

Radiation Risk Assessment in Pine Forests in the Pre-Irtysh Area

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Report for the "Environmental Assessment" component of the "Forest Protection and Reforestation Project in Kazakhstan" by Alexandr Miroshnichenko & Yuri Strilchuk. Translated by Dr. Djamila Aitmatova.

1 Introduction

The TOR provides the following tasks:

1. To gain access at the relevant institutions of Kazakhstan to the materials and reports on the radioactive pollution of the pine forest in the Pre-Irtysh area where nuclear tests were conducted.
2. To establish if there are any direct measurements in the pine forests on the character and degree of pollution, the condition of such polluting substances, and introducing these data in the report.
3. To establish if there were any monitoring of the level of the radioactive materials and if location has been conducted in the pine forests and, in particular, to determine the way of transferring the pollution substances into the soil and ground water.
4. To analyze investigations conducted on the absorption of radioactive materials by the trees with the particular reference to the deposition of such materials within wood, and possible risks for people when using it for fuel and construction purposes.
5. To assess the risks associated with the possible concentration of the radioactive substances in timber remnants collected and burnt before the transplantation of the forest suffered of fire.
6. If there are no such data available, it is necessary to stimulate and implement the program of selected measurements that will provide some definite information on the issue.
7. To develop recommendations on the question if additional measurements/ radiation monitoring during the project implementation appear to be needed. If yes, to define the ways to develop these measurements.
8. To analyze any available data on the analysis of pine timber in the Pre-Irtyshye area in terms of its possible final use. If such data do not provide confirmatory information on its safe use, it is necessary to design a selective control that will provide necessary information for such assessment.
9. If the data and analysis indicate significant risks of radiation hazardous impact of the forest or its by-products (for example, wood, abietene, ashes of fire-wood), it is necessary to develop recommendations on the specific measures to prevent the risks (for example, safe methods of processing, safe methods of waste removal, incentives, regulation, education programs etc.) that needed to be introduced into the Project's environmental protection plan.
10. If the data indicate that the forest zones with a high level of pollution can be found, it is necessary to develop recommendations how to introduce these issues into the process of forest protection planning that will be supported during the Project implementation phase, for example, zoning, approaches to struggle fires etc., and to reflect these measures in the environmental action plan.
11. To prepare some provisional assessment on the cost of measures associated with the evaluation of radioactive pollution and the risk management at the environmental action plan.

Expected results:

- (i) To prepare a brief/succinct report in hard copy and (wherever possible) in electronic format. The chapters should include, but not be limited to, the following information:
 - (a) The character and the size of pollution in the pine forest of the Pre-Irtysh area, including:
 - (b) Assessment of the up-to-date radiation situation in the forests and the possible pollution of timber;
 - (c) The risk assessment of the radioactive materials utilization during and after the forest fire;

- (d) The proposals on the low-cost forest and timber monitoring obtained from the pine forests of the Pre-Irtysh area, and
 - (e) The measures on the risk management associated with the issue of the radioactive pollution that should be introduced into the Project.
- (ii) To prepare the final report after the contributions from the Committee, the World Bank and the international experts on the radiation pollution.

1.1 Sources of information on the radioactive pollution in the Pre-Irtysh area

The basic source of information on the radioactive pollution of the region occurred under the impact of the Semipalatinsk Nuclear Test site (SNTS) is the National Nuclear Center of the Republic of Kazakhstan (NNC). The NNC was founded in 1992¹. Its responsibilities include implementation of the radiological investigations at the test site and in zones of its impact as well as collecting and systematizing data developed by other agencies and organizations. The NNC received from its headquarters (abolished in 1992) only part of the archive information. Due to this fact, the archives of the NNC dispose complete information only since the moment of its establishment.

The NNC did not conduct the purposeful radiological studies at strip pine forests (i.e. pine forests growing along the rivers on sand, well drained soils). The studies were widely distributed in the south part of the Western Siberia and Northern Kazakhstan. The study does not hold information regarding the works conducted by other organizations and institutions. Therefore, the given report contains indirect information on the radioactive pollution of forests; the components of forest ecosystems based either on the materials of limited investigations in the Semipalatinsk region, or on the publications on a more dimensioned research in the Russian Federation (Altay, Kyshtym) and in the Ukraine and Belarus (Chernobyl).

1.2 The history of nuclear tests at the SNTS

The decision concerning the Semipalatinsk Nuclear Test site (SNTS) establishment was made on the August 21st, 1947. The SNTS being located on the territory of three provinces (oblasts) of Kazakhstan – namely, Vostochno-Kazakhstanskaya, Karagandinskaya and Pavlodarskaya – occupies an area of 18,500 km² with a perimeter of about 600 km. In the territory of the former Semipalatinsk oblast, the area of the test site comprises 10,000 km². The nuclear tests were conducted 1949 – 1989. There in the test site, explosions of about 470 devices have been made (including 30 surface, 86 atmospheric and 340 underground explosions), the capacity of which comprised 17,400,000 tons in the trinitrotoluene equivalent. In doing so, during the period from 1949 to 1962, some 116 explosions have been made in the atmosphere and on the earth surface; in total, the radioactive clouds of 55 air and surface explosions and gas fraction of 69 underground explosions came beyond the boundaries of the test site.

The existing level of surface pollution of the territory adjacent to the test site is generally associated with the surface nuclear explosions. The picture 1 demonstrates the projections of main dose-forming traces and dates of appropriate explosions. Residual clouds of nuclear explosions made on the following dates at the Test site passed over the territory of the strip pine forest of the Pre-Irtysh area.

1.3 The places of nuclear tests

Testing range "Trial field" (surface tests): August 29, 1949, July 29, 1953, November 22, 1953, October 23, 1954, August 24, 1956, January 17, 1957, August 07, 1962, September 25, 1962. Testing range "Balapan" (underground test): January 15, 1965.

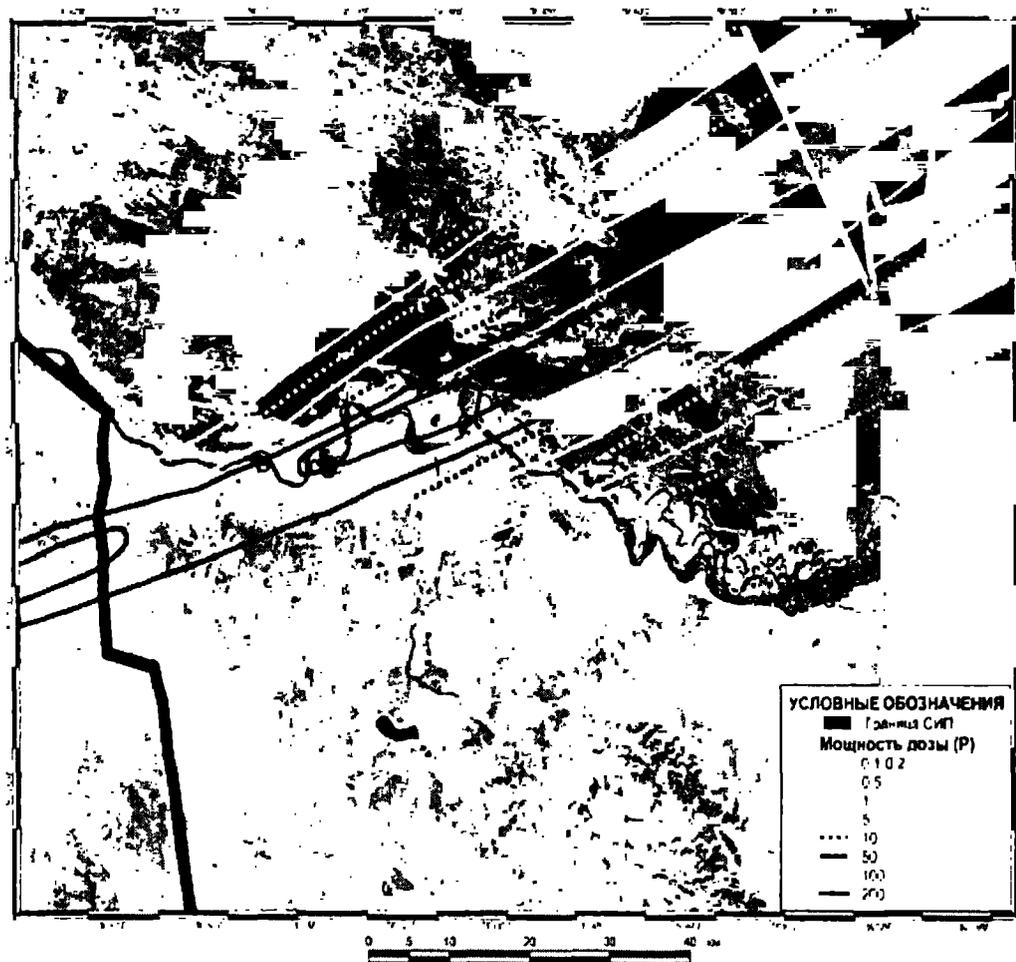
The largest contribution to the pollution of the north-east sector, where the strip pine forests are located, was made by the first nuclear explosion (on the August 29th, 1949) with the

and sharp gusts of wind. Strong surface wind formed a narrow radioactive trace of north-eastward direction. For example, the maximum assessment of total dose of the explosion radiation for the Dolon village made about 200 rem (roentgen-equivalent-man).

A sharp increase in the radiation intensity was observed at the distance of 300 km away from the testing range called "Trail Field". At the more distant points, increasing the dose capacity was insignificant. The territory, on which the dose exceeded 1 roentgen, extended as a gradually widening strip up to about 300 km away from the Test site border with a trace width of about 40-50 km. The Novopokrovsky and Beskaragaysky regions of the Semipalatinsk oblast and several regions of the Altay Territory (Krai) suffered from the radioactive pollution. The figure 2 demonstrates the territorial distribution of dose stress.

Figure 2

Map of the dose stress at the trace of the explosion on the August 29, 1949. The Semey town and the Irtysh River are in the middle of the picture and pine forests appear dark green. Light blue areas are salt pans. Also the Russian border is shown (white line).



LEGEND:
BORDER OF THE SEMIPALATINSK NUCLEAR TESTING AREA
DOSE RATE (P)

The Table 2 demonstrates the calculation data on pollution level as of July 1994 for the traces of the explosion on the August 29th, 1949.

Table 2. Radioactive pollution assessment of the August 29, 1949 explosion trace

Data of test	The number of biologically significant radionuclides as of July 1994, Ku		
	Strontium-90	Cesium-137	Sum. Plutonium
August 29, 1949	500	140	360

More detailed investigations of the radionuclide pollution of the front part of the August 29th, 1949 explosion's cloud, within the limits of the Test site territory, have been conducted during the period of 1994-1998 by the NNC that can indirectly characterize the radiation level on this trace.

The maximum concentration in the given direction was registered based on Cs-137 in the point 1 (2 km away from the explosion epicenter) and comprised 271 Bk/kg, based on Sr-90 in a point 1 (2 km away from the explosion epicenter) and comprised 269 Bk/kg. The laboratory sample of Pu-239/240 analysis showed that maximum fell on the point 6 (12 km from the explosion epicenter) and comprised 26600 Bk/kg.

During 1994-1995, the NNC RK jointly with two missions of the IAEA experts made investigations on the radioactive pollution of strip pine forest in the proximity of the Dolon village located at the route of the August 29th, 1949 explosion [45]. These data (Tables 3-5) indirectly characterize levels of strip pine forest pollution.

Table 3. Measured * radioactivity per unit of dry soil weight, (Bk/kg)

Populated area	Cs-137	Sr-90	Pu-238	Pu-(239+240)	Am-241.
Dolon	47-55 [24-60]	- [16]	- -	- [30-250]	<0,5-6 -

Table 4. Results of grass sample measurements

Concentration of radioactivity (Bk/kg of fresh weight)					
Sample	Cs-137	Sr-90	Pu-238	Pu-(239+240)	Am-241
Grass	2-4	-	0-0,006 0,16 Dolon	0,1-0,3 4 Dolon	-

Table 5. Capacity of gamma-dose in air

Populated area	Capacity of dose at the height of 1 m above ground (mkGray/h)		
	Mission 1	Mission 2	Other Investigations
Complete perimeter (more than 500 measurements during 1991/1992)	-	-	0,09 - 0,20
Dolon	-	0,09	0,13
Other populated areas (Totally about 20 ones)	-	-	0.11-0.17

It was established that the level of plutonium content in soil at the Dolon village is **immensely high**; the radiation impact on the local population was therefore assessed separately. The data on the doses received by adult people are provided in the Table 6.

Likewise, the child exposure to radiation (1-2 and 7-12 years old) was assessed; in all cases the total annual doses turned to be lower than those of the adults.

Table 6. Annual effective doses obtained by the population of village Dolon

Method of impact	Годовая доза dose (mkSv)	
	Dolon	Other populated areas
External gamma-radiation	0,01	0,01
Respiration		
Pu-238	0,007	-
Pu-(239+240)	0,04	0,001
Am-241	0,004	-
Absorption		
Cs-137	0,03	0,03
Sr-90	0,02	0,02
Pu-238	0,004	-
Pu- (239+240)	0,02	0,001
Am-241	0,002	-
TOTAL (rounded figure)	0.14	0.06

Doses provided in the Table 6 are considered to be generally appropriate to the majority of the local population. These appraisals are considered to be highly conservative. The levels of pollution measured at the populated areas, in their majority lie within the limits anticipated due to the global precipitates; the average dose taken by the local population due to the radioactivity of precipitates comprises approximately several mSv per year.

Approximate annual radiation of the population living outside the borders of the Test site is less than 0,1 mSv. It is a rather modest level; the actual radiation is much less and close to the global average level of the radioactive precipitation. Currently, there is no necessity to thoroughly study the radiological situation, except for the portable water.

Comparing with other populated areas, the higher content of Plutonium is in the Dolon village, whereby it became subject to the over-all soil sampling. However, approximate annual dose remains low (0,13 mSv per annum), and further study of the situation is considered to be unnecessary.

Table 7. Presumptive pollution levels

Radionuclide	Concentration of activity in soil		
	Out of the test site limits		Within the Test site limits
	Dolon	Other populated areas	Lake Balapan and "Trial Field"
Sr-90	20	20	10 000
Cs-137	50	50	50 000
Pu-238	30	1	5 000
Pu-239,240	150	5	15 000
Am-241	15	0.5	1 500

2 Characteristics of forest radioactive pollution risk

2.1 General information on forest radioecology in the CIS

In the forest radioecology, many individual (special) problems were in significant part solved earlier during the modeling experiments, with the global precipitation case studies, during the works at the radioactive trace area of the Kyshtym accident. In the framework of the forest ecosystems role study it has been showed that forests are clearly defined technogenic precipitation accumulators. The accumulating effect of the forest plantations depends on its composition and projective cover of phytocenosis, annual climate conditions and period of vegetation. By and large, the radionuclides are absorbed by the conifer tree crowns as well as under the neutral meteorological conditions and during the spring-summer period of assimilating organs surface maximum development of hardwoods.

Another peculiarity in the primary distribution of radionuclides is the so-called "border of a forest effect". It was marked in the most part of the radioactive pollution zone of the Kyshtym accident and displayed itself in the radionuclides heightened deposition in the crowns of trees that grow at the edge of forests at the windward side relatively the source of radioactive outbreak.

On the majority of the named statements, practically all the researchers are unanimous in their conclusions made both on the basis of the simulation experiments and in-situ studies in the zone of impact of the Chernobyl and Kyshtym accidents. The question of forest ecosystems impact on the primary redistribution of radioactive precipitates in global scale still remains debatable. Currently there are 2 view-points on this issue. The first one lies in the idea that the level of radionuclide activity is higher in forests if compare to adjacent bare areas; the second view-point is associated with the statement that forest ecosystems do not influence on the global redistribution of precipitations. The solution of this issue requires wide-scale investigations of forest and neighboring bare areas or comparison of the cartographical (map) materials on the density of the territory and plants pollution. At the same time, despite of the fact that this question is still arguable, one can nevertheless state that forests compared to other surface ecosystems are the pronounced biogeochemical barriers preventing migration of radionuclide flows and elements of technogenic precipitation.

Another, by right, the key issue in the forest radioecology is a question of establishment of time-spatial regularities of migration and radionuclide redistribution along the ecosystem components. It is in the framework of the given direction, where the intensity of migration processes in bio-geocenoses (BGCs) can be determined including that, which exists in the trophy chain that finally characterizes the dose stresses in all the links of the chain considered. The whole passed pre- and post-Chernobyl period of investigations showed baffling complexity of questions related to the analysis of radionuclide migration regularities and factors that determine it. Among the achievements of this line, there is an establishment of ^{90}Sr behavioral peculiarities, in particular its heightened migration capacity and coefficients of transfer (CT) into practically all the components of forest ecosystems, except for tree reproductive organs and mushrooms as well as establishment of the seasonal and long-term dynamics peculiarities if compare the ones existing for ^{137}Cs .

Thus, it was showed that dynamics of different radionuclides is unequal both at the components of the vegetative tier and in temporal rank. In the seasonal dynamics of ^{137}Cs , a unit-directional decrease of its concentration from spring to fall in the assimilating organs of wood species, and in that of ^{90}Sr , vice versa, - increasing the concerned index during the period of vegetation is fixed. At the same time, minimum of ^{137}Cs concentration is timed to the beginning of spring sap movement.

Seasonal dynamics of radionuclides content in components of grass-bush tier the character of which changes depending of the plants species type and conditions of their growing is even more complex and ambiguous. It was also established that as a whole seasonal fluctuations of radionuclides content correlate with the accumulative capability of separate BGC components and reach levels of interspecies variations of this index. It is necessary to emphasize that majority of noted regularities in the modern interpretation were formulated during the post-Chernobyl period, but in the framework of the considered issues, the reasons of the given phenomena still remain undiscovered up to now.

Investigations of spatial and temporal regularities of Chernobyl precipitation radionuclide migration demonstrated that long-standing dynamics of their accumulation in the components of vegetative cover is characterized by far from ambiguous regularities as it was stated before. The highest level of unanimity in specialists' opinion is noted on the questions of Sr content change in a long-term series. For the long-term dynamics of ^{90}Sr , increase of root consumption up to a certain level is typical; then some stabilization of its content in plants and consequent decrease due to radioactive decay and non-exchange fixing in soil occurs. Dynamics of this radionuclide in timber is an exclusion of the rule, where ^{90}Sr accumulation is fixed by the cumulative character for a long period in the long-term series.

There is no concordance in opinions of different scientists on the long-term dynamics of ^{137}Cs . A number of researchers believe that the long-term dynamics of ^{137}Cs is close to the one of ^{90}Sr ; i.e. at the first stage after the precipitation, unilateral increase of ^{137}Cs takes place. After that due to the radioactive decay, its stabilization and decrease occurs. Other researchers note that the radionuclide long-term dynamics is not so unambiguous and depends on the landscape features. The cumulative character of ^{137}Cs accumulation manifests itself only at the areas, where intensity of root inflow of a radionuclide is close or exceeds the intensity of its non-exchange fixing. Such picture can be observed in conditions of the hydromorphous or semi-hydromorphous landscapes as well as in the nearest 5-10 km zone of precipitates (in the case of 30-km zone of Chernobyl Nuclear Power Plant estrangement), where precipitates is represented by the sparingly soluble compounds. In the conditions of automorphic landscapes, the cumulative effect is not practically pronounced and long-term dynamics is characterized with the unilateral decrease of Cs content in the long-term series. The latter one is explained through the predominance of radionuclide non-exchange fixing processes in soil over its accumulation by the plants. The mentioned features of the long-term dynamics of ^{137}Cs were established during last several years on the base of Chernobyl precipitates case studies and have not received their proper appraisal yet. Therefore while the prognosis and simulation they have not been taken into account until recent times. In the majority of such papers, the prognosis assessments are still made only in the base of a single cumulative effect. However, it is obvious that for the dynamical features, varied/differentiated approach should be used that takes into account the impact of landscape peculiarities of the territory of pollution. Thus, it was established that climatic factor influence, in particular, amount of atmospheric precipitations during the vegetation period depending of the conditions of growing is different. It has the direct dependence at the automorphic and indirect one – at the hydromorphic landscapes. At the same time, the question of radionuclide content variation level in long-term series and factors defining them still remains unclear. Only knowing the mentioned features, one can effectively use the dynamic indices while the prognosis of radiation conditions change.

Investigation of the radionuclide content features in various components of biota allowed ranking them in accordance with their accumulative capability, evolving types and structures of accumulators (bio-indicators) and discriminators as well as assessing the relative contribution of these components into the ecosystem total pollution. This is highly important under the calculations of dose loads in the radionuclide migration along the trophy chains. In the integrated form, components of surface cover in terms of the ^{137}Cs concentration levels are located in the following order: wood tier < grass and bush tier < moss and lichen cover < mushroom complex. Investigations showed that mushrooms are absolute accumulators of

^{137}Cs in the forest BGC. Difference ratio on the index between mushroom and other BGC components comprises 2, in comparison with wood it makes 3 mathematical orders. For ^{90}Sr the above series have other form: mushrooms complex < moss and lichen cover < grass tier < < wood tier. In accordance with this factor, contribution of the given components varies into the ecosystem pollution as a whole. For ^{137}Cs , maximum accumulation (up to 47% of its total reserves in the ecosystem) can be in mushrooms. For ^{90}Sr , it can be in the wood tier (up to 20%), significantly less in grass and bush tier and moss cover, and practically insignificant (0,2-0,1 % and less) amount is in mushroom complex.

By the results of the Chernobyl investigations, it was demonstrated that intraspecific differences in the radionuclide accumulation is significantly less than variations of this index between various components of BGC. In doing so, some certain correlation between intraspecific variation and accumulative capability of the given component as well as its ash content can be observed. In other words, the higher ash contents the higher radionuclide accumulation. Minimum intraspecific variation (in particular, on ^{137}Cs) becomes perceptible in the wood species, maximum – in mushrooms. And nevertheless, question on the intra-component ranking of species in accordance with their accumulative capacity is still disputable. The reason lies in fact that radionuclide accumulation in separate species of plants and mushrooms is determined not only through their physiological features, but conditions of growing, root systems conjugation with zones of maximum pollution as well, i.e. by the character of radionuclide distribution in a soil profile. Questions of intraspecific and inter-specific variations of ^{90}Sr content in the forest ecosystems components area studied even in less degree. Solution of these questions as a whole is possible on the basis of summarizing available materials as well as under special experiments that provide verification of the obtained regularities. As a whole, it is necessary to emphasize that research in the concerned direction is necessary to be continued.

At the same time, till the last time, majority of investigations in the given areas of radioecology were characterized by the unavailability of the comprehensive approach and as a rule, were of the applied type, i.e. data on radionuclide accumulation and distribution among the BGC components were considered in terms of the assessment of doses and intensity of polluters' migration along the trophy chains. But while the environmental consequences of technogenic pollution including the radioactive one, it is necessary to carry out comprehensive investigations taking into account all the natural ecosystems components: wood-grass and bushes tier, moss and lichen cover, mushrooms complex, organogenic (turf, substrate) and mineral parts of soil profile as well as flows of technogenic polluters forming in these BGC. Establishment of the dense monitoring network in the system of geochemically conjugated landscapes will be most beneficial. The latter one allows the revealing of zones of carryover and secondary accumulation of elements-polluters, as well as geochemical, coenotic and biogeochemical barriers at the landscape system of pollution area with sufficiently high reliability. In turn, it provides not only a possibility of long-term prognosis of technogenic pollution re-distribution, but also allows outlining system of efficient counter-measures to localize and minimize a certain emergency situation.

The analyzed aspects are highly important under simulation and forecasting assessments of the radiological conditions as well. Unfortunately, similar comprehensive investigations for the present moment are few in number, but currently available achievements with due obviousness demonstrate the importance of such approach to the radioecological issues. The mentioned approach allowed showing that correlation of flows in biochemical cycles of technogenic radionuclides significantly differ from those of macroelements, particularly of their non-isotopic analogs of Ca and K. For these macroelements, reversion to the soil with abscission of leaves in majority of cases 2-3 times less than their delivery into plants for annual production at the expense of root consumption. For radionuclides, the given correlation changes, the degree of change therewith depends on the landscape features. At the forests of accumulative landscapes, annual root delivery of radionuclides into annual production in absolute values is approximately equal to their return. At the forests of eluvial landscapes, return is 2-5 times higher than their annual consumption by the root way. Along

with this, intensity of radionuclide involvement into the biological circulation significantly exceeds their carryover with infiltration flow of moisture beyond the bounds of root-inhabited stratum.

Another peculiarity of radiological investigations is establishment of biochemical barriers on the path of radionuclide migration in ecosystems. From the currently available scientific papers, the role of these barriers is shown to be ambiguous both in the BGC structure and in time. Soil is a pronounced biogeochemical barrier in the conditions of automorphic landscapes; biota, and first of all, micro-biota is such barrier in accumulative landscapes and coniferous cenoses. Barrier functions of soils in respect to radionuclides are the most significant among all the BGC components. Results of investigations show that tenth and hundredth parts of % form the total amount of radionuclides per year. Thus, basic amount of activity from 80 to 95% (taking into account micro-biota) at the forest systems and up to 100% at agri-ecosystems (depending on the plant vegetation period) is accumulated in soil. At the same time, barrier functions of soil regarding the various radionuclides manifest themselves in different ways. ^{137}Cs is the most intensively absorbed element, ^{90}Sr , ^{106}Ru , and $^{239/240}\text{Pu}$ are absorbed in significantly lesser degree. It is necessary to emphasize high sorption ability of soil with respect to ^{137}Cs is typical for all the sorts of soils and phytocenosis, including for turf and podzolic sand soil as well. Peat soils are excluded of the rule.

The barrier functions of ecosystems and their separate components have certain temporal dynamics. It is well known that coenotic barrier is clearly emerging during vegetation period for a number of macro- and micro-elements. Afterwards barrier functions again pass to soil. For radionuclides, this shows itself in some other way. However, these aspects have not been studied totally yet, they require to additionally be clarified and corroborated.

Despite of the numerous radio-ecological investigations of forest ecosystems conducted in the vicinities of Kyshtym and Chernobyl accidents, territories of forestlands in the zone of STPA still remain the least studied. The natural and climatic conditions of the region, characteristics of the soil and plant cover differing from the radiation accidents areas can impact nature of radionuclide accumulation and distribution in the components in Pre-Irtysh strip pine forest.

Under the radioecological investigations, a special attention is given to study of the ^{137}Cs и ^{90}Sr behavior peculiarities in the ecosystems. At the same time, there is not much information on the investigations of one of the most hazardous and long-living radionuclide that is $^{239/240}\text{Pu}$. As nuclear weapon tests are the main source of radionuclides delivery into the environment, under the study of the radioactive pollution of some territories, located at the zone of direct impact of Nuclear Test site, investigations of $^{239/240}\text{Pu}$ behavior in ecosystems should be made foremost.

It is known that up to 99% of the plutonium income into the environment is at the surface layers of soil and bottom sediments. As basic part of plutonium (more than 90%) is in soil in non-soluble form, redistribution of $^{239/240}\text{Pu}$ along the ground surface is conditioned mainly by the wind transport. The wind transport leads to $^{239/240}\text{Pu}$ accumulation near any obstacles, including plants. It becomes evident that the most concentration of $^{239/240}\text{Pu}$ is in undersized plants (grass, lichens, and mosses). In so doing, surface pollution is by several orders higher than accumulation due to the processes of assimilation. In the conditions of often gale-strength winds that rise dust clouds, not only undersized plants can be polluted, but trees (rind, conifer needles) as well. Use of this wood for fuel in private houses can cause significant additional irradiation of the population due to the $^{239/240}\text{Pu}$ inhalation delivery into human bodies. But the given aspects have not been studied completely yet and therefore require additional clarification and corroboration.

2.2 Radionuclides in Altay pine forest

Works on the radiation pollution assessment of top-soil and plant cover in Altay region, located in the closest vicinity of SNTA, have been carried out since 1991 by the researchers of the United Institute of Geology, Geophysics and Mineralogy, Siberian Branch, Russian Academy of Sciences (Novosibirsk).

The degree of radioactive pollution in various parts of Altay region turned out to be rather different. The average values of virgin lands pollution density by the year of 2000 comprised 87 mKu/km² (9-248) for Altay Krai, and 55 (3-173) mKu/km² for the Republic of Altay. Macro-heterogeneity in distribution of residual reserve of ¹³⁷Cs that manifests itself on the large territories undoubtedly has primary origin. Mosaic character of modern distribution of ¹³⁷Cs is defined, additionally to the features of primary pollution, by its change due to the migration processes as well.

Fires are the real reason leading to ¹³⁷Cs re-distribution predominantly in the forest BGCs. They affect not only turf, but almost completely eliminate the main ¹³⁷Cs deponents that are the forest substrate/bedding, mosses and lichens. Under the study of topsoil and plant cover of sites of fire in Altay Krai's strip pine forest, it was defined that ¹³⁷Cs carryover due to the burning-out of these components comprised from quarter to half of cesium's amount initially contained in them. In doing so, specific ¹³⁷Cs activity from the leeward side and at the areas not affected by fire, became higher.

Mosses, lichens, forest litter, steppe litter (floor) are the natural screen-accumulators of technogenic pollutions.

In forest BGCs, ¹³⁷Cs is mainly concentrated in coniferous substrates, lichens, and mosses. Coniferous substrates differ from the steppe floor (litter) in more capacity and sustainability against the organic mass decay. Therefore they "keep the memory" about the past pollution. Maximum specific activity of coniferous bedding/substrate can be observed at the areas of local soil pollution, though the direct dependence does not become apparent. While the whole bedding mass ashing, average specific ¹³⁷Cs activity in it comprises 545 Bk/kg. Specific activity of the upper layer of coniferous beddings is close to the activity of steppe floor – 24 Bk/kg, although in some cases it increases up to 50-60 Bk/kg and more, probably due to the process of secondary pollution. Vertical distribution of ¹³⁷Cs in cut-offs of coniferous beddings is highly uneven and is characterized by 1-2 maximums, in which its activity reaches 500-680 Bk/kg. Place of maximums in cut-offs (cross-section of a trunk of a tree) depends on the peculiarities of bedding formation and, possibly, partially associated with radionuclide volley delivery.

Many factors testify to the ¹³⁷Cs redistribution in beddings and its migration into soil, for example, there is ¹³⁷Cs accumulation in lower layer of coniferous beddings on the basement rock, its detection in soils under beddings. Thus, in soils under beddings of Altay Krai pine forest in 1994, i.e. in 32 years after the nuclear tests discontinuance, there were up to 40% of the ¹³⁷Cs total volume. In autonomous landscapes, level of ¹³⁷Cs keeping in coniferous beddings of capacity more than 7-10 cm, is significantly higher (usually it is 95-100%).

Mosses and lichens, in comparison with herbaceous plants, accumulate and keep ¹³⁷Cs. Our special attention was attracted by the wide interval of ¹³⁷Cs specific activity variation in these components. The source of the situation lies in difference in species composition of mosses and lichens, which possess individual abilities of its accumulation. In both cases, delivery of cesium from atmospheric precipitations is predominant. In 1993-1994, in their upper parts, only global ("that of Chernobyl") radio-cesium was revealed on the ¹³⁷Cs/¹³⁴Cs correlation basis. Due to the natural purification processes, values of specific activity only partially reflect their pollution level during the nuclear tests. ¹³⁷Cs migration deep down was revealed at the powerful peat-mosses open-pit mines. While the layer-by-layer ¹³⁷Cs fixing, its accumulation was found in predominantly lower parts of lichen rhizoids and in "bast mat" of mosses that

was 2-3 and more times higher as against the upper parts. But even in ash-laden common mass of mosses, ^{137}Cs specific activity variation is significant: 490 (264 - 760) Bk/kg.

Thus, radiation pollution of top-soil and plant cover by technogenic ^{137}Cs in Altay region has been stabilized by the beginning of the XXI century. Fixing/fastening of ^{137}Cs in soils occurred; in conifer beddings, mosses and lichens it accumulated in middle and lower parts of cut-offs; their self-purification currently takes place due to the embedding and radioactive decay.

2.3 Cesium-137 in the combustible materials of forests

1997 is a year of disastrous fires in forests. There in the suburban strips pine forest some 145 fires took place. More than 18, 000 ha of forestland has burnt away. During 2002, 31 fires in the area of 78 ha occurred. In 2003, 67 fires took place in forests with the total area of 1654, 4 ha.

In addition to the material losses, there is a danger of the secondary pollution by radionuclide in top-soil and vegetation cover.

Study of fires is conducted for a long time in different countries. Large-scale works to study fires are conducted in terms of their simulation; properties of forest combustible materials and character of fire spreading in various kinds of conflagrations are under investigation; air flows and composition of aerosols and other issues are in the process of investigation. The amount of papers and articles devoted to that issues is large.

A new direction in the sphere of forest pyrology appeared after the Chernobyl accident. Study of forest fires in the areas suffered from nuclear fall-outs showed that burning forestlands is accompanied by an active involvement of artificial radionuclides into the migration. Their carryover from the sites of fire by the atmospheric air contribute to the adjacent areas pollution causing additional dose stresses to the population [ii, iii]. ^{137}Cs is carried over from the seat of fire in the most active manner, other radionuclides of Chernobyl origin migrate in considerably passive manner [iv], therefore the greater part of scientific papers is devoted to this isotope. A possible mechanism of its transport is considered to be evaporation and carryover with particles of soot under the impact of the ascending hot air flows or surface drainage (melt water, rain) [iii]. The main share of migrating by the air ^{137}Cs is accumulated in aerosol particles of less than 1.8 mkm in size. It was visually established that it was associated with particles of pitch evaporating from the burning pitch [v].

Investigations in the adjacent to the Chernobyl APP zone showed that form of finding of ^{90}Sr and ^{137}Cs in top-soil undergo significant change at the high air temperatures. At the temperature of 200-700°C, content of ^{137}Cs increases in water-soluble, exchange, carbonate, and oxide fractions of soils extending its bio-assimilating share. With further increase in temperature (900°C), about 94% of ^{137}Cs is fixing by the interlayer space of soil clayey minerals and become not readily soluble. In contrast to cesium-137, at 450°C, ^{90}Sr becomes less assimilative being combined with Fe and Mn oxides [vi].

^{137}Cs concentration that was 25 times more than the background level at a lower fire was fixed in smoke aerosol. At an upper fire, this value increases up to 100 times. Establishment of the fact that plutonium isotopes available in the smoke, undoubtedly, necessitates to additionally take appropriate measures for protection of fire liquidation participants' respiratory apparatus [vii].

Complete mass concentration of aerosol emission over the fire varies from 30 up to 70 mg/m³, that 1000 times more than in the atmosphere. In doing so, average content of mineral and soil substances comprises 1-3% [viii]. Hence, not only artificial radionuclides, but some heavy metals as well should be involved into the air migration. According to the investigations of Russian scientists in Yamal-Nenets Autonomous District, forest fires in pine

and lichen forests were accompanied by the carryover of up to 16.3% of Hg and up to 11.5% of Pb, which initially were contained in forest cenoses [ix].

Soft forest layer of fallen away leaves, conifer needle, pinecones, branches etc., gradually decomposes and turn into substrate. Converting its amount into the air-dry condition of the substance, in average its quantity with growing mosses and lichens comprises about 11 tones/ha. The underwood consisting of grass and bushes, of which the Labrador tea and the heather represent the highest risk of fire contribute into the forest combustible materials another 5 tones/ha [x]. With the continuous (all-round) fires all these components of forest BGC have completely burn out. One part of ^{137}Cs is carried over the fire sites by the air in aerosol structure, the other one – by the washing away with melt and rain water as well as by winds, for which forest top-soil erosion properties rising is a contributing factor.

Basic components of forest bio-cenoses depositing ^{137}Cs and in one degree or another for a long time retaining it, are forest litters, upper (turf) layer of soils, lichens and mosses. In significantly lesser degree, this relates to grasses, bushes, coniferous needle, and rind.

^{137}Cs distribution in the forest bio-cenoses of Altay Krai was studied during eco-geochemical investigations in 1992-1996. Results of the investigations are represented in the Table 8.

Table 8. Cs-137 distribution in forest bio-cenoses

Item of study	Number of samples	Diapason of values of specific activity of ^{137}Cs , Bk/kg	Average value of specific activity ^{137}Cs , Bk/kg
Soil	100	1-187	50,2
Forest substrate	51	5-550	101
Lichens	61	15-150	50,8
Mosses	92	1-570	129,5
Conifer Needles	40	0-9	2
Bushes	29	0-29	9,8
Grass	180	0-27	1,4

Results of gamma-spectrometric analysis are provided being converted into air-dry condition of substance. In calculations for soil, data only for the upper 5-cm thick horizon (turf) have been used as it is a problem of combustible materials. As numerous investigations show, it is precisely the turf horizon where the basic content of cesium-137 is accumulated. The forest floor, mosses and lichens were sampled in interval manner, but in the table 1, averaged data have been provided. As is obvious from the provided information, the biggest ^{137}Cs amount is accumulated in the forest litter and mosses.

The listed above components of forest cenoses, of course, have different ability to ignite. Usually forest fires start in moss and lichen cover; lichen therewith are the most dangerous in terms of fire. Their humidity depends of the air humidity and it is enough 2.4 mm of precipitations for their complete moistening. On the second day after the rain, humidity of the cover decreases by 40-50% and lichen can burn [xi]. Studied lichens often grow on their rotted and compressed remains, which, as a rule, are intensively moistened. These formations place among litters and precisely in them the highest contents of cesium-137 can be observed. During the fires, the growing part of lichens burns completely and most often sinters with formation of coke breeze. For mosses, it is difficult to fix some preferable type of ^{137}Cs distribution by vertical: in one case, its heightened activity is fixed in upper divisions of a plant, in other ones - in the middle, in the third ones – in the lower parts. In so doing, ^{137}Cs activity by no means correlates with ash content.

Similar correlation is observed for the most number of studied forest litters formed by conifer needle abscission, but the most widely spread type of ^{137}Cs disposal is its accumulation in the middle horizons.

Observations on fire-sites showed that only during the strong fire these components of forest cenosis can burn completely. Under the superficial fire they are often scorched just in their upper parts or in its half. That makes calculations radionuclide carryover more difficult under the comparison of their content on fire-sites and adjacent areas, which were not suffered from the fire. Therefore, correct results can be obtained only during a fire-sites study, where all the combustible materials have completely burnt away.

2.4 The dynamics of ^{137}Cs and ^{90}Sr content and distribution in a conifer bough

Observations over the dynamics of ^{137}Cs и ^{90}Sr content and distribution in a conifer bough were conducted for 12 years since 1987 till 1998 in a motley grass and green moss pine forest (age of stand is 60 years old), formed on the turf and weakly podzol sand soil in the limits of 30 km zone of Chernobyl APP (so called "Ukrainian Polesye" - marshy woodlands in Ukraine. - *Interpreter*). By the beginning of investigations, density of pollution of the territory comprised 4.62 MBk/m^2 for ^{137}Cs and 1.3 MBk/m^2 for ^{90}Sr .

Sampling of the conifer bough was made in even manner along the whole crown of pine (*Pinus silvestris*) on the annual basis at the same periods with 20-40-repeated replications. To assess a contribution of bough's various structures into its total pollution, the obtained sample was divided into several fractions: growth of the current year of formation (needle + branches), needle of the past years of formation and branches. Conducted investigations showed that by mass in the structure of bough, the most percent falls on the fraction of conifer needle of the past years (40%) and increment of the current year of formation (35%), the rest part made of branches (25%). At the same time, in terms of radionuclide reserves, structural parts make the following decrescent series for ^{137}Cs : increment of the current year (66%) > needle of the past years of formation (20 %) > branches (14 %); for ^{90}Sr this series has an inverse character: branches (40%) > needle of past years (32%) > increment of the current year of formation (28%). This implies that radionuclides in the needle can be distributed unevenly and their content depends on its structural part and chemical nature of a radionuclide.

Concentration of radionuclides in separate components of bough is characterized by the high spatial unevenness. The coefficient of the given index variation is 60-70% for ^{137}Cs and 150-190 % for ^{90}Sr , exceeding the same indicator in soil 2 -3 times that as a whole is typical for variation of radionuclide content in vegetation. At the same time, diapason of variation of various components contribution into the total pollution of bough is not large that testifies of the sufficient stability of these values in definite temporal interval.

A place in a crown structure to sample bough is also important. The maximum radionuclide content is fixed in a bough sampled in the upper part of crown and the minimum one was sampled from the lower part. The difference reach 1.5-2-fold values.

Analysis of change of radionuclide content in a bough in a long-standing series showed that under the aerial delivery of maximum pollution can be observed soon after the fallout.

In succeeding years, a long-term dynamics of radionuclide (^{137}Cs) content changes in ambiguous manner depending of soil and ecological conditions of an eco-top and weather peculiarities in separate years. In the cenoses on the automorphic landscapes, on the major part of the territory, a unilateral trend of ^{137}Cs concentration decrease can be observed, although the intensity of the decrease slows down with time on the most part of the territory. Relatively lesser pollution becomes evident in extremely dry years; radionuclide content during humid years as a rule increases 1.5 times as compared with the median index.

In the long-term series, contribution of bough structures into its common pollution changes. During the first years, the basic contribution into its pollution is made by the components exhibited for the external pollution. They are the past years needle and branches. With time, as a result of the dominating process of radionuclide root delivery into the plants, the main contribution into the total pollution into a bough is made by the increment of the current year

of formation. For 12 years, after the aerial fallouts it increased from the tenth parts of a percent up to 50-70 %.

The long-term dynamics of ^{137}Cs content in bough of hydromorphic landscape cenoses has different from the described above nature. Here under the similar landscapes pollution to automorphic density, in 1.5-2 years after a fallout, radionuclide concentration increase up to maximum values begins by the fifth-sixth year. After that, some recession and certain stabilization of the index under consideration can be observed, but the higher level compare to cenoses of automorphic landscapes. However, the latest data (1998) testify to the possible changes in the curve of long-term dynamics that requires the increase in observations term.

Already in two years after the fallout, the main polluter of bough is increment of the current year of formation in the conditions of hydromorphism. Its contribution varies in the limits of 60-70%. Obviously, it associated with the fact that biological accessibility of radionuclide in hydromorphic soils is higher, and a root pass of radioactive elements delivery in such conditions become a decisive factor at the earlier stages of post-accident situation. Even basing on the maximum estimates, contribution of other structures of bough into its total pollution in these cenoses does not exceed 25%.

On the basis of the fact that nowadays radionuclide content in bough is defined mainly through the pollution level of the current year of formation increment, one can characterize seasonal dynamics of this indicator. As a rule, seasonal dynamics of ^{137}Cs accumulation in pine increment is characterized with unilateral change of its concentration from the spring to autumn. The most definitely it can be observed at young trees and in slightly smoothed form - at the full-grown plants that results from differences in growing processes intensity dynamics and chemical elements assimilation by young and mature specimens.

As a whole, analysis of radionuclide content and distribution dynamics in bough shows that practically during all the period passed since the Chernobyl accident (excluding only 1-2 years), its pollution 2-4 times lower that that of the herbage.

2.5 Mosses as radionuclide accumulators

Radionuclide delivery regularities from soil to plants have been studied by the researchers of the Dept. of continental radioecology, Inst. of plants and animals ecology, Urals Branch of the (former) USSR Academy of Sciences in the framework of the long-term investigations on soil and vegetation cover radioecology. Investigations of radionuclide distribution peculiarities in soil and vegetation cover in natural BGCs permitted to reveal a high concentrating capability of mosses. Actually, due to a number of ecological and morphological features (wide area of distribution, species diversity, slow growth of mass, large sorption capacity and stability of falling out of the atmosphere superfine radioactive particles fixation), it possesses a considerable part in the processes of primary interception and arriving on the Earth surface radionuclide accumulation. Thus, in moss cover of forest BGCs, more than 50% of all the reserves of radionuclides can be accumulated that income with global fallouts; concentration of radiators in mosses as a rule exceeds it in higher surface plants. Due to the long-term conservation of significant part of annual increment of moss cover and its feeble (poor) use for food by the other trophy chains organisms, mosses can serve a place of long term accumulation and deposition of radioactive fallouts.

^{137}Cs concentration is 2-10 times higher, than that of ^{90}Sr in mosses growing in natural conditions and in majority of substrates. In doing so, concentration of the latter one at the various species of mosses is approximately the same, as for ^{137}Cs ; they differ 5-6 times. Difference in both radionuclides in substrates is more significant. Thus, in the lake water, ^{90}Sr and ^{137}Cs concentration comprises only 0.4-0.5 Bq/l, whereas in the forest litter and in timber of rotten trees, it 4-5 orders higher. However, high content of radionuclides in substrates do not lead to the appropriate increase of radiators' concentration in plants. These

circumstances testify that in natural conditions mosses accumulate radionuclides not from the substrates, but from predominantly atmospheric precipitations and water solutions forming in the places of growing the mosses.

Investigation of radionuclide escape from mosses showed that ^{90}Sr and ^{137}Cs fixation resistibility in them does not depend on type of substrate, on which they grow.

It was mentioned that in natural conditions of growing, mosses accumulate ^{137}Cs in more amount than ^{90}Sr . Experimental data on radionuclide accumulation and escape from mosses, give us grounds to presume that one of the reasons of this phenomenon in natural conditions is more solid fixation of ^{137}Cs in plants tissues as compared with ^{90}Sr .

As a whole, both radionuclides possess sufficiently high mobility in the system of "water-mosses". This conclusion seems to be contradicting to the mentioned above information that is indicative of the moss ability to accumulate entering with fallouts one or another radionuclide in significant quantities. At the same time, a number of scientists point out that mosses in natural conditions possess sufficiently long (7-10 years) period of semi-ejection, which indirectly also indicates about the radionuclide solid fixation in the tissues of these plants [xii, xiii]. The noted contradiction can be explained from the specifics of water regime of the considered plants in the natural conditions, in particular, their high water-retaining ability. Considerable moss cover density that in natural conditions forms sufficiently dense formations as "carpets" and "pillows", contribute for the long-term retaining of water solutions in it. Owing to this fact, vegetation with time occurs enriched with radioactive substances entering with atmospheric precipitations and with surface water flows. Slow processes of moss growing and extinction as well as abscission unavailability that slows down radionuclide escape velocity from mosses in natural conditions.

2.6 ^{137}Cs behavior in forest fires of Altay Krai

Chernobyl accident gave a stimulus to numerous investigations aimed at not only revealing the radionuclide pollution scales, but also at the reasons of the secondary re-distribution of radionuclides in different ecological systems. A serious attention has been paid to the forest fires contributing to the artificial radioactive isotopes migration and secondary pollution of the ecosystems that were not harmed by fire. Despite of the fact that Altay Krai is one of the regions that suffered of the 1949-1962 nuclear tests of the Semipalatinsk test site in the most degree, the role of fires in re-distribution of artificial radionuclides on its territory is completely unexplored. Meanwhile starting since 60s, the number of forest fires grows, and if comparing with the mentioned period by the end of 90s, it increased almost 9 times.

In forest BGCs, ^{137}Cs is accumulated mainly in the litters, mosses and lichens. Investigations in Altay Krai show that activity of this isotope comprises in average: in forest litters – 130 Bk/kg of dry mass with spread in values from 20 up to 840Bk/kg; in mosses – 144 (1-541) Bk/kg and in lichens – 38 (15-56) Bk/kg. These components of bio-cenosis practically completely burn away when lower fires. Thickness of forest litters selected at the strip pine forest where fire sites were under investigation, reaches sometimes 20-25 and even more cm. Mosses and lichens in this forestlands are not widely distributed, but on separate areas they cover up to 30-40% of the total area.

On the territory of Altay Krai, three fire sites located in different places of the strip pine forest have been investigated. All the plants, pine cones and small branches/brushwood got to the soil samples; in the places that have been reduced to ashes, samples are represented by sand and ash remains. The route for sampling was selected with the idea that areas of the same relief forms, windward and leeward sides (where possible) have been embraced. Lichens and conifer needle have been sampled at places that have not suffered of fire and located within the fire sites and beyond its limits.

The first of the investigated fire sites is located on the Aeolian sands in the strip pine forest between villages Novoygorievskoe and Volchikha (~270 km from the area "Opytnoe pole" ("Trial field")). The fire took place in 1998, with south-west wind and embraced an area more than 20 ha. In the middle of the forest that has been completely destroyed by a fire, small plots (5-10 m²) unharmed by the fire remained intact, where little shrubs and grass persisted. Transect sampling have been started with the windward side, touched upon the fire site and endured in the forest unharmed by the fire each 40-45 m and merely on the relief forms of the same type. The following values have been obtained through the gamma-spectrometric analysis: (¹³⁷Cs, Bk/kg):

- Windward side soils - 56,3 (from 26 till 99).
- Fire site soils - 40,2 (29-59).
- Fire site soils in останцах - 76,6 (43-109).
- Leeward side soils - 87,4 (19-162).
- ¹³⁷Cs losses for fire site – 28,6%.

Thus, as a result of the crowning fire causes almost complete elimination of the forest litter and turf soil horizon, more than a quarter of radio-caesium originally contained in the BGC components has been displaced. In the pine cones and needles sampled outside the fire site, ¹³⁷Cs has not been found.

The second of the described fire sites located in 2 km eastward from the rayon administrative center Zavyalovo where the fire took place in July 1997 embraced an area of 11 ha at the similar Aeolian sands like at the first of the mentioned cases. At the fire site, the soil is represented by sand with small amount of ash and coaly remains of pine brushwood, behind the fire site by the forest litter and weakly developed turf layer. In the moss and lichen cover of the landscape, specific activity of radio-caesium comprises 50 Bk/kg of dry mass.

In the pine needles, out of the limits of the fire site, radio-caesium has not been found, and on a tree within the fire site, its activity is at the breaking point of gamma-spectrometry determination capability of 2 Bk/kg.

The third of the fires – Rakitovsky, took place due to the dry (thunder) storm in June 1997 at the south of Altay Krai at a strip pine forest (~240 km of the area "Opytnoe pole"). It was spreading for 54 hours and in the upshot, the area of the fire site reached 26,100 ha. The fire rose under strong (up to 20 m/sec) south-east wind that changed its direction several times – first for the north-east, then for the south, and was localized under the south-west direction. Therefore, radioactive pollution of the zone windward and leeward was practically impossible as smoke was spreading extensively.

On the territories under the investigation, soil, mosses, lichens, forest litters, rind, needles and pine timber have been sampled. In the middle of the burnt away area, plots of different sizes (but not more than 10-20 m²) have been found, on which separate trees and lichens retained. Analysis of obtained information shows that this forest fire resulted in removal of almost half of radio-caesium, originally contained in soil cover – 45.7%. At the same time, lichens sampled within the fire site at the areas that have not been burnt away turned to be 2.4 times richer with the radionuclide, than the plants of the same species sampled at the areas untouched by the fire. Similar correlation was noted in pine needle as well. On the unharmed areas, ¹³⁷Cs was not found at all in 60% of samples, within the fire site it is available in small quantities almost in all samples.

Comparison of the analytical data on the BGC components sampled at the fire sites and out of their boundaries on three sites showed significant removal of ¹³⁷Cs when the forestlands burning. Loss of radio-caesium from the soil alone comprised 28.6; 41.5 and 45.7%. The reasons of such wide dispersion of values of the removed radionuclide are ambiguous. At the first of the fire sites under consideration, where there are numerous soil areas, which almost have not been touched by the fire. The burnt away area is surrounded by the dense forest

that protects the fire site from winds from every quarter that excludes active Aeolian processes. In the rest two cases, this factor can play a significant part (the locality is opened for winds) that apparently leads to the heightened removal of radio-caesium from the fire sites. If so, about the third part of the initial amount of radionuclide is removed from the forest soils in with smoke, soot, and aerosol, or washed out by the melt and atmospheric water, 15-20 % is removed by wind. There are some evidence in the scientific literature that indicate lower values of radionuclide removal into the atmosphere – about 5%, but existing information about the high volatility of ^{137}Cs allows to suppose that this appraisal has been to some extent depreciated.

It was noted above that the main quantity of radio-caesium in the studied forestlands is accumulated in the forest litters and turf layer; needle and other components of trees, mosses and lichens are characterized by low values of caesium activity and spread in the studied forests fragmentarily. It is the first two of the listed BGC components serve as main ^{137}Cs sources in smoke, soot and aerosols, which being transferred with water or atmospheric flows are responsible for the secondary radioactive pollution of new/virgin areas. In doing so, some part of radionuclide settles in mosses, needle and rind retained on the burnt away territory as well as on the located nearby areas. In the composition of dust-soot-aerosol particles, radio-caesium is transferred at much more significant distance: smoke of the fires in 1997 could be observed at the enormous territories: practically the whole south of Altay Krai has been embraced by it.

Comparison of radio-caesium activity levels in lichens and needles in the studied zone of the Rakitovsky fire and in samples taken in different time periods practically on the whole territory of Altay Krai can serve as an additional evidence of the fact that plants actively capture radio-caesium entered into the atmosphere during a fire. Correlation is expressed by the figures 54.4/38 for lichens and 2.75/1.63 Bk/kg for needle. In other words, on the areas knowingly got into the fire impact, lichens and needle almost 1.5 times richer with radio-caesium than in average in the region.

For the present moment, conducted investigations cannot correctly answer the question about ^{137}Cs transport form from the fire site and its availability in newly polluted components of the forest bio-cenoses. Majority of the researchers agree in opinion that evaporation and removal with the volatile ashes as well as washout with rain and melt waters cause the radionuclide migration. In our case, the important role apparently belongs to the partial leakage of radio-caesium into the sand and migration with the ground flows as well as Aeolian processes, rather than to the surface washout.

One way or the other, the obtained data gives us grounds to consider that forest fires in strip pine forest of Altay Krai, and hence in strip pine forests in Kazakhstan as well, result in the significant loss of ^{137}Cs , outflow of which from the site of fire promotes the radioactive pollution of new/virgin areas. Undoubtedly, this process presents certain danger for the human beings as well, especially for those who fight the fires or lives in forestlands vicinities.

3 Recommendations for the Project measures

In the structure of the Project's second phase, it is necessary to make provision for the set of measures to study residual pollution level of strip pine forest in Pre-Irtysh, define risks of radionuclide carry-over with the combustion products, risks of the population irradiation through the forest foodstuff (mushrooms, berries, hay-milk-meat), develop in the case of necessity radiological conditions monitoring system in forests.

The recommended Project measures structure:

1. In site identification of explosion clouds tracks, in particular of the primary "polluter", August 29, 1949 explosion. Maps of traces provided in the given review as well as numerous maps available in the NNC can be used for identification purposes. As control points indicating the heightened pollution dots one can use the IAEA and NNC RK made sampling data in the vicinities of Dolon and Mostik villages. The identification will result in development of forestlands maps with marked areas of explosion clouds passing-over on them.
2. In the vicinities of defined on the base of identification area it is necessary to conduct a prospecting gamma-dosimetry, first of all at the western borders of forest, taking into account the "border-of-forest effect" revealed in Chernobyl and Kyshtym. It makes sense to accumulate gamma-dosimetry at the tree trunks (north exposition, usually moss-grown and lichen). Dosimetry of top-soil can give distorted results that associated with heightened content of natural radionuclides of uranium group in rubby soils, on which strip pine forest usually grow.
3. Air-borne gamma-spectrometric survey on Cesium-137 for the area where clouds pass over the forest territory can be effective. Its use, however, can be associated with high expenses that can cause problems of funding from the Project budget.
4. At the sites of abnormalities, revealed through gamma-dosimetry, it is recommended to conduct sampling of all the forest community components - bark, cross-section of the trunk of a tree, boughs, lichens, mosses, soil, forest substrate, mushrooms, and berries. At fire-sites it is recommended to sample all the above mentioned items as well as ashes deposited first of all at the relief depressions, especially in peat bogs, which are unfortunately rare in strip pine forest of Pre-Irtysh. Areas of mature forest or of the one that is of about ripeness age (for a pine, this age is 80-100 years old), of heightened standing density with полнота of 0,7-0,9 are preferable for the sampling. Such forests are the best barrier for radioactive falling-outs, than underwood. Minimum necessary number of sampling points is 20-30.
5. Control sampling, for comparison of polluted regions with unpolluted ones, it is expedient to conduct at the forests areas not older than 40. Number of sampling points is 25% of the sample volume of general sampling.
6. Sampling should be made in two numbers of replications and be accompanied with radiometric measurements.
7. Radiochemical analysis is expedient to be conducted at the laboratories of NNC RK combining it with the control of 10-20% samples in other laboratory.
8. Under the availability of funds, it is necessary to consider a possibility of radionuclide carryover from the combustible material. Modeling can include incineration of material from anomalous areas, expulsion of smoke with air-exhauster and air aspiration to filters. Second option is modeling of ashes entrainment from the surface of latest slash fire. This sort of modeling entrainment of radionuclides with soil particles have been hold by NNC RK on the Test site territory.
9. Calculation of risks for the local population.
10. It is necessary to make provision for the monitoring system development in the case of significant risks. It is also necessary to integrate radiological risk monitoring into a regional system of general radiological monitoring associated with forests.

Cost of radiochemical analysis in current prices in Kazak hstan

1. Gamma-spectrometry (K, Ra, Th, Cs) – 7250 tenge
2. Radiochemistry for Sr - 13 240 tenge
3. Radiochemistry for Pu – 50 780 tenge.

4 Conclusion

Data provided in the review on the level of forest potential pollution give us grounds to conclude that significant risks due to the forest stuff consumption and radionuclide carrying-out during the forest fires are improbable for the local population. At the same time, taking into account the psychological state of the population in the region, carrying out some minimum, but reliable volume radiological explorations is necessary.

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6 Calculation of analyzing expenses

Table. Calculation of expenses for additional sampling and laboratory analyses.

ⁱ 'Ukaz' (Decree) of the President of the Republic of Kazakhstan, May 15, 1992, #779.

Summary estimate

		Collecting materials, preparatory activities	Field work	Laboratory work	Processing obtained data, Final Report	Total
1	Salary	93895,6	77020,6	960550,0	196089,0	1327555,2
2	Social Insurance Fund Tax	15887,1	13031,9	162550,0	33178,3	224647,3
3	Travel allowance	11798,0	54544,0		105710,0	172052,0
4	Materials, fuel	27843,2	130451,0	443900,0	25393,4	627587,5
5	Miscellania	46963,3	125412,1	248200,0	109869,1	530444,5
6	Sub-total:	196387,2	400459,5	1815200,0	470239,8	2882286,4
7	Over-head expenses	39277,4	80091,9	363040,0	94048,0	576457,3
8	Sub-total:	235664,6	480551,4	2178240,0	564287,7	3458743,7
9	VAT	35349,7	72082,7	326736,0	84643,2	518811,6
10	Total	271014,3	552634,1	2504976,0	648930,9	3977555,3

Volume of work

Sampling	100
Laboratory analyses	
- Cs	100
- Sr	50
- Pu	50