect people, although it is often their fault that forest fires occur.

When peat bogs are burning, an increased concentration of nitrogen oxide, carbon monoxide (CO) and fine particles of soot may occur in air. But the quantity of nitrogen oxides in the urban air is much more dependent on car emissions, so it does not have a significant role in this issue. Toxicologists believe that the exhaust gases and poisonous fumes of asphalt constitute a vast majority of air pollution in the city. Carbon monoxide (CO) is much more dangerous; this gas is colorless and odorless, causing headaches, nausea, fatigue and rapid weakness. Formed by incomplete combustion of carbon or its compounds (furnaces, internal combustion engines, and fires), carbon monoxide is poisonous. The content of carbon monoxide depends on the composition of combustion products: if the peat is clean, its combustion products are similar to the smoke from the fire.

However, near such metropolis as Moscow soil cannot be environmentally "clean" by definition, and therefore the combustion products are at least toxic, or, rather, poisonous. The most dangerous result of combustion is carbon black, which the International Agency for Research on Cancer has designated as the first class carcinogen along with asbestos, benzene and radon.

Carbon black is a black dispersed product of incomplete combustion or thermal decomposition of carbonaceous substances accompanying various chemical industries. The presence of suspended particles of soot in the air causes significant damage to the health of humans and animals. Considering that ultraviolet rays kill microbes, then in the conditions of lack of solarization, which happens due to suspended particles (the sun is not visible in the capital city sometimes for weeks during heavy fires), bacterial contamination of air increases and its relative humidity reduces. Smog is a visible manifestation of air pollution, which represents a combination of dust particles, including soot, fog droplets and gaseous chemical pollutants emitted by automobile transport and industry. Professor G. Stupakova, deputy director of the Moscow Institute of Human Ecology and Environmental Health, considers the situation to be the most unfavorable for the health because of considerable increase (20 %) of carbon dioxide content. People experience real oxygen starvation. Great damage is done to the immune systems, even of healthy people, so that doctors predict unavoidable episodes of various viral and infectious diseases. What can one say about people with heart cases or lung diseases, highly allergic individuals and hypertension sufferers, which are the most vulnerable?

Moscow is a crowding urbanized formation, completely dependent on the environment, which evidences its “ecological parasitism”. The city breathes the air of other areas, for which it has to pay. At the same time, it emits a large amount of waste products into the atmosphere - around 150 mln tons of dust, water vapors and other toxic substances. It should be noted that a part of human activity wastes is transported to the city dumps, located in region, which, as a rule, do not have modern technologies for normal processing, thus wastes are consolidating for a long time with a tendency to spontaneous combustion. One can pick up not only the soot particles, but also a hefty dose of radiation near the smoldering wastes. Another part of wastes (liquid) is collected at aeration stations, at which fires may also occur. An example for that is a fire in Lyubertsy. In 2002, a disaster covered several constituents of the Russian Federation, which allows speaking about a direct threat to national security. The most strategically important objects of the country were caught in centers of contamination, to which the entire capital city with its administrative, defense and transport infrastructure refers first and foremost.

Direct and indirect damage was caused to the economy of some regions. And, which is of utmost importance, significant losses of lives. Doctors say that in periods of heavy smoke contamination (about 30 days, of which 5-7 days with peak values) performance capability of even absolutely healthy people decreased by at least one-third (for people with heart cases or lung diseases even by 50-70 %). The losses of man-hours are not counted. Moreover, according to medical statistics, the data about visits to doctors, hospitalization and fatal cases are not adequately reflecting the situation, because this is an emergency with "extended effect." Not only the soot itself is harmful, which the Moscow air is filled with, but also the substances it has absorbed. People breathe this "air cocktail" for a few months. The theses of a report prepared by Russian doctors show the data "about the possible damage to people health caused by unfavorable ecological situation in the summer of 2002 in Moscow," pointing out that the impact of nitrogen dioxide might have taken the lives of 103 people in the three summer months. There are distant consequences of heavy smoke contamination: increased mortality among patients with cardiovascular diseases from myocardial infarction; growth of infant mortality due to low body weight; increase in frequency of malformations of the cardiovascular system among neonates and respiratory diseases among infants; sudden infant death syndromes; increased incidence of lung cancer (in the longer-term). At the beginning of September 2002, the peat fires in Moscow caused serious environmental problems. There has not been such smoke ever since 1812, when wooden Moscow was burned to ashes. The city could not see anything in the truest sense of the word. Visibility in the capital city constituted 1-3 kilometers, and on September, 5, it decreased devastatingly down to 300 meters, and in some places down to 50 meters. Cars moved with headlights on a low speed. Many highways turned into huge traffic jams. Capital city airports were almost paralyzed because of the thick smog. Departure and arrival of tens of flights were delayed until the increase of visibility. The specialists of "MosEkoMonitoring" discovered about three dozen of substances, extremely harmful to human health, in the smog that folded the capital city. It became almost impossible to breathe in the city. Impurity contents in the atmosphere dramatically increased.

When in the blood, CO is permanently bound to hemoglobin and latter loses the ability to carry oxygen across the body. The CO concentration in air of some Moscow districts was exceeded four times. In the first place, this situation is a threat to people suffering respiratory problems and diseases associated with lack of oxygen in the blood. Doctors strongly advised them to never go outdoors. Healthy people were also advised to spend less time outside – only short distances from subway to work.

11. Conclusions, Suggestions and Recommendations

Create electronic maps of the forest fund on the territory of the Bryansk region showing the density of soil contamination by Cs-137:

- review data on radionuclide contamination of forest fund on the territory of Bryansk region;
- create a database on pollution of Bryansk region forestry enterprises with Cs-137;
- digitize the network of Bryansk region forestry enterprises and related cartographic information;
- prepare schematic maps of soil contamination density with Cs-137 in 15 forestry enterprises of Bryansk region in electronic form and other media as used by commercial entities.

In the most polluted forest enterprises (Zlynkovsky and Klintsovsky), the electronic maps are to be transferred to commercial entities. On this basis, thematic electronic maps of contamination of forest food resources on the territories of these forestry enterprises are to be developed, which implement the principles of forest areas differentiation, indicating the integrated impact of density of soil contamination with radionuclides and ecological silvicultural conditions.

In addition to maps, atlas and catalogues are to be published on radiation-safe use of forest products on the contaminated areas of the southeast of Bryansk region. With the use of geographic information (GIS) technologies, thematic multi-layer maps are to be developed on radiation-safe forest utilization in the most contaminated areas of Bryansk region.

In addition, it is proposed that following measures are fulfilled:

- strengthen radiation control over forest resources; certify forest products in affected areas; disposal of radioactive wastes will reduce the dose of additional exposure of population; reduce the health, social and psychological consequences of the disaster at the Chernobyl nuclear power plant. In addition, these measures will help to improve the investment attractiveness of the Bryansk region, creating new jobs and improving profitability of production in the forestry enterprises up to 30 %;
- according to results of radiometric investigations, determine stocks of wood that can be used for commercial purposes under the condition of respecting the principles of economic viability and radiation safety;
- develop departmental target program for rehabilitation of contaminated forests;
- in order to develop the forest resources of Bryansk region and to improve their sanitary state, it is required to establish mobile processing units based on radiation-proof, highly-automated manufacturing technologies. The

overall performance of only four units is 100 thousand m^3 of timber per year, the cost of equipment about 100 millions rubles;

- it is necessary to undertake comprehensive forest-protection activities;
- it is necessary to create a network of the Unified State System for the radiological environment on the whole territory of the Bryansk region;
- organize cooperation with the population living in the contaminated areas on questions of precautionary measures in the forests with high radiation background;
- organize production of visual information materials for the public.