Mayak: A 50-Year Tragedy

Greenpeace Russia 2007

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Summary

September 29 2007 is recognized the world over as a depressing date – the 50th anniversary of a radiation catastrophe at a factory processing nuclear materials in the Southern Ural area. Fifty years ago an explosion occurred in a liquid radioactive waste tank at ‘Mayak’[1] – one of the leading military nuclear enterprises of the Soviet Union. Until the Chernobyl disaster, it was the biggest radiation catastrophe in the world.

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[1] Full modern name of the plant – Federal State Unitary Enterprise ‘Production Enterprise Mayak’

As a result of this explosion, known as the ‘Kyshtumskaya catastrophe,’ 272 000 people from 217 settlements, towns and villages were subjected to irradiation. A radioactive trace with a width of 30-50 km stretched for 300 km. An area of 1000 km2 was taken out of economic production.

The Kyshtymskaya catastrophe half a century ago has left a mass of unsolved problems. First of all is the situation of the health of inhabitants living on the land affected by the radioactive trace. The official point of view is that the irradiation of these people does not exceed ‘regulatory norms’. But the health of these people differs considerably from the average in Russia. For example, the specific number of cancer cases in the settlements of Tatarskaja Karabolka and Musakaevo is almost five times the Russian national average.

The lack of any rehabilitation programs, or of resettlement of these people, demonstrates clearly the immoral attitude of the Russian atomic energy company.

At Mayak, the plant known as RT-1 has been in operation since 1976 for reprocessing SNF from civil atomic stations. The technology of the process means that the volume of radioactive waste exceeds the initial volume of SNF by thousands of times. A method of reprocessing SNF without producing radioactive waste are unknown.

The reprocessing of one tonne of SNF results in the following amount of liquid radioactive wastes being generated (shown in curies per litre):

- Highly radioactive - about 45 $м^3$, activity up to 10 Ci/l;
- Medium-level radioactive - about 150 $м^3$, activity up to 1 Ci/l;
- Low-level radioactive - about 2000 $м^3$, activity up to10^{-5} Ci/l.

The majority of the waste is in liquid form, disposed of into ponds. An amount of 140 tonnes of SNF is reprocessed at the Mayak plant annually.

In this report, pollution analysis concentrates on the result of the disposal of liquid radioactive wastes into the environment. Contemporary atmosphere emissions and subsoil water pollution caused by the activity of RT-1 also need to be studied.

The subject under consideration of the consequences of RT-1 activity is the pollution of the Techa river, on the banks of which about 7000 people still live. Among the settlements are Muslyumovo, Brodokalmak, Russian Techa, and N.Petropavlovskoe. In the 1940s and ‘50s, during the operation of the military program, these settlements were not evacuated.

One of them, the village of Muslyumovo, is officially regarded as a testing ground for research into the influence of low radiation. Though the representatives of the nuclear complex deny any negative effects of low radiation upon human health, nevertheless the data statistics show otherwise.

Sociological data obtained by Greenpeace in Russia during a poll among the local people shows the rate of malignant cancers in Muslyumovo is 2.6 times higher than the average range in Russia. According to official data, 249 of the 4500 inhabitants of Muslyumovo are on the oncological register, which is 3.9 times higher than the Russian average numbers of people having malignant neoplasms. For a further 818 inhabitants of Muslyumovo, additional examination is necessary.

According to the results of cytogenetic examination of some families in Muslyumovo, genetic abnormalities exceed the norm by 25 times. The experts consider the revealing of genetic abnormalities to be the consequence of living with high background radioactivity.

At present the management of the Russian agency for atomic energy are initiating a project of Muslyumovo migration. But due to lack of funding, the authorities will resettle only those people living next to the river. They will be re-settled to the other side of Muslyumovo, where according to the sanitary services’ data the radioactivity of drinking water is 2-3 times higher than the so-called ‘interference level’ when protective measures become necessary. Ironically, the new district of Muslyumovo, named ‘Novomuslyumovo’, will be located near the village cemetery.

It is hard to estimate the amount of the contemporary contribution of the Techa river pollution that is the result of the civil stations’ SNF processing, and that which is the influence of the military legacy. Nevertheless the contribution of the RT-1 plant to the pollution exists and the scale of its contribution is substantial.

In spite of the dam system and the man-made reservoirs into which Mayak disposes of liquid radioactive wastes, these wastes still find their way into the Techa river. According to the experts' estimates, the contribution of so-called bypass canals by stronzium-90 disposal into the Techa river is 17-46%, depending on the volume of annual precipitation. Radioactive filtrate from the reservoirs into the Techa river is 5-6 mln m^3/year.

In 2002, Gosatomnadzor of Russia refused Mayak a licence for the storage of liquid radioactive wastes using the system of Techensky cascade reservoirs. From Note of Gosatomnadzor №3-13/701 as of 20.12.2002: "*Due to the Gosatomnadzor of Russia determination as of 19 December 2002, the Mayak was not given the licence for exploitation of complex with nuclear materials meant for radiochemical reprocessing of the irradiated nuclear fuel (factory 235) because of the following reasons: the Mayak keeps on dumping average- and low active wastes into the open water bodies (violation of article 51 of Federal Law «About environmental protection", art. 104 of Water code of Russian Federation , art. 48 of Federal law "About atom energy use…*"

SNF reprocessing is an inseparable part of the atom power engineering of Russia and many other countries. The absence of reprocessing facilities in some countries does not mean that the nuclear industries of these countries do not produce waste. They can deliver SNF to the UK, Russian Federation and France, which are reprocessing SNF from other countries.

In the history of Mayak more than 1540 tonnes of foreign SNF have been reprocessed (data from 2001). As a result over 3 million m^3 of liquid low-level and middle-level radioactive wastes were spilled into the environment. Over 70 000 m^3 of highly radioactive wastes are stored at the Mayak facility (approximately).

Table 1. Reprocessing of SNF at Mayak

	SNF volume (tonnes of heavy metal)	**Highly radioactive liquid wastes, m^3**	**Middle-level radioactive liquid wastes, m^3**	**Low-level radioactive liquid wastes, m^3**
Bulgaria	331.5	14 918	49 725	663 000
Hungary	269.3	12 119	40 395	538 600
Czechoslovakia	80.5	3 623	12 075	161 000
Finland	311.7	14 027	46 755	623 400
Germany	235.0	10 575	35 250	470 000
Ukraine	314.2	14 139	47 130	628 400
Iraq	0.12	5.4	180	240
Total	**> 1542**	**69 390**	**231 300**	**3 084 000**

From the year 2000 the amount of SNF received from abroad lessened considerably. Nevertheless due to the management of the Russian nuclear complex at least four countries of the European Union (EU), which have agreements for SNF delivery to Russia, are likely to renew their contracts. They are: Bulgaria, Hungary, Slovakia and the Czech Republic. The new Russian legislation adopted in 2001 permits not returning highly radioactive wastes occurring from SNF processing to the country-supplier. According to the Russian atomic agency (Rosatom) Bulgaria, Hungary and Slovakia would welcome a scheme.

Among new potential clients of SNF treatment Rosatom is considering **Switzerland, Germany, Spain, South Korea, Slovenia, Italy,** and **Belgium**. It means that these countries at least do not have a fixed policy at legislative level that their SNF will not be sent to Russia or any other country for processing.

On the other hand is Finland, which adopted a law saying that SNF shall be handled, stored and permanently disposed of in Finland. Rosatom therefore considers Finland as unlikely to be a potential client.

In cases where countries considered by Rosatom as potential clients decide to export SNF, the government of Russia would immediately suggest the territory of Russia for SNF export. At present the national legislation for comprising favorable conditions of SNF import from other countries is being revised. In 2001 the following amendment was made: SNF could be imported for storage without reprocessing, and storage of the highly radioactive wastes of foreign SNF reprocessing allowed in Russia, for ever. This contradicts world practice. In 2007 the direct prohibition of importation for storage and final disposal of nuclear materials was excluded from legislation.

The second reprocessing factory for dealing with SNF imports, including SNF from Western-design reactors, is being constructed by the authorities of the Russian Federation in the Krasnojarsk region. Financed by the federal budget, the experimental-demonstrative centre of SNF processing is to be put into operation by 2015. The estimated cost of the centre is several billion rubles (several hundred million euros). The factory itself will be put into operation after 2020. Aside from the new factory construction, Mayak is being modernized in order to receive the SNF from Western-design reactors. In addition, as recently stated by President Putin in 2007, the SNF utilization factories may be located in the centers of uranium enrichment. This would mean facilities for SNF utilization near Irkutsk, on the base of the Angarsk electrochemical complex, where the construction of an international center of uranium enrichment is being planned.

SNF reprocessing is economically ineffective. This is confirmed in the work of the RT-1 facility. The reprocessing of foreign SNF would make a profit and support ineffective production over a very short period of time, due to the postponement of dealing with the problem of radioactive waste and the refusal to solve social problems around Mayak.

The purpose of this report is to demonstrate that atomic energy will not be able to solve the problems of climate change and energy security with ecologically and socially acceptable methods. At the beginning of 2007 Greenpeace prepared the report ‘Energy revolution’ which showed, on the basis of scientific data, that an alternative, nuclear-free energy scenario is possible. This scenario allows the exclusion of atomic power from the energy balance by 2030. It should be noted that the share of atomic power engineering in the world’s common energy balance does not exceed 6%. The report can be found at www.energyblueprint.info

Among the first steps in the rejection of atomic power engineering must be the termination of SNF reprocessing, as one of the dirtiest of technological processes. In accordance with the conclusion of the ‘Energy revolution’ report, mankind must invest in energy conservation and renewable sources of energy instead of dangerous and risky power engineering. The limits of financial resources and a short time span mean the authorities of the world’s leading countries must urgently revise the policy of investment in the sphere of power engineering.

The history of Mayak is one of the reasons why we should do this.

1. The history of ‘Mayak’

The Federal State Unitary Enterprise ‘Production Enterprise Mayak’ (the FSUE ‘PE Majak’) was founded for the industrial production of plutonium for nuclear weapons. It is located in Cheljabinsk province in the South Urals, not far from the cities of Kishtym and Kasli. The Ozjersk city (or Cheljabinsk-65) in which the Majak staff and their families live is situated not far from the enterprise itself.

Fig. 1. Location of the FSUE ‘PE Mayak’

The launch of a weapons reactor for extraction of the fused substances may be considered the beginning of Mayak activity. The reactor was put into the project capacity in June 1948 [See Note 1 at the end of the document]. At the time of different programs coming into being Mayak had several weapons reactors (some sources say up to 10), a facility to extract plutonium from the irradiated nuclear fuel (spent nuclear fuel - SNF), and production of nuclear bombs [See Note 2].

In 1976 at Mayak the processing factory for SNF of civil (rather than military) origin was put into operation – the so-called RT-1 (the abbreviation means ‘fuel regeneration’). The factory was destined for the processing of SNF from nuclear power stations with reactors of the soviet design: VVER-440, BN-350, BN-600, exploratory reactors and reactors of the icebreaking and naval fleet of USSR. Reprocessing supposes plutonium and debris extraction of SNF, with retention of the so-called regenerated uranium, which is used for fresh fuel production. The extracted plutonium is sent for use by the atomic power industry based on the so-called fast neutrons reactors. The factory is able to process 400 tonnes of SNF a year.

Present military production has at least two military reactors. On the civil side, the RT-1 factory processes up to 140 tonnes of SNF a year, limited by ecological and economic limitations. At Mayak there is also isotope production, and the storage of plutonium and weapons grade uranium.

It is important at the Mayak facility to divide the civil from the military production, with divisions both organizational and financial, which is logical when it comes to atom power engineering entering into market relationships. But in spite of the declared desire of such a division by the atomic branch authorities, real steps have not been observed yet. According to official plans to reform the nuclear complex, the nuclear complex in Russia should be divided into four organizational-legal areas:

- Nuclear weapons complex
- Industrial power complex
- Radiation safety
- Fundamental science.

According to the decree of the President of Russian Federation #556 'Restructuring atomic industrial-power complex of Russian Federation' dated Apr. 27, 2007, the industrial-power complex is to be incorporated with the formation on its bases of several of the enterprises of the integrated holding company Atomenergoprom. Though the SNF processing is a technological part of the industrial-power complex, the civil part of Mayak will not join Atomenergoprom. At a similar half-military enterprise, the Siberian chemical plant, the non-military production part (uranium enrichment) will join Atomenergoprom. Perhaps it is connected with the initial non-profitability of SNF reprocessing of Russian NPPs. See Chapter 6.

Obviously Mayak will be required to join the group of enterprises, representing the area of 'Radiation safety'. This group will be responsible for the storage and processing of nuclear materials and also for the final disposal into the ground of radioactive waste. The future legal status of this group of enterprises, with respect to radiation safety, is unclear; at state level the Russian policy regarding radioactive wastes has yet to be determined, and lacks the corresponding legislation, and the economic responsibility for the utilization of radioactive waste is also not determined.

2. Radioactive pollution: a result of the military program

The releases and discharges of radionuclides as a result of Mayak's activity have taken place, and are still, in regulation and accident regimes. It is hard to analyze the regulation emission in the accident-free regime.

There is some information on accidental release and discharges. There were hundreds of accidents with concrete consequences at the Mayak. Among them are three of the greatest official catastrophes connected with the emission of radionuclides into the environment [2].

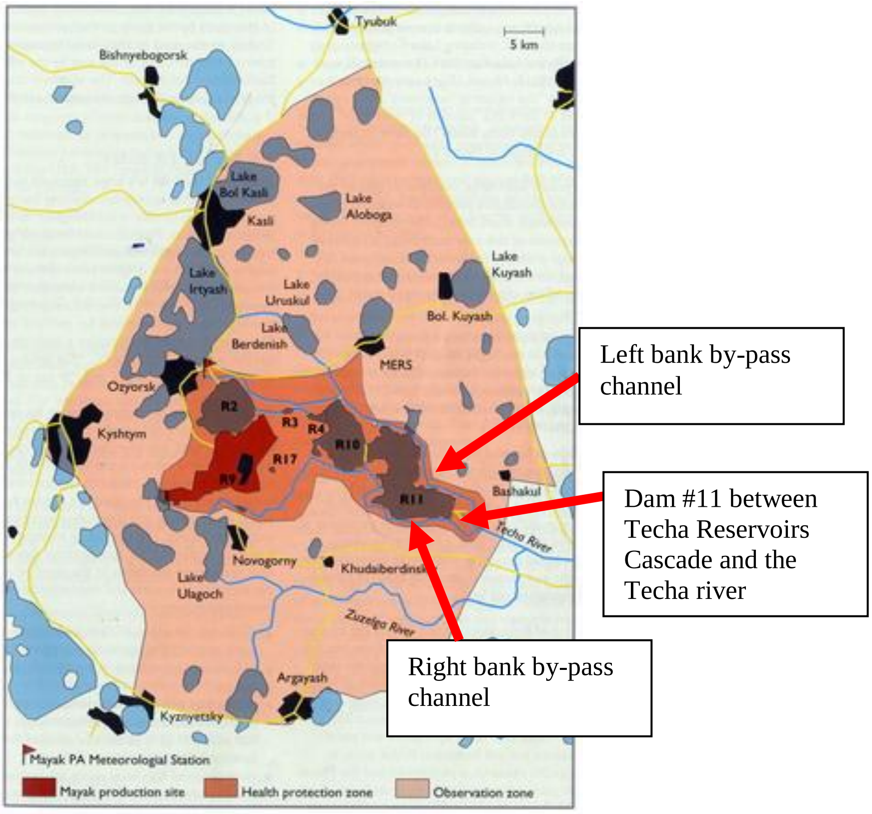
2.1. Release of radioactive waste into the Techa river, 1949-51

The first catastrophe is considered to be the emission of liquid radioactive wastes into the Techa river, which took place from March 1949 to November 1951. During this period over 2.8 million curies of activity were spilled into the river network. For comparison, the Chernobyl emission made up 380 million curies. An estimated 124 000 people in 41 settlements were subjected to radiation. Settlements totalling 8 000 inhabitants [3] were evacuated, but some nearby (about 7 000 people) were not evacuated – settlements such as Muslyumovo, Brodokalmak, Russian Techa, and Nizhnepetropavlovskoe (fig. 2).

Fig. 2 Hydronet in the area of the Mayak location, with indication of settlements evacuated and not evacuated in the valley of the Techa river [4]. The zone of location of the Techa water bodies' cascade is marked on the picture, see Fig. 3.

In order to limit the emission of radioactive wastes into the environment, a system known as the Techa cascade of water bodies (TCWB) system of dams was built at the beginning of the '50s, with continued building later. It consists of a system of dams, by which the man-made reservoirs were created, see Fig. 3.

Fig. 3. Techa cascade of water bodies. (The water bodies are numbered in accordance with official numeration.) [4].



At present there is no direct dumping of liquid radioactive wastes into the open hydronet. But liquid radioactive wastes being turned out by civil production get into the Techa river through the system of bypass canals and filtrate of the dam 11, separating Techa from the TCWB (see Chapters 3 and 4 for more detailed information).

It is difficult to define the degree of influence of direct dumping at the end of the '40s, during the practice of military programs, and contemporary dumping as a result of SNF processing. Nevertheless we may state that the results of dumping due to contemporary SNF reprocessing at the factory RT-1 exist, and the scale of this pollution is quite considerable (see Chapter 3).

As the result of the dumping of radioactive wastes, the Techa river and its flood plain are rather polluted. According to the report of activity of Gosatomnadzor of Russia in 2002, the stronzium-90 concentration in the Techa river water in the area of Muslyumovo in 2002 was 13.9 Bq/l, which is approximately by 1.6 times higher than that of 2001 (8,7 Bq/l). These rates exceeded the interference level[2] by 2.8 times, determined by SRF99-5 Bq/l [5].

According to the data [3], in 2000 the specific activity of river water by ^{90}Sr as it passed Muslyumovo was higher - from 15 to 40 Bq/l. The density of soil pollution in the flood plain area from dam 11 of TCWB to the Muslyumovo settlement is from 0.01 to 0.07 Ci/km^2. The maximum registered rate of pollution density of the area of the lower flood plain at Muslyumovo by ^{137}Cs is 833 Ci/km^2. Weight average density of soil pollution by ^{90}Sr of flood plain within the Muslyumovo area is 85 Ci/km^2, by ^{137}Cs – 71 Ci/km^2.

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[2] In accordance with the norms of radiation security accepted in the Russian Federation, - this is the level of radiation factor. It is necessary for protective measures to be taken when it is exceeded.

In 2002 Greenpeace Russia took soil samples in the flood plain of the Techa river. The data of laboratory researches [6] are given in the table below.

Table 2. Content of Cs137, Pu239,240, Am241 in the soil of flood plain of the Techa river near the Muslyumovo settlement (2) and in the place of river crossing and roadway Cheljabinsk - Sverdlovsk (1)

№ of sample	**Cs137 Bq/kg**	**Pu239, 240 Bq/kg**	**Am241 Bq/kg**
1.	1674±38	960±90	60±30
2.	111.3±1.9	647±89	20±12

For comparison:

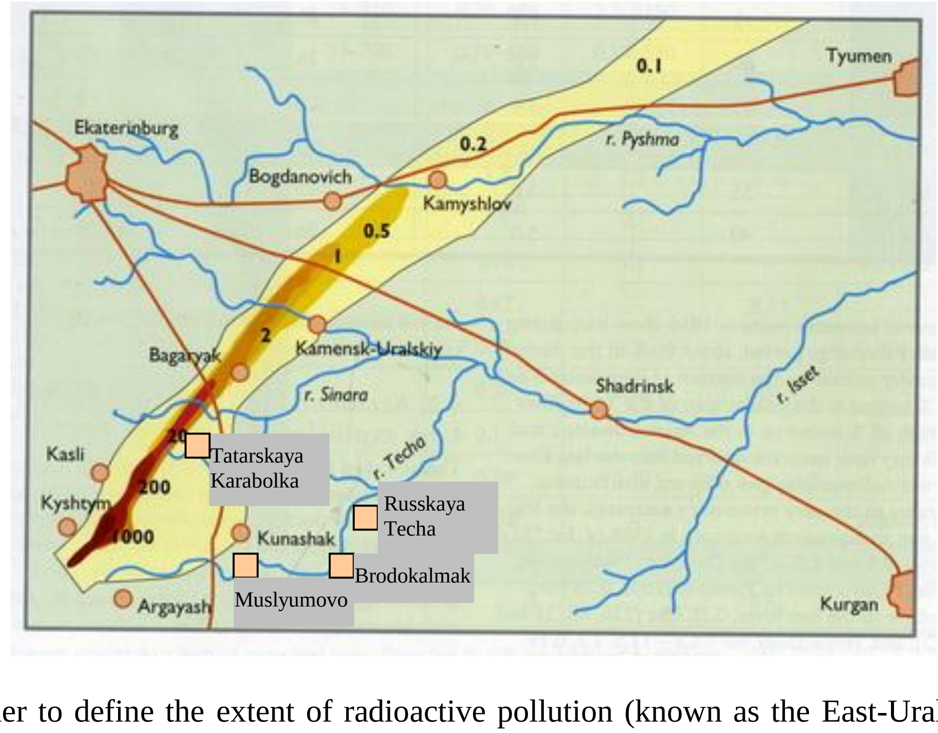
- The pollution level by isotopes of plutonium outside the zone of influence by nuclear installations is about 2-2.5 Bq/kg or by 300-400 times lower, than in samples taken in the flood plain of the Techa river.

It should be mentioned that outside the flood plain of the Techa river the pollution is much lower and the doses obtained depend upon duration and contact forms with flood plain of the river, see chapter 7.

2.2. Explosion of liquid radioactive waste tank on September 29, 1957

The second radiation catastrophe, the 50th anniversary of which falls in 2007, is connected with the explosion of a tank of highly radioactive waste on the territory of Mayak, when 20 million curies was released into the environment, 2 million of which were found outside the production territory. Until April 26, 1986 this radiation catastrophe was the greatest in the world. (The Chernobyl discharge was 380 mio curies). As a result 272 000 people from 217 settlements were subjected to radiation.

Fig. 4. Radioactive pollution as the result of the explosion on September 29, 1957 [4] (pollution density is given for Sr90 Ci/km²).



In order to define the extent of radioactive pollution (known as the East-Ural radioactive trace) the density of strontium-90 was taken. The length of trace with pollution density 0.1 Ci/km (exceeding the global level of strontium-90 disposal by 2 times) was 300 km, with a width varying from 30-50 km. The analyzed polluted square was 15 000-20 000 km² [4].

In 1958 the land with a pollution density of over 2 Ci/km2 covering an area of over 1000 km² were taken out of economic use. The settlements of this territory were evacuated.

But several settlements were left on the polluted border, with a density of 2 Ci/km², including Tatarskaja Karabolka (about 500 residents) and Muskaevo (about 100 residents). According to officials, living on the border of the area of land excluded from economic use is safe. But the practice shows otherwise.

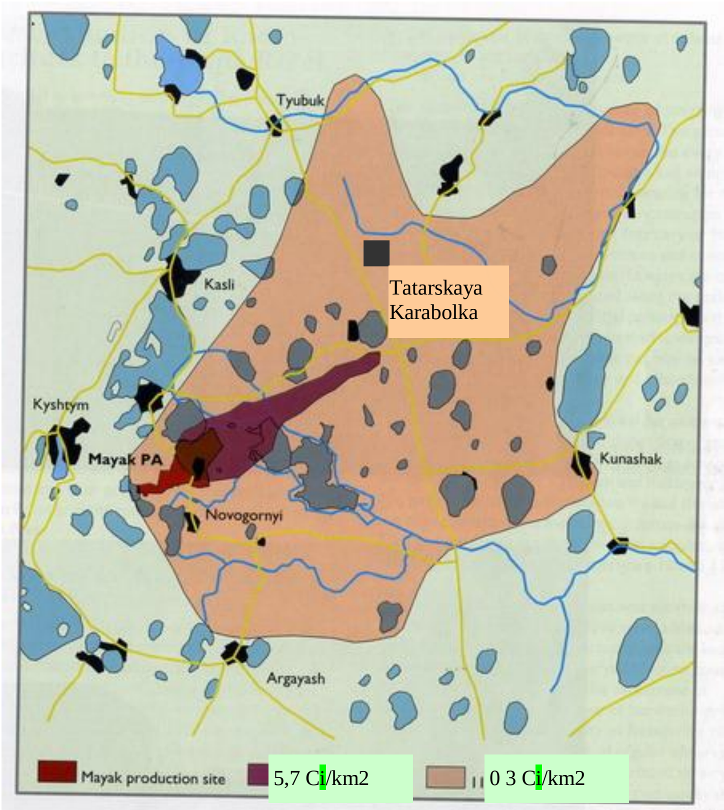
For instance, there is the problem of so-called secondary pollution, when the pollution of the land increases rapidly after usage of dung as fertilizer, from cows that had been pastured on the polluted fields. Due to the ‘Rosgidromet’ note № 20-59/176 as of 17.07.2001, the Sr90 content in some gardens of Tatarskaja Karabolka is 5-7 Ci/km2 [9], while the Tatrskaya Karabolka is located on the territory with pollution density by Sr90 0.2-0.4 Ci/km2 [10]. For comparison, according the law ‘Of social defense of citizens, subjected to radiation activity in the result of catastrophe on the Chernobyl Nuclear Power Plant (NPP)’, the areas with a pollution density of over 3 Ci/km² were referred for resettlement.

In 2002 Greenpeace Russia took soil samples near the Tatarskaja Karabolka. The analysis revealed that the content of plutonium isotopes 239 and 240 to be 21.1 Bq/kg [6]. For comparison the pollution level of plutonium isotopes outside the zones of influence from nuclear installations was about 2-2.5 Bq/kg, or by 10 times lower than in samples taken near the Tatarskaja Karabolka.

2.3. Radioactive dust discharge of Spring 1967

The third catastrophe was caused by the wind blowing radioactive dust from the banks of the Karachay lake (water body №9, Fig. 3), used as a reservoir for middle-active wastes. As a result, in the period from April 10 to May 15 1967, 0.6 mln curies was dispersed into the environment. These wastes accumulated on an area of 2 700 km², see. Fig. 5. This land had a population of 42 000 people, living in 68 settlements. The polluted area is the same as that of after the explosion of 1957; see Fig. 4.

Fig. 5. Pollution as the result of wind-blown radioactive dust in Spring 1967. [4] (Pollution density is given for Cs137 Ci/km^2).



Tatarskaja Karabolka was caught in the polluted zone. According to the analysis of soil samples made by Greenpeace Russia in the Tatarskaja Karabolka area, the content of Cs-137 is 230 Bq/kg.

3. Contemporary radioactive pollution: a result of reprocessing spent nuclear fuel

The technology of SNF reprocessing involves the release of a great volume of liquid radioactive wastes into the environment[3]. There are no known alternative technologies that would make it possible to eliminate such a release. As a result of processing one tonne of SNF, the following liquid radioactive wastes are produced:

- Highly radioactive - over 45 m3, activity up to 10 Ci/l;
- Middle-level radioactive - over 150 m3, activity up to 1 Ci/l;
- Low-level radioactive - over 2000 m3, activity up to 10^{-5} Ci/l. [11]

Over 140 tonnes of SNF are being reprocessed annually at the Mayak plant [12].

Due to the main sanitary rules of radioactive safety provision (SRRSP-2002), accepted by the decision of the chief state sanitary doctor of the Russian Federation as of December 23, 2002 № 33, the liquid radioactive wastes are: "*Organic and inorganic liquids which are not for further use, pulps, slimes; the specific activity of those which exceed the interference level by more than 10 times are given in Appendix 2 of Standards of Radiation Safety-99 (SRF-99)*". In accordance

[3] In this report only pollution connected with liquid radioactive wastes is considered. Air pollution and that pollution connected with the storage of solid radioactive wastes are also of great importance from the ecological and social points of view, and need separate consideration.

with SRF-99, the interference level is: "*The level of radiation factor. In the case of it exceeding this, certain protective measures are to be held*".

For example: due to the SRF-99, the interference level for one of the most dangerous radionuclides, stronzium-90, is 5 Bq/kg of water. So water containing stronzium-90 in volume exceeding 50 Bq/kg or 1,4x10^{-9} Ci/kg, is relegated to liquid radioactive wastes (1Ci=3,7x10^{10} Bq).

3.1. Storage of liquid radioactive waste

At Mayak, low- and middle-level radioactive liquid wastes are being spilled into the Techa cascade of water bodies and an isolated lake connected with ground waters, here and further afield (See Fig. 3). Highly radioactive wastes are stored within the confines of the enterprise.

Low active wastes are spilled into water bodies №s 2, 3, 4 and 17. Radioactive wastes with specific activity 2x10^{-7} Ci/l, coming through the sewage waste system of the Mayak factories are exposed to **water body № 2** [13]. Their volume is 0.7-1 million m^3 per year, commonly with activity of 140-200 Ci/year [4]. For comparison: the volume of total activity, accumulated in water body № 2, is according to various assessments 22 000, or 100 000 Ci [13]. The average specific radioactivity of water in water body №2 is 2.6 x 10^{-7} Ci/l [12]. Sr90 activity is over 2 000 Bq/kg, exceeding the interference level determined by SRF-99 [13] by almost 500 times. Water body № 2 is defined as the reservoir for radioactive wastes.

For comparison: the volume of radioactivity spilled as the result of the accident at the Chernobyl NPP was 380 million Ci.

In accordance with the sources of information available, water body № 2 has a flow into the Techa cascade of water bodies. Accordingly [4], water flows into water body № 3.

Liquid radioactive wastes are being disposed of into **water body № 3**. Their volume is 0.1 million m^3 a year, specific activity 4 000 000 Bq/l (1x10^{-4} Ci/l) [12]. So the total radioactivity coming to the water body is 10 000 Ci/year. The total accumulated radioactivity of the water body is 44 000 Ci [11]. The Sr90 specific activity is 24 000 Bq/kg, which exceeds the interference by thousands of times, determined by SRF-99.

Up to 12.2 thousand m^3 of liquid radioactive wastes were spilled in twenty-four hours in to **water body № 4** [13]. The total accumulated radioactivity of the water body is 7 300 Ci [13]. The Sr90 specific radioactivity is 15 000 Bq/kg, which exceeds the interference by thousands of times, determined by SRF-99.

Water bodies №s 3 & 4 are the official part of the Techa cascade of water bodies. In the event of overflow and filtration through the dam system, the low-level radioactive wastes from water bodies №s 3 & 4 flow into water bodies №s 10 & 11, and from there further, into the Techa river. Besides this, there is a filtration from water bodies №s 10 & 11 into the bypass channels flowing nearby – canals on both the left and right banks, which lead directly into the Techa river.

Middle-level radioactive liquid wastes flow in to the water bodies №s 9 and 17 [11, 13].

Into **water body № 9 (lake Karachaj)** 20 000 m3 of middle-level radioactive liquid wastes flow annually. Their specific activity is 10-20 Ci/l [13]. Water body № 9 is the reservoir of liquid radioactive wastes. The filtration of 1976-1997 led to losses of water from 70 800 to 483 700 m3 a year (at the project volume of the body 300 000 m3) [13]. Liquid radioactive wastes from water body № 9 constantly leach into the system of ground waters and migrate to the water intake of the ground waters of neighboring settlements.

3.2. Radioactive pollution of the Techa river

Liquid low-active waste discharged by Mayak eventually flows into the Techa river. The flow takes place indirectly, via the system of the Techa water body cascade (the dam of water body No. 11) and the bypass channels (on both the right bank and the left).

Filtration through the dam of water body No. 11

The dam and the sides of water body No. 11 are the last barriers separating the Techa water body cascade from the open hydrographical network, the Techa river. According to reference 14, irretrievable filter losses via the sides and bottom of the water body reach, as some assessments state, 10 mln m^3 water annually. According to other estimates, filtrate of water body No. 11 amounted, during 1984 - 1998, to 0.066 – 0.11 mln m3 annually, while afflux of Sr90 amounted, during the same period, to 0.1 – 0.73 Ci annually [14]. According to ref. 13, filtrate escaping under and around the dam amounts to 5-6 mln m3 annually.

Afflux of radionuclides through the right bank channel

The right-bank channel is located near water body No. 11. As a result of filtration, most of the radionuclides flow into the channel from water body No. 11. According to assessments made in ref. 14, the forecast discharge of strontium-90 in the Techa River via the right-bank channel as a result of filtration from No. 11 will amount, in the next few years, to 15 Ci per year.

Afflux of radionuclides through the left bank channel

The left-bank bypass channel is located near water bodies Nos 10 and 11. As a result of filtration, radionuclides flow into the channel from these water bodies and via narrow channels [14]. According to assessments made in ref. 14, the forecast discharge of Sr90 in the Techa River via the left-bank channel as a result of filtration from Nos. 10 and 11 and via narrow channels will amount, in the next few years, to 10 Ci per year.

Therefore, the total afflux of activity into the open hydrographic network (the Techa river) from the system of the Techa cascade of water bodies is about 25 Ci per year, solely with regard to strontium. According to expert assessment, the bypass channel contribution alone of carrying strontium-90 into the Techa river water (without filtration from the dam of water body No. 11) is 17- 46%, depending on annual precipitation [13].

For comparison: the stock of strontium-90 in the floodplain of the Techa River from the dam of water body Nr. 11 to the Muslyumovo village is 970-1200 Ci [14].

Most of the Sr90 flows into the Techa as a result of washing off from the bottom sediments after flooding. However, it is necessary to take into consideration that most of the Sr90 flowing from the Techa cascade is deposited in the sediments. According to the assessment [14], the discharge of Sr90 in the area of the Muslyumovo village in the period of 1995 - 1998 was 17.9-26 Ci per year, which can be compared with the volume of strontium-90 flowing from the Techa cascade of water bodies.

3.3. Possibility of reducing pollution of the Techa river through ending the reprocessing of spent nuclear fuel

A substantial part of radionuclide input into the Techa river is directly associated with the current activities of the Mayak in reprocessing SNF from nuclear power plants. According to ref. 14, the only effective way to decrease the concentration of radioactivity and discharge of strontium-90 into the Techa river is to decrease the concentration of this radionuclide into the river head from hydro-technical constructions (filtrate of dam 11, left-bank and right-bank channels).

In the long run, pollution in the river is influenced by the level of specific radioactivity in water bodies Nos. 10 & 11 that, in turn, depend on the level of specific radioactivity of water bodies Nos. 3 & 4, where Mayak annually discharges liquid radioactive waste. It can be supposed that if the discharge of liquid radioactive waste from SNF reprocessing into the Techa cascade were to be ceased, afflux of radioactivity into the Techa River would reduce as well.

We do not have at our disposal either information nor calculation of figures of theoretical reduction of radioactivity afflux into the open hydrographical network in the case of the cessation of radioactive discharges by Mayak. Nevertheless, on the basis of the available data, the following can be supposed:

1. The total accumulated radioactivity of the Techa water body cascade is about 300 000 curies, most of which is concentrated in the bottom sediments [13]. Discharge of low-level radioactive liquid solely in water body No. 3 amounts to 10,000 Ci per year, or 3% of the existing total radioactivity of the Techa water body cascade. However, taking into account that 95% of the radionuclides already accumulated are deposited in silt [13], it is also recognized that the additional discharge means that not less than 30% of radioactivity is concentrated in the water of the water body cascade.

2. The fact that 90% of the affluxing radioactivity is fixed in the bottom sediments (including those in newly built silt – 5 mm per year) [13], cannot serve as a justification for additional discharge of radioactive waste, since 10% of radionuclides stay in water and migrate toward the open hydrographical network.

3. If radionuclide discharge were to be ceased, growing levels of silt (bottom sediments) will accelerate the process of reduction of radioactivity in the water of the Techa water body cascade while absorbing the accumulated radioactivity.

4. As an indirect proof of the huge impact of newly discharged liquid radioactive waste on the level of radioactivity of the Techa water body cascade and the volume of afflux of radionuclides into the Techa water, the list of radical measures proposed by official experts for the safety of storage pools can be used, which should include:

- Cessation of discharges into water bodies No. 3 and 4 (see above, the volumes of afflux into water body No. 3)
- Increase of efficiency of water purification before discharge into water body No. 2 [13].

Furthermore it is necessary to calculate a reduction of specific activity in the water of the Techa water body cascade due to the concentration of radionuclides in newly growing silt, in the case of the cessation of discharge of liquid radioactive waste effected by Mayak.

Achievement of such a cessation of the discharge of liquid radioactive waste with the use of modern technologies is possible only through cessation of SNF reprocessing as such.

It is important to note that the natural disintegration of radionuclides does not cause a rapid reduction in the level of total radioactivity of water, since the main dose-forming elements in pools are Sr90 and Cs137 with a half-life of about 30 years.

4. Legal regulations for the discharge of liquid radioactive waste into the environment during SNF reprocessing

Russian legislation prohibits the discharge of radioactive waste into the environment. Thus, in accordance with Article 51 of the Federal Law ‘On Environmental Protection’, discharge of production and consumption waste, including radioactive waste, into surface and underground waters, into watersheds, into the ‘bowels of the earth’ and onto soils is prohibited.

According to Article 104 of the Water Code, the burial and discharge of radioactive and toxic substances into water bodies are prohibited.

The illegality of the discharge of liquid radioactive waste by the enterprise was confirmed by the Federal Supervision of Russia for Nuclear and Radiation Safety (Gosatomnadzor). From a letter of Gosatomnadzor No. 3-13/701 of 20.12.2002: "*With the decision of December 19, 2002, Gosatomnadzor of Russia refused to grant Mayak a license for the right of use of the complex with nuclear materials designed for radiochemical reprocessing of irradiated nuclear fuel (plant 235) due to the following circumstances: Mayak continues to discharge moderately-active and low-active waste into open* [water] *bodies (violation of Art. 51 of the Federal Law 'On Environmental Protection' of the Russian Federation, Art. 104 of the Water Code of the Russian Federation, Art. 48 of the Federal Law 'On Use of Nuclear Energy'…"* [18].

As a result of negotiations with the Federal Agency for Atomic Energy, the license was returned, and Mayak adopted a program for the modernization of the enterprise, in order to reduce the discharge of radioactive substances. However, it must be noted that the technology of reprocessing of SNF is such that it does not allow a reduction, completely or partially, of the discharge of radioactive substances into the environment. It can be stated that the discharge of liquid radioactive waste into the environment has continued at the same level up till the present day.

5. Consequences of Mayak's activities for the local population

Below are data which give an idea of the medical effects of Mayak's activities, with the example of three settlements: Muslyumovo due to radioactive waste released into the Techa river, and Tatarskaya Karabolka and Musakayevo due to the catastrophes of 1957 and 1967.

Muslyumovo

Due to reasons unknown, the Muslyumovo village was not evacuated together with the other settlements up and down the Techa river in the period of mitigation of the effects of the discharge of liquid radioactive waste in the late 1940s and early 1950s. The Muslyumovo population was exposed to combined external and internal radiation. The sources of internal radiation were radionuclides entering the body with river water and products of local production. The main dose-forming radionuclide was Sr90, which was accumulated and held in bone tissue for a long time. Measurements of this radionuclide in bones obtained during autopsies of dead inhabitants of Muslyumovo were begun in 1953. In 1959, intravital measurements of superficial beta-activity of teeth were started; and in 1974, measurements of Sr90 in the body tissues using a human radiation meter began [3]. According to Ref. 3, by 2001, individual measurements of Sr90 in tissue, teeth or bones were received for 3880 inhabitants of Muslyumovo village.

According to official medical data of Ref. 3, the difference between the medical indices of the Muslyumovo village and mean-Russian indices, is a more frequent pathology of the locomotor system (degenerative-dystrophic diseases of osteoarticular system, deforming osteoarthroses, osteochondroses, etc.) and registrations of 153 cases of chronic radiation sickness in 50-60 year olds. Moreover, according to [3], during 33 years (1950-82), the coefficient of cancer mortality of Muslyumovo village inhabitants was 129.0 per 100,000 persons, while the control figure is 114.9 per 100,000.

According to the opinion of Rosatom representatives, morbidity of the still-living irradiated population during the 10 years after the accident was characterized by an absence (as compared to the non-irradiated population) of differences in the frequency of lung diseases and tuberculosis, lung cancer, mortality of children younger than 1 year and other indices, including total morbidity and mortality and the state of reproductive function [19]. According to [19], there was received no proof of an increase in growth of cancer mortality among the irradiated population. Observations carried out during the 21 years after the accident showed that the structure of malignant neoplasms of the population and their frequency are practically the same as that of the non-irradiated population. Current doses of additional irradiation to the inhabitants of Muslyumovo, Tatarskaya Karabolka and Musakayevo represent absolutely no danger to health, since they do not increase the value of 1 m3v/year.

Nonetheless, according to [3], official medicine discerns inhabitants of the Muslyumovo village as a unique group for the influence of small doses of radiation. According to [3], *"Currently, Muslyumovo village residents belong to a unique cohort uniting all residents of the riverside villages of the Techa river exposed to chronic radiation (Original and Expanded Cohorts of the Techa River). This cohort is currently internationally significant for assessment of values of the risk of carcinogenic (cancer and leucosis) and genetic effects of chronic irradiation of humans. Results of observation over cohort members can become a basis of new assessments of threshold of doses of chronic irradiation of the population"*.

The people of Muslyumovo village know about these studies. According to the sociological polling made in 2002 by Greenpeace Russia, most of inhabitants of the Muslyumovo village (62%) believe that they are involved in a medical experiment. The specialist from Mayak are not trusted by 74% of the residents.

From the point of view of non-governmental organizations, the situation with the health indices of the Muslyumovo village differs from official statements.

In many respect it is connected with the fact that contact with the Techa river still exists. More than 13% of people swim in the river. Mostly they are the children. Eight per cent of the population go fishing. A typical scene for Muslyumovo is cows grazing on the flood plains.

A declaration by ex-minister of atomic energy A. Rumjantsev was made in the program '*The moment of truth*' on January 26, 2003: "*The water in this lake* [one of the lakes of TCWB, being the reservoir of low-level radio active wastes, see Chapter 3] *is absolutely clean. It means that they are fishing at the surface. The fish are absolutely harmless, we have checked, both bones and meat were studied by all the devices.*"

In 2003 Greenpeace Russia analyzed fish from the Techa river, which is less polluted than the lakes (reservoirs) of TCWB. According to the results of the analysis, *"The fish does not meet accepted sanitary and hygienic demands".* [7] See Tables 3 and 4.

Table 3. Radionuclide content in the sample of fish, fished out of the Techa river

Radionuclide	Meat	Bones	Organs
Sr90 Bq/kg	215±15	2700±50	95±10
Cs137 Bq/kg	93±4	1400±60	690±30

Table 4. Hygienic demands for food safety according Sanitary Norms and Rules of Russian Federation 2.3.2.1078-01

	Sr90 Bq/kg	**Cs137 Bq/kg**
Live fish, fresh fish, frozen fish	130	100

It is necessary to point out the problem of the pollution of ground waters, which are officially used in Muslyumovo as the source of the drinking water supply. In 2005 the Cheljabinsk administration of Federal supervision service for the consumer rights protection and wellbeing of man announced that in accordance with this, the drinking water from the underground sources of water supply in Muslyumovo does not meet sanitary rules [8], see Table 5. The radioactive excess is by 1.26-3.36 times.

Table 5. Results of laboratory tests of drinking water from wells in Muslyumovo

	Total alpha activity, Bq/l	Total beta activity, Bq/l
Borehole № 4122, Muslyumovo	0.336	
Borehole without number, Muslyumovo station	0.2	1.26-2.08
Standard, Bq/l	0.1	1.0

Below are given the data from local NGO Nabat (Alarm) on mortality as a result of illness from carcinogenic diseases. The data are made on the basis of the name registry of persons who died from carcinogenic diseases.

Table 6. Data for mortality as a result of carcinogenic diseases in Muslyumovo village

Index	**Total**	**Incidence per 100,000 persons (Muslyumovo village, 4,500 persons)**	**Incidence per 100,000 persons on average in Russia**	**Excedance of the average Russian index**
Cancer morbidity 1998	**23**	511	202.5	**2.5**
Cancer morbidity 1999	**13**	280	205	**1.3**
Cancer morbidity 2000	**12**	260	205.5	**1.3**
Cancer morbidity 2001	**12**	260		
Cancer morbidity 2002	**17**	378		

According to sociological data of Greenpeace Russia, 57 people out of 1400 polled residents of the Muslyumovo village have malignant formations. Recalculated per 100,000 inhabitants, it is 2.6 times higher than the average Russia index – 4071 against 1553 persons per 100,000 inhabitants, respectively. According to official data [20], in 2000, due to medical examination of the Muslyumovo village, 249 persons were "registered with an oncologist". Recalculated per 100,000 inhabitants, it is 5533 persons registered with an oncologist, which is 3.6 times higher than the Russian average. According to the same data [20], another 818 residents of Muslyumovo were sent for further examination.

According to the results of cytogenetic examination of three families of the Muslyumovo village carried out in 1998, serious genetic distortions were found in all subjects (20 persons including 5 children). Generally, there were found 51 dicentrics and other metabolic aberrations of chromosomes per 10,000 cells, which exceed the norm approximately in 25 times [21]. According to [21], detection of dicentrics and other metabolic chromosomal aberrations is a consequence of living under conditions of increased levels of environmental radioactivity.

According to the data of the Nabat non-governmental organization, by December 1, 2002, 88 residents of the Muslyumovo village officially had the status of a chronic radiation sickness (RPS) patient. The presence of a great number of patients with RPS diagnosis means that there exist, as a result of the impact of small radiation doses, conditions for the deterioration of indices of all disease groups.

An indirect proof of the unfavorable situation of the Muslyumovo population is the fact that Muslyumovo village is formally related to the zone of radiation control according to SRF-99. However, it does not stipulate any compulsory evacuation (see Table 7). Besides that, the Muslyumovo population receives compensation payments for living in a polluted zone. (The compensation sum is between 40-200 rubles per month, or 1-6 euros per month, which is definitely not enough for the purchase of drugs or for traveling to regional medical centers). The administration of the Chelyabinsk province implements measures for the rehabilitation and removal of the Muslyumovo village residents, under the framework of the federal target program 'Coping with Consequences of Radiation Accidents for the Period until 2010'.

Another proof of the fact that living in Muslyumovo is dangerous is also the official prohibition of using water from the Techa River for domestic and other necessities, for use on the hayfields for agricultural needs and so on (for example, in the area of the Muslyumovo village, the access to the Techa water and to the river corridor is fenced off by barbed wire). If it is the case that small doses are not dangerous, then contact with the river should not be prohibited.

Nowadays, the administration of the Russian agency for Atomic Energy has initiated the project of resettlement of Muslyumovo village. But due to the shortage of allocated funds, the authorities will remove only the riverside part of the village. Notably, it will be removed to the other edge of the village, where, according to the sanitary services, the potable well water radioactivity level is 2-3 times higher than the intervention level, when measures for population protection become necessary. Ironically, the new Muslyumovo district, Novomuslyumovo, will be located near the village cemetery.

Tatarskaya Karabolka and Musakayevo

As a result of the explosion of the tank for storage of highly active liquid waste that took place on September 29, 1957 and caused pollution of a large area, it was decided to evacuate some settlements. Tatarskaya Karabolka was one of them. According to the decision of the Executive Committee of Chelyabinsk District Council of Working People's Deputies No. 546 SS of September 29, 1959, Tatarskaya Karabolka settlement had to be resettled by the end of '50s [26].

However, due to unknown reasons, no resettlement took place. During the 50 years after the day of the accident, the population of Tatarskaya Karabolka decreased from 2700 to 600 persons.

The radiation level of this land does not exceed, for Sr90, 3 curies per square kilometer, which gives no opportunity for resettlement, since according to the FL 'On Social Protection of Citizens Exposed to Radiation due to the Chernobyl NPP Catastrophe', resettlement is possible only in case of Sr90 pollution of more than 3 curies per square kilometer.

According to the opinion of representatives of the Chelyabinsk province administration, *"The radiation load on the population of territories adjacent to the Eastern-Ural radioactive trace, is below the regular one"* [24].

However, there exist several factors that discredit the correctness of the conclusion that the radiation load is lower than normal.

The first factor is farming within the forbidden territory, i.e., in the East Ural Radioactive Trace sanitary-protected zone. Thus, in accordance with the letter of the Administration for Radiation Safety of the Ural Region of the Ministry for Emergency Situations of Russia Nr. 42-84 of May 16, 2000, *"Unregulated and unsanctioned use of the territory of the sanitary-protected zone by population for hay and grazing considerably increased the irradiation doses of the Tatarskaya Karabolka village".*

The other source of irradiation is farming on allowed land that, however, is polluted by radionuclides. In 2002, Greenpeace Russia took soil samples near Tatarskaya Karabolka. The analyses showed that the content of isotopes of plutonium 239 and 240 in the samples is 21.1

Bq/kg. For comparison, the level of pollution by plutonium isotopes outside the zones of impact of nuclear objects is about 2-2.5 Bq/kg, or ten times lower than in the samples taken near Tatarskaya Carabolka. Pollution of Cs137 isotopes is 230 Bq/kg or, approximately, 0.3 Ci/km^2 which is lower than the detection threshold for determination of a living zone with privileged social-economic status, but is several times higher than pollution outside the zones of impact of nuclear objects.

Another source of irradiation is secondary pollution. For example, according to the letter of Rosgidromet No. 20-59/176 of 17.07.2001, content of strontium-90 on some garden plots in Tatarskaya Karabolka is, for Sr90, 5-7 curies per square kilometer. The secondary pollution is an objective consequence of farming on the polluted territory, including highly polluted territories with pollution density for strontium of more than 2 Ci/km^2.

According to the data of the local administration (the letter of administration of municipal entity 'Kuyashsky Selsovet' No. 118 of 13.11.2002), the whole population of the Tatarskaya Karabolka and Musakayevo is 507 and 39 persons, respectively. The official number of cancer patients for these villages is 40 persons, or, recalculated per 100,000 persons, 7,300 cases [12]. For comparison: the average Russian index is almost five times lower at 1,553 patients with malignant formation per 100,000 persons (data for persons registered as oncological patients in Russia for 2003).

Unlike Muslyumovo, Tatarskaya Karabolka and Musakayevo do not fall in any zone of radioactive pollution established by Russian laws and norms, see Tables 7 and 8.

Table 7. Determination of zones of radioactive pollution in accordance with the law 'On Social Protection of Citizens Exposed to Radiation due to the Chernobyl NPP Catastrophe'

Radioactive Pollution Characteristics	**Resettlement Zones**	**Zone of Living with the Right for Resettlement**	**Zone of Living with privileged social-economic status**
Cesium-137	More than 15 Ci/sq.km or	5-15 Ci/sq.km	1-5 Ci/sq.km
Strontium-90	More than 3 Ci/sq.km or	To be determined additionally by the government	To be determined additionally by the government
Plutonium-239, 240	More than 0.1 Ci/sq.km	To be determined additionally by the government	To be determined additionally by the government
Mean annual equivalent effective dose		More than 1 m3v	Not more than 1 m3v

There is also **Alienation Zone -** territory around the Chernobyl NPP, as well as a part of the territory of the Russian Federation polluted by radioactive substances due to the Chernobyl NPP, where the population was evacuated in 1986 and 1987 according to the Norms of Radiation Safety.

Table 8. Zoning on the regeneration stage of radiation accidents in accordance with Norms of Radiation Safety-99

	Alienation Zone	**Resettlement Zone**	**Zone of Limited Living of Population**	**Zone of Radiation Control**
Annual effective dose	More than 50 m3v.	20 m3v - 50 m3v.	5 m3v - 20 m3v.	1 m3v - 5 m3v.
Measures	Residence is not allowed, and farming and nature management are regulated by special acts. Measures are carried out of monitoring and protection of workers with obligatory and individual dosimetric control	Entrance to the said territory for the purpose of permanent residence is not allowed. In this zone, settlement by persons of reproductive age and children is prohibited. Here, radiation monitoring of persons and environmental objects is carried out, as well as necessary measures of radiation and medical protection.	The same measures of monitoring and protection of population are performed as in the zone of radiation control. Voluntary entrance to the said territory is not limited. Persons entering the said territory for permanent residence are informed about the risk of health damage caused by radiation impact.	Besides monitoring of radioactivity of environmental objects, agricultural products and doses of external and internal irradiation of persons, measures are carried out to lower radiation on the basis of the principle of optimization and other necessary active measures of population protection.

6. The economic inefficiency of SNF reprocessing

SNF reprocessing is economically ineffective. This is confirmed both by foreign experts and by domestic Russian practice.

According to the opinion of French experts, *"The fuel cycle in the scenario of the complete processing of SNF, as compared with the scenario of cessation of reprocessing, demands additional expenditures which are estimated as 39 billions of French francs, - per 800 billions of francs per each year of the remaining operating life of the nuclear plant… perspective of import for reprocessing of spent nuclear fuel in Russia looks very dubious"* [15].

According to the strategy for the development of the Russian nuclear industry, reprocessing of the main bulk of the radiated nuclear fuel is now unreasonable, and it should be "*prepared to begin the serial construction of fast reactors of the new generation*", i.e. after 2020 [16].

The non-profitability of reprocessing of SNF from domestic NPPs is proven by the fact that 'profitability' of reprocessing of spent nuclear fuel at Mayak was held up due to foreign commercial contracts [17]. According to [17], "*Activity related to the importation of SNF of Russian production [from Soviet design reactors abroad] is profitable enough, provides maintenance of current operation of enterprises and provides <u>partial</u> financing of ecological problems. Together with that, amounts of finance incoming from rendering services for reprocessing of Russian-made SNF are not sufficient for investments for further development of Russian infrastructure".*

It should be noted that in this case it refers to commercial contracts for the reprocessing of SNF coming from abroad, from reactors of Soviet design. Besides expensive commercial contracts for the reprocessing of SNF that is 'made in Russia', there are contracts for the reprocessing of SNF from nuclear stations of Russia and Ukraine, which are considerably cheaper. For example, the price for the reprocessing of SNF from Hungary was 660-750 USD for 1 kg of SNF. The same reprocessing of SNF from NPP in Ukraine was 333-343 USD/kg. Therefore, the cost of processing SNF, taking into account storage and transportation of radioactive materials is 322 USD/kg [17].

After foreign delivery of SNF was decreased, the economic situation of Mayak, as relating to SNF reprocessing, deteriorated considerably.

Even considering the presence of other enterprises, such as isotope production, the funds received are definitely not enough for financing of the enterprise's modernization program and solving the problem of the Techa water body cascade, to say nothing of the social rehabilitation of the population living in the zone of Mayak activities.

The result is that finance from the federal budget will be used to artificially prop up the enterprise. In accordance with the Concept of Federal Target Program 'Promotion of Nuclear and Radiation Safety for 2008 and for the Period until 2015', several billion rubles (a few hundred million euros) will be assigned from the federal budget for solving the Mayak's problems.

Moreover, Mayak receives a large amount of international aid; several years ago, the US government assigned about 400 mln USD for the construction of storage for fissile materials such as plutonium, which is released due to the reprocessing of SNF from nuclear plants.

7. Reprocessing and storage of foreign nuclear materials

7.1. History of contracts for the importation and reprocessing of foreign SNF at Mayak

Below are data on countries sending SNF to be reprocessed at Mayak with specification of the amount of reprocessed SNF until 2001, according to [17] and waste received from the SNF reprocessing (approximately).

Table 9. Reprocessing of foreign SNF at Mayak

	SNF Amount (tonnes of heavy metal)	**Highly active liquid waste, m3**	**Moderately active liquid waste, m3**	**Low active liquid waste, m3**
Bulgaria	331.5	14 918	49 725	663 000
Hungary	269.3	12 119	40 395	538 600
Czechoslovakia	80.5	3 623	12 075	161 000
Finland	311.7	14 027	46 755	623 400
DDR	235.0	10 575	35 250	470 000
Ukraine	314.2	14 139	47 130	628 400
Iraq	0.12	5.4	180	240
Total	**> 1542**	**69 390**	**231 300**	**3 084 000**

In total in 2001, Mayak reprocessed more than **1542 tons** of SNF from abroad. As a result of reprocessing, about 3 million cubic meters of moderate and low radioactive waste were disposed of into the environment.

The situation with highly radioactive waste is more complex. Until 1993, reprocessing of SNF was effected in terms of leaving out highly radioactive waste, SNF reprocessing products, Mayak (in world practice, low and moderately active waste is buried in the country which receives the SNF).

Until 1993, the status of highly radioactive waste generated as a result of reprocessing foreign SNF was not regulated by law. As stipulated by the terms of the contracts for SNF reprocessing, highly radioactive waste stayed in the USSR (afterwards the Russian Federation) forever.

Since 1993, after adoption of the Decree of the President of the Russian Federation No. 472 'About fulfillment by the Russian Federation of inter-governmental agreements on cooperation in construction of nuclear power stations abroad', after preparing new inter-governmental agreements on the operation of NPPs abroad, standard contracts contain the stipulation that highly radioactive waste produced during the reprocessing of SNF should be returned to the country that supplied the SNF to be reprocessed in Russia. So some agreements were revised, including agreements with the governments of the Slovak Republic, Czech Republic and Republic of Bulgaria. The provision on returning of highly radioactive waste produced as a result of SNF reprocessing was fixed into the agreement with the government of Russian Kazakhstan. Besides that, before the adoption of the Decree, an agreement was signed with Ukraine about the reprocessing of SNF with returning highly radioactive waste to Ukraine.

Reprocessing of SNF from Finland and Hungary after 1993 was effected on the basis of old agreements, without returning highly radioactive waste.

With regard to Hungary, on July 16 1997, the Government of the Russian Federation, on the initiative of Minatom, agreed an order to accept a limited amount of spent nuclear fuel from the Paksh nuclear power plant according to the old rules: *"Expressing the goodwill and meeting the compellation of the Hungarian government, to accept, as an exception, SNF of NPP 'Paksh' in amount of 3,550 spent assemblies during the 'transition period' on terms of previous practice, i.e., without further returning of high radioactive waste and products of reprocessing into the Hungarian Republic".* The order of the government of the Russian Federation, in accordance with which this decision was accepted, was cancelled by the decision of the Upper Court of the Russian Federation on February 26th, 2002, on the basis of the lawsuit by the employees of the 'Dvizheniye za Yadernuyu Bezopasnost' non-governmental organization (Chelyabinsk province) with the support of Greenpeace Russia.

After adoption of the decree of 1993, during the period of 1993-2001, Mayak reprocessed the following amount of SNF of foreign origin:

Table 10. Reprocessing of foreign SNF after the adoption of the 'Decree of Returning of Highly-Radioactive Waste to the Country which Supplied the SNF'

Country	Amount of SNF Reprocessed in 1993 - 2001
Bulgaria	27.4 t
Finland	129 t
Hungary	203 t
Ukraine	163 t

According to [17], Hungary and Finland did not have any highly radioactive waste returned during this period, acting on the basis of the contracts signed before the Decree in 1993. Highly radioactive waste from these countries is located at Mayak. Since 1996, Finland has not brought her SNF into Russia, after taking up the concept of final burial of SNF in Finland without it being reprocessed.

As for Ukraine, there exists an acting agreement on the importation of SNF, where it is written that the conditions of returning highly radioactive waste are determined by contracts. According to some sources, an agreement exists on the returning of highly radioactive waste after 2010.

With Bulgaria, the situation needs to be specified. According to the agreement between Bulgaria and Russia, signed in 1995, *"Organizations of competent organs of the Russian Federation will accept, for reprocessing, spent nuclear fuel of NPP 'Kozloduy' with further returning into the Republic of Bulgaria of highly-active vitrified waste according to programs and terms agreed upon by the Parties".* According to the contract between JV Tekhsnabexport and NPP Kozloduy № 08843672/8001-09D of June 16, 2000, for the supply of the next batch of

Bulgarian SNF to Russia, returning of highly radioactive vitrified waste will be effected on the basis on additional contracts which will be concluded not later than 10 years before beginning to return the waste [22].

On November 1, 2002, the Decree of 1993 with the requirement of the obligatory returning of highly radioactive waste was changed. The 'return' requirement was withdrawn and brought to compliance with the new revision of the law 'On Protection of the Natural Environment' adopted in 2001. According to the new revision, the order of SNF importation is determined *"by taking into consideration of priority of the right to return radioactive waste which was produced after reprocessing of radioactive waste into the state of origin of nuclear materials or to ensure their returning"*.

It should be stressed that all the above-mentioned agreements of returning radioactive waste related to, and still relate to, only highly radioactive waste. The legislation of Russia and other countries does not set any stipulation for the status of low- and moderately radioactive waste. This leads to the fact that low- and moderately radioactive waste in Russia and elsewhere in the world are disposed of in the countries reprocessing foreign SNF. So burial or disposal is by way of simply discharging radioactive waste into the environment, which leads to great social-ecological consequences (see Chapters 3 and 5).

7.2. Perspectives on the importation and reprocessing of foreign SNF at Mayak and new SNF processing factories

Perspectives on the importation of SNF from VVER-440 and BN-350 reactors at Mayak.

Currently, Russia has the following agreements of cooperation in the nuclear industry regulating SNF importation:

Country	**Conditions of Cooperation Reg. SNF Import**	**State of Cooperation According to [17] and [27]**
Armenia	According to the Agreement between the Government of the Russian Federation and the Government of the Republic of Armenia on cooperation in the area of peaceful use of nuclear energy, *"Conditions of realization of cooperation are determined in accordance with the legislation of the Party states"*.	Contains no direct regulation of the order of SNF importation. On the territory of the NPP in Armenia, there was put into operation a dry storage of SNF. In the case of adoption of a decision on returning SNF to the Russian Federation, there may appear difficulties in implementing transportation through transit countries.
Bulgaria	According to the Agreement between the Government of the Russian Federation and the Government of the Republic of Bulgaria on cooperation in the area of nuclear energy, (Sofia, May 19, 1995), *"Organization of competent authorities of the Russian Federation will take, for reprocessing, spent nuclear fuel of the NPP Kozloduy with further returning into the Republic of Bulgaria of highly active vitrified waste according to programs and terms agreed by the Parties"*.	Preliminary consultations with the Bulgarian party showed **that in the case of readiness of the Russian Federation for cooperation on conditions of reprocessing of irradiated fuel without further returning to Bulgaria the products of reprocessing, including radioactive waste, Bulgaria is ready to sign a long-term contract for exporting SNF to the Russian Federation.**
Hungary	According to the Protocol to the Agreement between the Government of	The Protocol was signed one day before Hungary entered the European Union, and

	the Union of Soviet Socialist Republics and revolutionary government of working people and peasants of Hungarian People's Republic on cooperation in the area of construction of nuclear power plant in Hungarian People's Republic of December 28, 1966 (Moscow, April 29, 2004). *"Contracts specified in Article 3 of this Protocol determine conditions of import into the Russian Federation of irradiated heat-releasing assemblies of nuclear reactor for the purpose of provision of temporary technological storage with further reprocessing, including that they can also stipulate conditions, under which reprocessing products generated thereat, stay in the Russian Federation" [27].*	settled a possibility of importing SNF into Russia for reprocessing without the returning of highly radioactive waste. According to [17], **the Hungarian party expressed its interest in the continuation of cooperation in the area of SNF handling, but only upon conditions of importing of SNF without further returning of products of reprocessing, including radioactive waste.**
Kazakhstan	According to the Agreement between the Government of the Russian Federation and the Government of the Republic of Kazakhstan on cooperation in the area of peaceful use of nuclear energy of September 23, 1993, the Russian Federation has obligations for acceptance of SNF BN-350 with further returning of radioactive waste to Kazakhstan.	The importation of SNF from reactor BN-350 to the Russian Federation has not been put into effect due to difficulties with financing of this importation from the Kazakhstan side.
Slovakia	According to the Agreement between the Government of the Russian Federation and the Government of the Slovakian Republic on cooperation of completion of construction of the first order of the Mokhovtse Nuclear Station of October 31, 1995, *"The Government of the RF guarantees acceptance of spent nuclear fuel of Slovakian nuclear power plants for reprocessing with further technological extract according to effective laws and legal acts of both countries upon conditions stipulated by the contracts".*	In Slovakia, active consultations are carried out with the Swedish firm ABB on the technology of direct burial of SNF on the territory of Slovakia. **The Slovakian side expressed its interest in changes in Russian legislation in the area of the handling of SNF from foreign nuclear reactors and is ready for large-scale cooperation upon conditions of importation of SNF without further returning of products of reprocessing, including radioactive waste.**
Ukraine	According to the Agreement between the Government of the Russian Federation and the Government of Ukraine on scientific-technical and economic cooperation in the area of nuclear industry of January 14, 1993, "*Conditions of cooperation stipulated by this Agreement, including those for supply of Ukrainian uranium concentrate to Russia, fresh nuclear fuel to Ukraine and for dispatch of spent nuclear fuel to Russia for temporary storage or reprocessing with*	Currently, Ukraine is the greatest partner of the Russian Federation in the area of SNF handling. Ukraine is developing a strategy of development of its own infrastructure for SNF handling, with gradual reduction of the exportation of SNF to the Russian Federation. There was put into operation a dry storage on the Zaporozhskaya NPP. There is under consideration a proposal to construct a 'landfill' of radioactive waste, including SNF storage at Chernobyl NPP.

	following returning radioactive waste to Ukraine, shall be determined by contracts (agreements) between enterprises and organizations of both Parties in accordance with acting legislation of the Russian Federation and Ukraine".	
Czech Republic	According to the Addition to the Agreement between the Government of the Russian Federation and the Government of the Czech Republic about cooperation in the area of nuclear industry of December 4, 1994, *"The Russian party (on request of the Czechian party) provides acceptance, for reprocessing, of SNF produced in the Russian Federation and used in power and research reactors of the Czechian Republic. Radioactive waste produced during SNF reprocessing will be returned into the Czechian Republic".*	Perspectives of the export of SNF from Czech NPP are determined by decisions of Czechia for of SNF handling. On the one hand Czechia has begun to 'delay the deision' on SNF handling. Fuel is stored in special dry storages of the 'CASTOK' type. Research is being conducted on possible final burial of SNF in former uranium mines in Western Moravia. On the other hand, there **exists a probability of agreement of the Czechian side for cooperation upon conditions of export of SNF without further returning of reprocessing products including radioactive waste.**

According to the opinion of the administration of the Russian nuclear complex, at least four EU countries - Bulgaria, Hungary, Slovakia and the Czech Republic - with which there are effective agreements, are perspective in terms of the importation of SNF from reactors of the Soviet design VVER-440 to Mayak (see bold-marked paras). With these agreements, the new Russian legislation allows for not to return highly radioactive waste to the country that supplied SNF, as is welcomed by representatives of Bulgaria, Hungary and Slovakia.

Among prominent partners of Mayak, Ukraine is distinguished. In the long run, importation of SNF from Armenia and Kazakhstan is also possible.

Perspectives of SNF imports to new plants for SNF reprocessing. The above-mentioned countries all use reactors of the Soviet designs VVER-440 and BN-350. Mayak can reprocess fuel assemblies with spent nuclear fuel only from nuclear plants of these designs. The enterprise cannot reprocess fuel assemblies with SNF from the Soviet-design reactor type VVER-1000, and PWR of the Western design.

Therefore, the government of the nuclear industry of the Russian Federation has adopted the concept of a closed fuel cycle, upon which SNF is considered as a high-value energy source and must be reprocessed and not buried. In this connection, the government of the Russian Federation plans to build new plants for SNF reprocessing and is carrying out modernization of Mayak for the purpose of SNF reprocessing from reactors of Western design and Soviet VVER-1000.

A New plant for SNF reprocessing – RT-2 – is being constructed in the Krasnoyarsk province (Krasnoyarsk-26 closed town) at the Mounting Chemical Combine base. The construction started in 1977 and is ongoing. The projected plant capacity is to reprocess 1500 tons of SNF per year. Until now, only the SNF wet storage complex has been launched at this plant. The storage is filled by SNF from VVER-1000 reactors in Ukraine and Bulgaria. Storage is effected on condition of reprocessing this SNF and returning the highly radioactive waste produced as a result of this SNF reprocessing. It is not known when the reprocessing plant itself will be launched. Construction rescheduling is associated primarily with economic reasons.

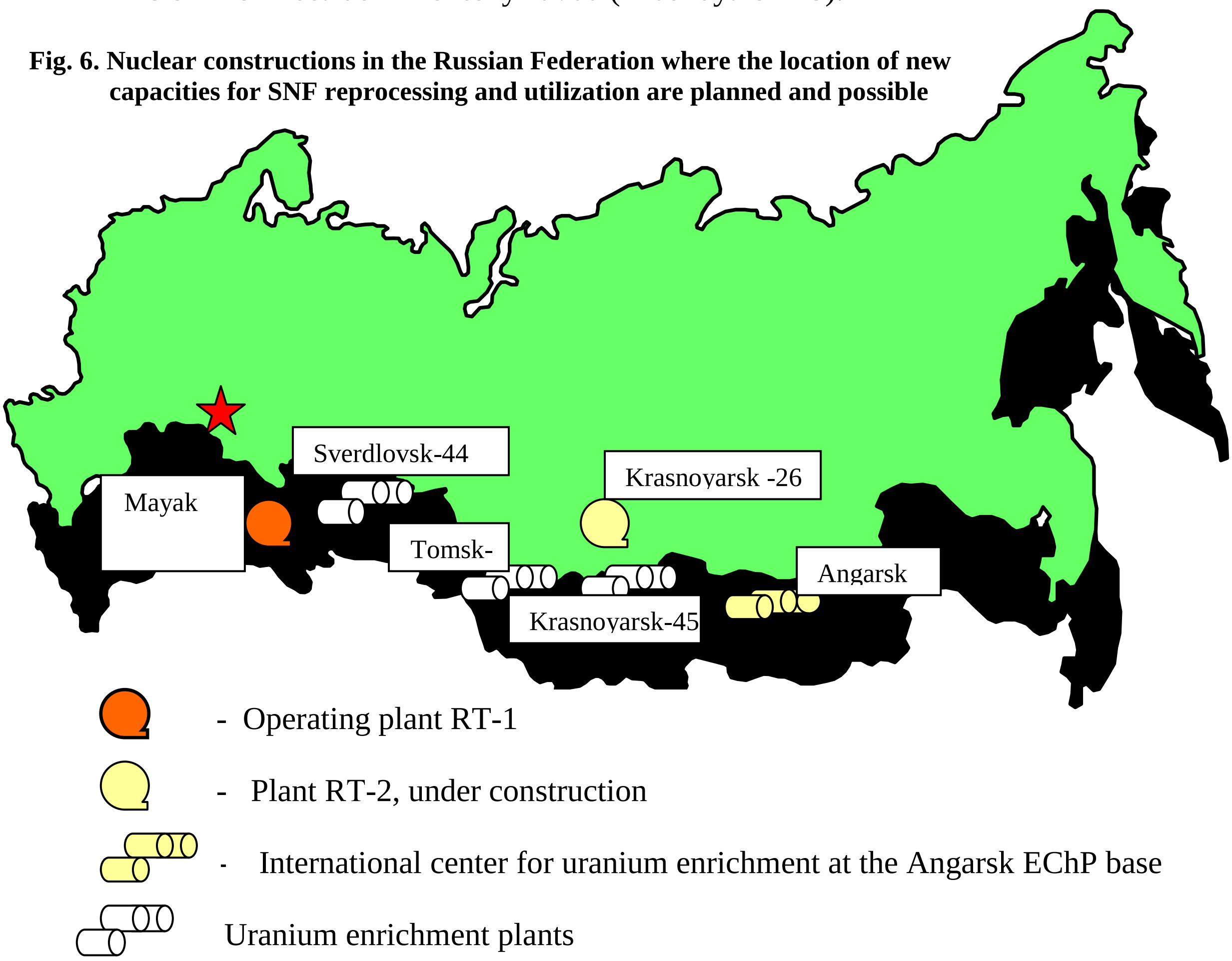
In accordance with the Concept of the Federal Target Program 'Promotion of Nuclear and Radiation Safety for 2008 and for the Period until 2015', by the year 2015 there will be created, at the RT-2 base, an experimental-demonstrative center for the reprocessing of spent nuclear fuel using innovative technologies. The Center will be created exclusively at the expense of the Federal budget. The cost of the Center is unknown, but could be several billion rubles (several hundred million euros). In accordance with the Strategy of Development of Nuclear Energy in the Russian Federation, construction of the plant itself shall be completed, theoretically, after 2020 - before the beginning of the large-scale program to construct fast reactors.

At present, ***modernization of the RT-1 plant at Mayak is taking place*** so that it will be able to accept SNF from VVER-1000 and PWR. According to [20], modernization must have been completed by 2006. After modernization, the plant capacity can exceed 1000 tonnes of SNF reprocessed per year. The plant will be able to reprocess up to 600 tons of SNF from PWR reactors per year. We have no information confirming the fact of completion of the modernization program.

The ***new plant for SNF reprocessing based at the Angarsk ElectroChemical Complex*** is a new political initiative of President Putin. Currently the Russian government is working on the creation of an International Center for Uranium Enrichment at Angarsk EChP. In the long run, international centers for uranium enrichment can become places for the acceptance and utilization of spent nuclear fuel. This was stated by President Putin, who said: “*These nuclear centers for enrichment will evidently overtake the obligation of utilization of spent fuel and nuclear waste”*. Therefore, a political course was set for the creation of a plant for reprocessing spent nuclear fuel and/or center for SNF storage at least at the Angarsk EChP. The other centers for uranium enrichment, which exist in Russia, besides the Angarsk EChP, are as follows:

- FGUP Uralsky Electrochimichesky combinat (Sverdlovsk-44),
- FGUP Sibirsky chimichesky combinat (Tomsk-7),
- FGUP PO Electrochimichesky zavod (Krasnoyarsk-45).

Fig. 6. Nuclear constructions in the Russian Federation where the location of new capacities for SNF reprocessing and utilization are planned and possible



In order to obtain business for the new plants to reprocess SNF from Western-design reactors, negotiations are taking place with various different countries. Primarily, talks with the US government, which has jurisdiction over 80% of SNF in the world, including SNF in Taiwan and in South Korea.[4] All together, Rosatom claims to be importing about 20,000 tons of SNF from VVER-1000 and/or PWR reactors (the latter ones of the Western design) in the next few decades.

Despite the efforts of US commercial circles to organize the importation of SNF into the Russian Federation, there is not any agreement for the organization of such importation. The main barrier to the negotiations with the USA administration is the construction of a NPP in Iran carried out by the Russian Federation, and a concept of a closed cycle accepted by Rosatom, according to which practically the whole of the imported SNF will be processed with the receipt of plutonium which can be used for production of nuclear weapons or a 'dirty' bomb. However, considering the recent initiatives of President Bush, it can be supposed that the last barrier to negotiations regarding SNF reprocessing can be overcome.

Besides the USA, the Rosatom administration is negotiating with Iran on returning SNF from the nuclear plant in Busher, which has a VVER-1000 reactor.

Among potential countries-consumers of services for SNF handling, the Rosatom administration is considering **Switzerland, Germany, Spain, South Korea, Slovenia, Italy,** and **Belgium** [17, 23]. This means that these countries, at least, are not fixed in their politics and have made no clear political statements addressed to the government of the Russian Federation that SNF from these countries will not be sent abroad for reprocessing.

On the other hand, among countries that Rosatom does not consider as potential clients, there is Finland, which adopted, on the legislative level, the concept of rejection of SNF export. The likelihood of cooperation with Finland is seen by Rosatom as improbable [17].

If the states which are considered by Rosatom as potential clients decide to export their SNF, the Russian government would immediately suggest the territory of Russia for this exportation. At present, the government of the Russian Federation is actively reconstructing the national legislation in order to create favourable conditions for organizing the importation of SNF and other nuclear materials, for reprocessing and storage.

7.3. Russian legislation to regulate the importation of nuclear materials for reprocessing, storage and final disposal

Soviet legislation historically contained no regulation on SNF imports. In 1992, a law came into force of the RSFSR, 'On Protection of Natural Environment' which prohibited imports of radioactive waste and materials for the purpose of storage and burial. According to the opinion of the government of the Russian Federation, the importation of SNF from other countries for reprocessing with further burial of the radioactive waste produced as a result of SNF reprocessing, did not fall under this requirement [17].

Nonetheless, this law definitely prohibited importation of any nuclear materials - including the SNF of other countries - for storage or burial, leaving an opportunity for imports of SNF only for reprocessing. (For the status of radioactive waste produced as a result of SNF processing, see section 7.1)

In 2001, together with the adoption of the statement allowing burial of highly radioactive waste produced as a result of reprocessing foreign SNF, one more principal change was accepted to the Russian legislation. In the new revision of the law 'On Protection of the Natural Environment', permission was fixed for the importation of foreign SNF for temporary technological storage. There are no definitions to legally fix for how many years 'temporary

[4] The total of the world's accumulated SNF is about 220,000 tonnes. Annually, about 10,000 tonnes of SNF are dealt with.

technological storage' can last. Therefore, temporary technological storage can last for decades, as happens with SNF from VVER-1000 reactors at nuclear plants in Ukraine and Bulgaria.

The next step in relaxing the regime for the importation of nuclear materials for storage was another change of the law 'On Environment Protection' in April of 2007[5]. According to the latest revision of the law, the direct statement on the prohibition of imports of nuclear materials from foreign states for storage and burial was excluded. The prohibition stayed only for radioactive waste.

Comparison of statements of the Russian Legislation regarding imports of radioactive materials for the purpose of reprocessing, storage and burial.

Legislation before 2001	**Legislation of 2001-2007**	**Legislation after 2007**
Prohibition of imports of radioactive waste from other countries for the purpose of storage and burial.	Prohibition of imports of radioactive waste from other countries for the purpose of storage and burial.	Prohibition of imports of radioactive waste from other countries for the purpose of storage and burial.
Prohibition of import of nuclear materials from other countries for the purpose of storage and burial.	Prohibition of imports of nuclear materials from other countries for the purpose of storage and burial, with the exception of fuel assemblies with SNF for which temporary (technological) storage is allowed.	**Cancellation of prohibition** of imports of nuclear materials from other countries for the purpose of storage and burial. Retaining of a separate article about allowance of imports of SNF from nuclear reactors for the purpose of temporary (technological) storage
Importation of SNF only for reprocessing	Importation of SNF for reprocessing and/or temporary (technological) storage	Importation of SNF for reprocessing and/or temporary (technological) storage
Obligatory return of reprocessing waste to the SNF country-supplier	Non-obligatory return of reprocessing waste to the SNF country-supplier	Non-obligatory return of reprocessing waste to the SNF country-supplier

Modern Russian legislation has created privileged conditions for the importation of SNF for reprocessing.

There are laws to prohibit the importation, for storage or burial, only of foreign radioactive waste. If it concerns nuclear materials not relating to the category 'radioactive waste'[6], then imports of these materials from other countries for storage is possible. Therefore, in the legislation there is no definition of terms for the storage of foreign nuclear materials. Theoretically, this storage can be endlessly long.

This last step, which will open Russian borders for imports of radioactive waste, can allow for the importation of radioactive waste for storage or burial. Calls for changes to this legislation sound periodically at the international level. So, in the report of the Forum for Nuclear Disarmament 'Russian Weapons Plutonium and the Western Option,' in the preparation of which representatives of the Russian nuclear complex also participated, it says: "*The legislative situation existing in Russia does not allow any direct burial of radioactive materials (yet). It is supposed that Russia will need a longer period of 20 years or more for contemplation in order to*

[5] In 2002, the law 'On Protection of the **Natural** Environment' was changed to the law 'On Environmental Protection' which repeats the previous law regarding the statements of SNF importation.

[6] According to Russian legislation, nuclear materials are those which contain fissionable materials or materials which can create fissionable materials; radioactive waste is nuclear material not considered for further usage.

reach the final decision… It is supposed that the above-mentioned political and sometimes legislative difficulties can be overcome under the aegis of disarmament through international agreements" [25].

Abbreviations

BN-350, BN-600 – fast reactors with electric capacity of 350 and 600 MW respectively
Ci – curies
EChP – ElectroChemical complex
FSUE – Federal State Unitary Enterprise
NPP – Nuclear Power Plant
PWR - pressurized water reactor
RAW – Radioactive Waste
RT – Fuel Regeneration
SNF – Spent Nuclear Fuel
SRF-99 - Standards of radiation safety adopted in 1999
SRRSP-2002 - main sanitary rules of radioactive safety provision of Russian Federation
TCWB - Techa cascade of water bodies
VVER-440, VVER-1000 – water-water reactor with electric capacity of 440 & 1000 MW respectively

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