ROSATOM'S MAYAK:

more reprocessing, more contamination

GREENPEACE

ROSATOM'S MAYAK: MORE REPROCESSING, MORE CONTAMINATION

Editor: Jan Haverkamp

Publisher and copyright:
Greenpeace Central and Eastern Europe

Fernkorngasse 10
1100 Vienna
Austria

Tel: +43 1 545 4580
Fax: +43 1 545 4580-98
Email: office@greenpeace.at

www.greenpeace.org

Acknowledgements: The author of the report would like to express his gratitude to Rianne Teule, Iryna Labunska, Ilona Biro, Shawn-Patrick Stensil and Cedric Counord.

The reference:
Haverkamp, Jan (ed.), Rosatom's Mayak: more reprocessing, more contamination, Vienna (2017) Greenpeace Central and Eastern Europe

GREENPEACE

ROSATOM'S MAYAK:
more reprocessing, more contamination

September 29, 2017 is the 60th anniversary of the Mayak or Kyshtym explosion in Russia - the third largest nuclear accident in history. The consequences of this disaster are still present today, made worse by ongoing radioactive discharges.

Mayak, located in the Southern Urals, is one of the largest nuclear complexes in the world. The Rosatom site operates a facility for reprocessing spent nuclear fuel and radioactive waste management. Rosatom is the Russian state nuclear energy corporation, comprising both its military and civil nuclear industry.

Nuclear fuel that has been irradiated in a nuclear reactor to the point where it is no longer useful in sustaining a nuclear reaction is called spent fuel. Reprocessing is extracting fissionable materials including uranium and plutonium from spent fuel, which leaves behind a reduced volume of high-level radioactive solid waste, newly created high-level liquid wastes and large volumes of liquid and solid low- and mid-level waste.

Sixty-years after the Mayak disaster, radioactive contamination still puts nearby communities at risk. Water and fish samples taken by the Greenpeace Radiation Protection Advisors team under responsibility of Greenpeace Central and Eastern Europe in 2017 were found to exceed Russian regulatory limits. Despite this ongoing contamination, Rosatom has been increasing operations at the site. Increased reprocessing in Mayak cannot but add to the existing contamination of the environment.

In the last two years, Mayak increased the volume of spent nuclear fuel it was reprocessing twice[1]. It increased the types of accepted fuel as well, and began to accept spent fuel from Rosatom-designed VVER-1000 reactors, the most common reactor type in Russia. Before that, Mayak reprocessed spent fuel from VVER-440, BN-600, submarine and icebreaker reactors, and research reactors[2]. Mayak management has stated that the nuclear complex will be able to reprocess 'any spent nuclear fuel' by 2020[3]. Furthermore, Rostekhnadzor, the Russian nuclear regulatory authority, has stated that it expects all Russian 'damaged' spent nuclear fuel will be reprocessed at Mayak by 2030[4]. An executive of Rosatom has also stated that he expects all spent nuclear fuel accumulated in Russia will be reprocessed to "clean up our nuclear legacy" and "close the nuclear cycle"[5].

Mayak's RT-1 plant has been reprocessing spent nuclear fuel since 1977. As with similar large scale reprocessing facilities in the US, the UK, France, India, and Japan, nuclear fuel reprocessing results in significant increases in the total volume of radioactive waste[6]. In addition, nuclear fuel reprocessing creates massive amounts of environmental contamination and leads to the accumulation of plutonium, which can be used for nuclear weapons.

Although Rosatom plans to build another reprocessing plant in Zheleznogorsk in Krasnoyarsk region, the facility is still in the planning phase and only a pilot installation operates at the site[7].

ONGOING CONTAMINATION AND GREENPEACE SAMPLES

The main artificial radionuclides that determine the radioactive contamination of the ecosystem of the Techa River are strontium-90, cesium-137 and tritium. The Techa River is a part of the Techa-Iset-Tobol-Irtysh-Ob river system that drains into the Kara Sea, which is part of the Arctic Ocean north of Siberia.

According to official data, in 2015 the average annual concentration of strontium-90 in the water of the Techa River in the Chelyabinsk region exceeded the Russian "intervention level" (IL) of 4.9 Becquerel[8] per litre (Bq/l)[9], whereby values at four control points (Muslyumovo, Brodokalmak, Russkaya Techa, Nizhnepetropavlovskoe) varied from 5.9 to 6.7 Bq/l. The previous year, these values ranged from 7.3 to 10.7 Bq/l. The maximum concentration of strontium-90 was registered in Muslyumovo in February and amounted to 13.2 Bq/l, which is 2.7 times higher than the IL[10].

In July 2017, the Greenpeace Radiation Protection Advisors team under responsibility of Greenpeace Central and Eastern Europe took water and food samples in several villages on the Techa River. The concentration of strontium-90 in all water samples taken in the Techa River exceeded the Russian IL for this radionuclide.

Another sample taken for reference in the same area, but at a remote distance from the Techa river (village Smolnoye 55°33.021' N, 061°16.694' E), showed less than 0.5 Bq/l of strontium-90 (less than 0.1 IL).

Water samples from the federal road (W-20170720-ROA-10) and Brodokalmak (W-20170720-BRO-05) were analyzed for cesium-137 as well, with activities of 0.5 Bq/l and 0.1 Bq/l respectively, which is 0.05 and 0.01 IL for cesium-137.

The water samples were analyzed in two laboratories in St Petersburg (CIKV and NIIRG). The Greenpeace sampling results were consistent with the data of previous research in the area mentioned in the previous paragraph. In 2004, figures were higher – average concentrations of 3.6-5.9 IL, with maximum concentrations up to 10 IL - because of increased water levels in the Pond 11[11]. Flooding of the reservoirs and possible accidental discharge of radionuclides into the Techa river still pose a threat[12].

Activity of strontium-90 in the samples taken by Greenpeace near the almost completely relocated village of Muslyumovo (1.0-2.3 IL) lay in the same range as activity of strontium-90 near the villages that have not been resettled: Brodokalmak (1.4-1.6 IL), Russkaya Techa (1.3-1.9 IL), Nizhnepetropavlovskoe (2.0-2.1 IL). This means that people living in the villages which have not been relocated are currently affected by the strontium-90 contamination as much as the inhabitants of 8 homes in Muslyumovo that have not been resettled due to problems with documents.

In addition to the exposure to strontium-90 via water from the Techa River, the local population is exposed to highly contaminated dust particles that form when the banks of the Techa River dry out in summer. These dust particles and the sediments along the Techa River contain especially high concentrations of cesium-137[13].

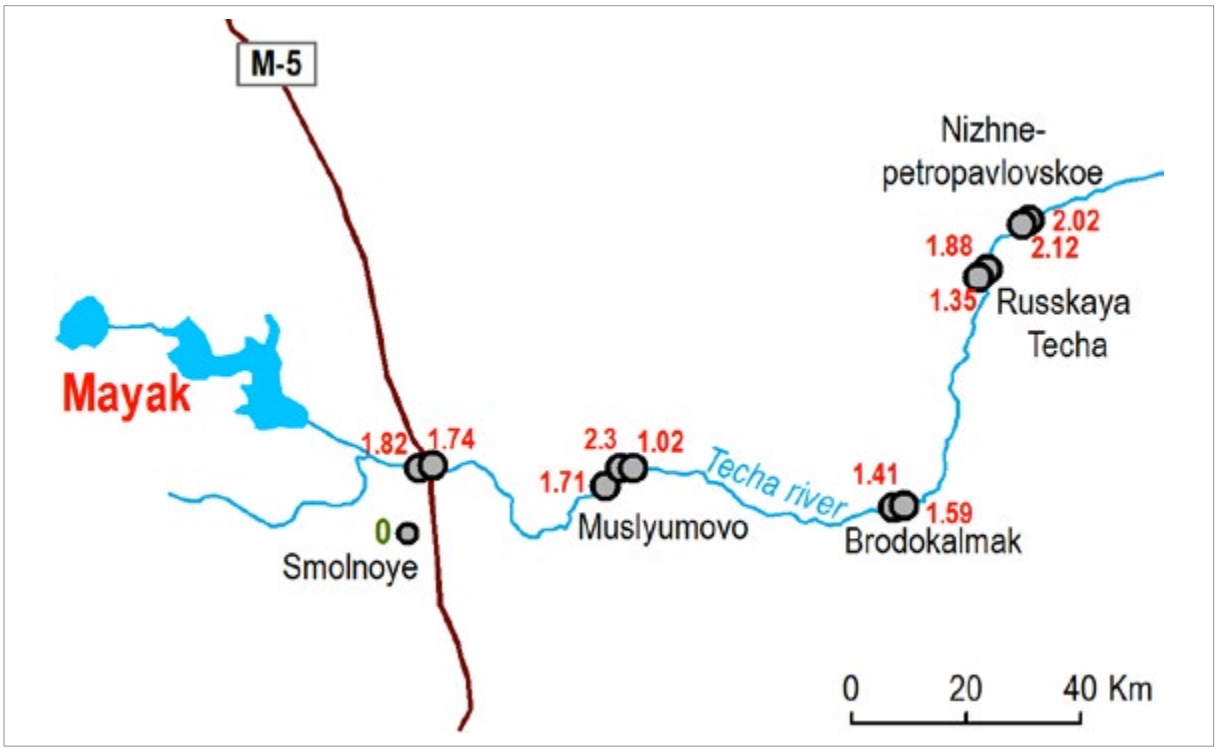
From the food samples taken by Greenpeace, the most contaminated were from fish caught in the Techa river near Muslyumovo (one roach, two ruddings, one burbot, gutted, peeled: 117.25 ± 29 Bq/kg of strontium-90, in which the Russian limit for strontium-90 in fish of 100 Bq/kg is exceeded). Cesium-137 activity found in this fish sample was 77±19 Bq/kg, which is about 0.7 of the Russian limit for fish (130 Bq/kg of cesium-137). Other samples of fish caught near the villages on the Techa river showed contamination by strontium-90 in the range from 448 Bq/kg to 980 Bq/kg[14].

Other food product samples taken by Greenpeace (beef, garden vegetables) had detectable traces of strontium-90, but which didn't exceed the existing Russian limits (the limit for strontium-90 in meat was abolished several years ago). Food samples were analyzed for cesium-137 too, the activities of cesium-137 were below the Russian limits in all samples.

Media reports indicate that people routinely fish in secured areas at the channel of pond 11.**[15]** These contaminated fish could easily be sold by fishmongers at the local market. Previous reports indicate that fish caught in contaminated lakes were supplied to hospitals, schools, kindergartens and an orphanage of a nearby town (where it was ground into cutlets with bones which accumulate strontium-90)**[16]**.

Existing research shows a high content of strontium-90 in the bone tissue of livestock (up to 1500 Bq/kg), poultry (up to 3100 Bq/kg) and fish (up to 8200 Bq/kg). A notable concentration of strontium-90 and cesium-137 is present in vegetables (cabbage, zucchini, and pepper) and in green vegetables like dill and green onions[17]. Significant contamination with caesium-137 can be found in chicken eggs (158 Bq/kg, well above the Russian limit of 80 Bq/kg)[18].

Plutonium is also found in the soil surrounding Mayak. Mayak does not monitor alpha-emitting nuclides (such as plutonium) in the Techa River due to the "negligible radiation significance"[19]. However, the discharge of any quantity of plutonium into the environment is unacceptable because of its high radiotoxicity, as well as its persistence in the environment due to long half-lives of a number of plutonium isotopes. For example, the half-lives of plutonium-239 and plutonium-240 are more than 1000 years.



Ratios of measured activity of strontium-90 to intervention level (IL) in samples taken by the Greenpeace Radiation Protection Advisors team under responsibility of Greenpeace Central and Eastern Europe at the Techa River

Sample n°	Date	Location (name)	Location (GPS)	Time	Photo/remark	Activity, Bq/l	Error	Ratio of measured activity to IL
W-20170720-PET-01	20.07.2017	Nizhne-petropavlovskoe	55°49.499' N 062°14.707' E	16:56	Under bridge, between second and third pillar from church side	6,90	3,50	2,12
W-20170720-PET-02	20.07.2017	Nizhne-petropavlovskoe	55°49.498' N 062°14.850' E	17:15	River bank, around 700 m from bridge, kids play there.	6,6	3,3	2,02
W-20170720-RUS-03	20.07.2017	Russkaya Techa	55°46. 657' N 062°10.516' E	18:38		6,1	3,1	1,88
W-20170720-RUS-04	20.07.2017	Russkaya Techa	55°46.657' N 062°10.516' E	18:45		4,4	2,2	1,35
W-20170720-BRO-05	20.07.2017	Brodokalmak	55°34.470' N 062°02.691' E	20:18		5,77	1,15	1,41
W-20170720-BRO-06	20.07.2017	Brodokalmak	55°34.470' N 062°02.691' E	20:28		5,2	2,6	1,59
W-20170720-MUS-07	21.07.2017	Bridge near Muslyumovo	55°35.538' N 061°35.414' E	14:46		5,6	2,8	1,71
W-20170720-MUS-08	21.07.2017	Muslyumovo	55°36.633' N 061°36.915' E	16:04	Bank of Techa	3,3	1,7	1,02
W-20170720-MUS-09	21.07.2017	Muslyumovo	55°36.851' N 061°37.464' E	17:21	Large bridge	7,5	3,8	2,3
W-20170720-ROA-10	21.07.2017	Federal road	55°36.388' N 061°18.782' E	19:12	Bridge	7,12	1,42	1,74
W-20170720-ROA-11	21.07.2017	Federal road	55°36.388' N 061°18.782' E	19:40	Bridge	5,9	3	1,82

PATHWAYS OF THE TECHA RIVER CONTAMINATION

Mayak continues to receive spent nuclear fuel for reprocessing. Discharges of liquid radioactive waste after reprocessing into ponds then enter the Techa River and then take one of two pathways: excess water spilling over the dam during the spring flood (this has not happened recently) and seepage through soil, which happens naturally on a continuing basis.

It is worth noting that official Mayak reports deny any discharges, however they mentioned "placing liquid radioactive waste for storage" into the ponds[20]. Earlier estimates indicated that about 5-6 million cubic meters of radioactive wastewater seep from these ponds into in the Techa River every year[21]; other sources refer to 10-15 million cubic meters of water from the ponds filtered through the channels around the last pond and the dam dividing it from the Techa river. [22]

Currently Mayak discharges radioactive waste into the ponds 17 (lake Staroye Boloto), 3 (Metlino pond), and 4 (Koksharovo pond). The ponds 6 (lake Tatysh) and 2 (lake Kyzyltash) were used for closed water supply, and ponds 10 and 11 received radioactive substances from the neighbouring ponds[23]. The ponds 3, 4, 10 and 11 are called the Techa cascade of ponds, because they were formed on the Techa River (now divided by a dam).

At the end of 2002, Gosatomnadzor, the Russian nuclear regulatory agency at the time, refused to issue Mayak a licence for the storage of liquid radioactive wastes in the Techa cascade of ponds. The official decision stated[24]: *"The Gosatomnadzor decision taken on the 19th December 2002 is that Mayak does not receive permission for operation of the complex with nuclear materials designated for radiochemical reprocessing of the irradiated nuclear fuel (factory 235) because the Mayak reprocessing factory keeps releasing medium- and low-level radioactive wastes into open water bodies (violation of article 51 of the Federal Law on Environmental Protection, art. 104 of the Water Code of the Russian Federation, art. 48 of the Federal Law on the Use of Atomic Energy)."*

The discharge of liquid radioactive waste into the Techa River was in 2004 the subject of a criminal case. Mayak's Director General V. Sadovnikov was charged under articles 246 and 247 of the Criminal Code. The court recognized the unauthorised release of radioactive substances and pollution into the Techa River, but Sadovnikov was released from responsibility in an amnesty in connection with the 100th anniversary of the State Duma of the Russian Federation[25]. Two years later, in 2006, Russia's State Duma discussed ending reprocessing at Mayak because of persistent environmental contamination[26].

In 2010, Russia's current regulatory agency Rostekhnadzor and the Russian Ministry of Natural Resources designated these ponds as "objects related to the use of atomic energy". This status describes the ponds as "special industrial ponds", though historically not all the ponds are man-made, but also include natural lakes. As an example, Lake Kyzyltash, or Pond no.2, was famous in the 19th century for its fish[27]; today, contaminated fish from this lake is caught and sold by poachers[28]. Some of the ponds existed before Mayak, e.g., the Metlino pond, Pond no. 3, and the Koksharovo pond, Pond no. 4.

LEGAL STATUS OF THE PONDS AROUND MAYAK

From the legal point of view[29], the term “special industrial ponds” is not correct, as it doesn’t exist in legislation governing water protection or environmental legislation. Russian federal law no. 190-FZ “On the Management of Radioactive Waste...” does not contain this term either.

The phrase “special industrial ponds” used by Rosatom should not exclude these ponds from regulations protecting bodies of water. The Water Code of the Russian Federation establishes a legal regime for the use of water bodies, and prohibits the disposal of nuclear materials and radioactive substances in water bodies (Part 5 of Article 56). In addition, Article 51 of the Federal Law on Environmental Protection prohibits discharge of radioactive waste into surface and groundwater bodies. In addition to national legislation, norms relating to the protection of nature from radioactive contamination are also present in international environmental law.

The document declaring “special industrial ponds” of Mayak to be “objects related to the use of atomic energy” has no legal status as it is simply minutes from a meeting[30] and cannot be a source of legislation. Furthermore, Article 3 of the Federal Law on the Use of Atomic Energy, which has a list of objects related to the use of atomic energy, does not contain the category of “special industrial ponds”. Natural objects and structures found in the natural world are normally subject to environmental regulation and protection, not included in legal regulations concerning the use of atomic energy. Furthermore, the ponds have no specific barriers (only a dam at Pond 11, dividing it from the Techa River), and spread of radionuclides is, therefore, not prevented.

In 2015, the highly contaminated Pond No.9, also known as Lake Karachay, was filled with rocks. Rosatom stated that the contamination problem had been solved. But in fact, in the porous rocks under Lake Karachay lies a large underground water body from which radionuclides continue to spread into the environment. This water body is estimated to contain more than 5 million cubic meters of radioactive waste[31]. In the 1990s pollution was estimated to be in dangerous proximity of the Mishelyak River. The isotope of highest concern was strontium-90 due to its solubility in water.

In 2016, Rostekhnadzor approved a method for calculating the permissible discharge level of strontium-90, based on stabilisation of activity in the river. The approved leak rate equals 10 times the legal intervention level, whereby population exposure may exceed the internationally recognised long term dose limit of 1 mSv/year. This permission practice is severely criticised by others, inlcuding radiation specialist B.E. Serebryakov[32]. Currently, Mayak claims that the annual discharge of strontium-90 from the ponds into the Techa River is 2.95×10^{11} Bq, or 15% of the permitted level [33].

In a warm period, many residents (mostly children) bathe in the Techa River. Cattle also graze on its floodplain. The river is not fenced off, and there are no warning signs indicating a radiation hazard. An additional source of radiation may be the homestead plots where the water of the Techa River is used for irrigation because of the lack of any other reliable water supply. The poor economic state of the villages also forces inhabitants to use the Techa as a water source for a variety of uses.

According to the latest environmental report of the administration of the Chelyabinsk region[34], in 2015 it observed five cases of extreme radioactive contamination by radioactive atmospheric aerosols in daily samples collected in the town of Novogorny and in the village of Asgayash, on specific dates in January, February, May and November.

HEALTH IMPACTS

Today, up to 20,000 people are officially considered to have been affected by the consequences of the 1957 accident and Mayak's ongoing activities. The official medical commission that was set up to assess the connection between health effects and radiation exposure due to the activities of Mayak has, likely in violation with Russian legislation, not been in operation in operation since 2016 due to the lack of funds.

Around 5,000 people still live in direct contact with the highly polluted Techa River and on contaminated land in Brodokalmak, Russkaya Techa, and Nizhnepetropavlovskoye, among other villages.

The official estimated annual doses arising from man-made radionuclides for residents of these settlements do not exceed the established effective dose limit of 1 mSv per year. However, according to NRB-99/2009, the beginning of the period for the assessment of the effective dose was January 1, 2000, which didn't take into account doses accumulated before 2000.

Mayak often refers to "additional doses from industrial sources" suggesting such figures are not significant. But it is not accurate to use only a part of the total radiation dose to calculate the risk of radiation-induced diseases. In accordance with NRB 99/2009, the permissible individual dose limits for citizens should include all radiation sources: natural sources, medical sources, man-made sources from normal operation of technical installations, as well as sources formed as a result of accidents involving the release of radioactive substances.

There is currently insufficient information about transgenerational effects of radiation exposure. This may put an additional risk on the second and third generations after the 1957 accident, because genetic effects from higher exposure could possibly lead to higher predisposition of certain health effects due to further radiation exposure. For that reason, it might be necessary to correct exposure limits downwards for this part of the population.

An earlier study by Greenpeace Russia[35] found that the rate of malignant cancers among local people in the village of Muslyumovo is significantly higher compared to the rest of Russia. Official data[36] have also shown that the number of Muslyumovo inhabitants in the national oncology register is 3.6 times higher than the Russian average.

Another study[37] found that genetic abnormalities in Muslyumovo are 25 times higher than in other areas of Russia.

In May 2007, after international attention was drawn to the situation in Muslyumovo village, Rosatom announced a so-called resettlement project for its inhabitants. The programme finished in 2012. Each Muslyumovo family had a choice: to accept money and buy a home elsewhere, or to be resettled with their neighbours only slightly further away from the Techa River. About half of the people preferred to be resettled nearby. According to the inhabitants of the new village, the distance of these new houses from the Techa River was insufficient, they have no other river for their water supply. In addition, new houses were built in violation of sanitary and construction standards. But as this area geologically has somewhat higher concentrations of naturally radioactive radon gas in the soil, increased levels of radon inside the homes adds to the already accumulated radiation doses[38]. Inhabitants of eight houses were not resettled at all due to problems with documents and are still living in the deserted village without any infrastructure.

In the summer of 2017, Russia's Presidential Human Rights Council visited Brodokalmak and after meeting with local inhabitants confirmed[39] their basic human rights had been violated. Apart from the ongoing contamination of the Techa River itself being a factor in human rights violations, the Council found human rights violations as a result of economic depression in the region, which is a direct consequence of the radioactive contamination. The bad economic situation led to further human rights violations, this time in the quality of medical care. The Council stated, "The consequences of radiation accidents and possible continuing discharges led not only to additional exposure of residents of the surrounding territory, but also to an increase in social tension in the settlements located on the Techa River".

Russia's Presidential Human Rights Council recommended that the government of the Russian Federation "research the possibility of resettling inhabitants of the settlements situated on the Techa river (Muslyumovo, Brodokalmak, Russkaya Techa, Nizhnepetropavlovskoye etc.) and from the settlements affected by the Eastern-Urals radioactive Trace (Tatarskaya Karabolka, Musakayevo)". Another recommendation by the Council to Rosatom, Mayak and Rostekhnadzor is "to speed up implementation of measures (e.g. vitrification and concretization of spent fuel and radioactive waste) which would prevent discharges of radioactive substances into the environment"[40].

THE ROLE OF MAYAK

The most recent shipments to Mayak are from the Rostov VVER-1000 nuclear power plant (NPP) in 2016, and shipments of spent nuclear fuel from Balakovo NPP and Leningrad NPP are expected in 2017[41].

Mayak receives spent nuclear fuel not only from Russian nuclear power plants, but also from international sources. Mayak's RT-1 has received spent nuclear fuel from Hungary (Paks), Finland (Loviisa), Germany (Greifswald), Bulgaria (Kozloduy), the Czech Republic (Dukovany), Slovakia (Bohunice), and Ukraine (Rivne)[42].

According to official figures[43], by 2001 Mayak had reprocessed 1,540 tonnes of foreign spent nuclear fuel, creating over 3 million cubic meters of liquid low-level and mid-level radioactive wastes, which was pumped into tailing ponds. Over 70,000 cubic meters of foreign high-level radioactive wastes remains stored at the Mayak facility. In 2001, the Russian government overturned a ban on the import of nuclear spent fuel from other countries for temporary storage and reprocessing. Russia projected at the time that it could earn as much as $20 billion from accepting foreign nuclear spent fuel for reprocessing, but actual figures have fallen well short of projections. Rosatom claimed that these new conditions would attract contracts with Bulgaria, Hungary, Slovakia and the Czech Republic. These countries had signed agreements with Russia, opening the possibility for future reprocessing contracts. Rosatom was also pursuing reprocessing contracts with Switzerland, Germany, Spain, South Korea, Slovenia, Italy and Belgium. In 2008, Russia signed an agreement with the US[44], opening the possibility of shipments of spent nuclear fuel of US origin to Russia[45].

In 2014, Mayak received spent nuclear fuel from the Hungarian Paks NPP unit 2 for reprocessing[46]. This fuel resulted from an accident in 2003, during which fuel rods were broken. A public consultation about this shipment took place in Russia in March 2013 as part of an environmental impact assessment[47]. The project declared explicitly that the radioactive waste resulting from reprocessing of this spent nuclear fuel would stay in Russia[48], although Russian legislation[49] defines imports of spent nuclear fuel as possible only "with priority of the right to return radioactive waste after reprocessing to the state of origin of nuclear materials or [the rights] to secure such a return".

In 2002, Russia's Supreme Court[50] ruled in a favour of a court challenge filed by environmentalists and find the import of spent nuclear fuel from Hungary was unlawful while the agreement allowing for final disposal of Hungary's nuclear waste in Russia contravened Russian legislation[51]. However, inspite of this ruling, the spent nuclear fuel was shipped by train from Hungary to Mayak in 2014. The shipment passed Ukraine, which was at that time in a state of civil war[53].

Shipments of spent fuel have also occurred from Ukraine and Bulgaria,[54] Ukraine recently started negotiating a possible return of secondary waste from Russia[55] as well as cancellation of future reprocessing at Mayak due to the increased costs of the operation[56].

Mayak also receives spent nuclear fuel from research reactors, among others because of the US-Russian intergovernmental agreement to prevent proliferation. That is still a dubious practice from the viewpoint of Russian legislation, because the resulting secondary radioactive waste will stay in Russia, as illustrated by the Environmental Impact Assessment of the project to reprocess spent fuel from the reactor of the Hungarian Academy of Sciences[57]. Environmentalists highlighted that the storage of research waste fuel is safer in the European Union and thus there is no sense in returning such fuel to Russia[58]. Indeed, because of apparent Mayak malpractice, Germany refused in 2010 to send research reactor fuel from Rossendorf to Russia[59].

Under the RRRFR agreement[60], Mayak received[61] spent nuclear fuel from research reactors from countries including Uzbekistan (2006[62], 2015[63]), the Czech Republic (2007, by air over Slovakia and Ukraine), Latvia (2008), Bulgaria (2008 – by ship over the Danube to Ukraine, further by train), Hungary (2008 – by ship from Slovenia, later by train), Kazakhstan (2007), and Poland (2010)[64].

Country	Year	Shipment description
Uzbekistan	2006 2015	
Czech Republic	2007	by air over Slovakia and Ukraine
Latvia	2008	
Bulgaria	2008	by ship over the Danube to Ukraine, further by train
Hungary	2008	2008 – by ship from Slovenia, later by train
Kazakhstan	2007	
Poland	2010	

Table 1 *Countries from which Mayak reprocessing plant received spent nuclear fuel from research reactors*

In 2017, Mayak received spent nuclear fuel from submarines at the former naval base Andreyeva Bay in the Murmansk region[65]. Norwegian financial support of this operation provoked criticism[66] from Russian environmentalists and was characterised as "irresponsible", because reports from the Norwegian radiation protection authority[67] showed contamination around Mayak and its impacts on the health of the local population.

It is also possible that spent nuclear fuel from countries where Rosatom is currently constructing new nuclear power stations like Belarus, as well as from countries where Rosatom may become involved, could be transferred to Mayak. Currently, Russia's bilateral agreements with Bangladesh[68], Belarus and Hungary foresee reprocessing of spent nuclear fuel in Russia, and the agreement with Turkey states that spent fuel "may be reprocessed" in Russia. It can be expected that the reprocessing option may be included in intergovernmental agreements with other countries[69]. An agreement with India[70] currently states that India will reprocess spent nuclear fuel itself, in spite of the fact that India did not sign the Non-Proliferation Treaty that would prevent the resulting plutonium from being used for military purposes.

REPROCESSED URANIUM (REPU)

Reprocessed uranium resulting from spent nuclear fuel reprocessing is used for producing new nuclear fuel.

Rosatom's daughter company TVEL delivers fresh fuel to Russian-built nuclear power plants and to a number of nuclear power plants built by other countries. Shipments of fuel produced at MSZ plant in Elektrostal include Finland (Loviisa), Sweden (Oskarshamn), UK (Sizewell), the Netherlands (Borssele), Switzerland (Beznau, Gösgen), Germany (Gundremmingen, Brokdorf, Neckarwestheim, Grohnde), Slovakia (Bohunice, Mochovce), Hungary (Paks), the Czech Republic (Dukovany, Temelin), Ukraine (Rivne, Khmelnitsky, South-Ukraine,), Armenia (Metsamor), India (Tarapur,), China (the CEFR research reactor near Beijin))[71]. The fuel fabricated at the Novosibirsk Chemical Concentrates Plant is shipped to Iran (Bushehr), India (Kudankulam), China (Tianwan), Bulgaria (Kozloduy), Ukraine, and fuel for several other PWR reactors[72] including reactors in Sweden and in the US[73].

A document received by Greenpeace shows that during fabrication, fuel with reprocessed uranium from Mayak and fuel with reprocessed uranium from Western Europe (la Hague, France, and Sellafield, UK) are produced at the same installations and not specifically separated. [74]

Apart from the fresh fuel exports listed here, Rosatom supplies uranium in other forms, e.g. enriched uranium for fuel rod production elsewhere. For example, in 2015-2016, 40% of the uranium used in Lingen in Germany for the production of nuclear fuel rods was enriched in Russia[75].

Mayak is also a possible link in the supply chain of fuel for the future Finnish Hanhikivi NPP. The project company Fennovoima stated in a 2014 report that it has plans to use fuel from reprocessed spent nuclear fuel, while this type of fuel is "currently only produced in Russia" [76]. Although it is not clear at the moment whether fuel from the new VVER-1200 reactors will also be reprocessed at Mayak, this is highly possible. Also, until the end of 1996, Finland was sending spent nuclear fuel from its Soviet-built NPPs to Mayak for reprocessing[77].

In 2011, the Swiss company AXPO under pressure from environmental groups, refused to receive fuel which could be linked to Mayak because of environmental safety doubts and lack of transparency (the Swiss company was denied access to Mayak)[78].

MAYAK ACCIDENTS

THE 1957 ACCIDENT

In September 1957, a storage tank with highly radioactive liquid waste exploded, releasing about 740 PBq[79] of radioactivity into the environment, exposing 272,000 people from 217 towns and villages to radiation for a prolonged period. Until the Chernobyl NPP disaster in 1986, this was the worst radiation accident the world had ever seen[80].

The radioactive fallout spread across an area of 50 km wide and 300 km long with 23,000 square kilometres contaminated by strontium-90 with a density of more than 3.7 kBq/m^2. A year later, 1,000 km^2 was declared a closed zone, and people in that area were relocated. But many people were never evacuated. Half a century later, the territory near Mayak is one of the most radioactively contaminated places on Earth, with thousands of people in surrounding towns and villages still living on contaminated land.

Before the fall of the Soviet Union, publications about the accident at Mayak appeared only in Western media. As Mayak and the town of Ozyorsk where it is situated (named then as Chelyabinsk-40, later Chelyabinsk-65, until 1994) were not marked on maps, the accident iis also known as Kyshtym disaster, by the name of the nearest known town.

Until the 1990s, citizens were not told about radioactive contamination, they were only advised not to use the water of the Techa River. However, scientists had been researching the impacts of the Mayak accident. The true number of people affected by radiation from Mayak, including the number of potential casualties, will probably never be known. A special law to acknowledge and support survivors of the accident was passed only in 1993, with the current valid version adopted in 1998.[81]

People living in the Mayak region have high rates of malignant cancers, genetic abnormalities and other health problems that may be related to radiation exposure[82].

1957 ACCIDENT WAS ONE OF MANY

The 1957 explosion was the worst accident at the Mayak nuclear complex, but it was not the only one. Since operations began in 1948, there have been a number of accidents resulting in radioactive releases.

From 1948 to the mid 1950s, radioactive waste was discharged directly into the Techa River, which was then a source of drinking water for thousands of people. During this period, more than 100 PBq[83] of radioactivity released into the river exposed 124,000 people in 41 towns and villages.

In the spring of 1967, a storm blew nuclear dust containing more than 20 PBq of radioactivity[84] from Lake Karachay, one of the ponds used to store wastes from nuclear reprocessing. The contamination spread across 2,700 km^2 (contaminated by strontium-90 with a radiation density of more than 3.7 kBq/m^2) affecting 42,000 people in 68 towns and villages.

The territory affected by the 1957 explosion and the wind dispersion of dust from the lake in 1967 is referred to as the East Urals Radioactive Trace. In 1957-1960, more than 10,000 people were evacuated from this territory. Official data show[85] that major fires on the East Urals Radioactive Trace territory (1996, 2004 and 2008) caused short-term changes in radiation levels at a distance of up to 10 km from the fires because of the dispersion of radionuclides as a result of combustion.

REFERENCES

1 Ozersk74.Ru, 12.07.2017, http://www.ozersk74.ru/news/it/361912.php (in Russian)

2 International Panel on Fissile Materials. Reprocessing plant at Mayak to begin reprocessing of VVER-1000 fuel. 19.12.2017, http://fissilematerials.org/blog/2016/12/reprocessing_plant_at_may.html (in English)

3 Ozersk74.Ru, 22.07.2017, http://ozersk74.ru/news/it/360344.php (in Russian)

4 World nuclear news, Rostechnadzor outlines used fuel targets, 26.09.2014, http://www.world-nuclear-news.org/WR-Rostechnadzor-outlines-used-fuel-targets-26091401.html (in English)

5 TASS, 22.09.2014, http://tass.ru/ekonomika/1459145 (in Russian)

6 Russian data show that reprocessing one tonne of spent nuclear fuel creates the following extra amount of liquid radioactive waste, see earlier Greenpeace report Mayak: A 50-Year Tragedy, http://www.greenpeace.org/international/Global/international/planet-2/report/2007/9/mayak-a-50-year-tragedy.pdf :

- category high-level radioactive waste (activity up to 370 GBq/l) – about 45 cubic metres (m^3)

- Medium-level radioactive (activity up to 37 GBq/l) – about 150 m^3;

- Low-level radioactive (activity up to 370,000 Bq/l) – about 2,000 m^3.

See also: Union of Concerned Scientists. Reprocessing and Nuclear waste. Factsheet. July 2009. Ucsusa.org.

7 RIA Novosti, 07.10.2016, https://ria.ru/atomtec/20161007/1478712664.html (in Russian)

8 Becquerel is a unit of radioactivity and represents one radioactive decay (leading to a release of radiation) in the given object per second.

9 Established in Russian standard, “Norms of radiation safety”, NRB-99/2009, annex 2a. This standard refers to “drinking water”. But another standard for surface waters (SanPiN 2.1.5.980-00 Hygienic requirements for the protection of surface waters. Annex 1) refers to the same IL both for “drinking and domestic water supply, as well as for water supply of food enterprises” and “for recreational water use, as well as within the boundaries of populated areas”.

10 Ministry of Ecology of the Chelyabinsk region, 15.11.2017, http://www.mineco174.ru/htmlpages/Show/protectingthepublic/2015/25RADIACIONNAYAOBSTANOVKANAT (in Russian)

11 Chelyabinsk regional court, 11.05.2006, http://www.greenpeace.org/russia/Global/russia/report/energy/nuclear/Sadovnikov-justice.pdf (in Russian)

12 Atomeco-2013 presentation by Mayak, 30-31.10.2013, http://www.atomeco.org/mediafiles/u/files/Prezentetion_30_10_2013/MOKROV.pdf, p 11 (in Russian)

13 V.M. Kuznetsov, M.S. Khvostova, S.P. Kolotukhin, V.A. Chuprov, B.A. Schukin, V.A. Moskalenko, V.V. Ponurovskaya. Final Report “Radiation Monitoring in the Rivers, Lakes in the Zone of Influence of «Mayak» Production Association”, 2013, http://bellona.org/assets/sites/3/2015/06/fil_report_3_Eng1.pdf (in English), e.g. p. 13 (Cs-137 acitivity in sediments exceeding 14kBq/kg)

14 First Deputy Minister of Public Security of the Chelyabinsk Region Svetlana Kostina, Presentation “On the problem of establishing special conditions for the use of contaminated land in the floodplain of the Techa River: the current state and ways of solving”. Materials for the meeting of the Russian Scientific Commission for Radiation Protection July 3, 2017. (in Russian)

15 LentaChel.Ru, 24.05.2017, https://lentachel.ru/news/2017/05/24/troe-chelyabintsev-lovili-rybu-v-radioaktivnom-vodoeme.html; Delovoy Kvartal, 25.05.2017,,http://www.dk.ru/news/pod-ozerskom-zaderzhali-rybakov-s-radioaktivnoy-ryboy-237079466; Bezopasnost RAO, 25.05.2017, http://bezrao.ru/n/1026 (all in Russian)

16 Izvestia.Ru, 9.04.2003, https://iz.ru/news/275330 (in Russian)

17 Romanovich I.K., NIIRG, Presentation “On the issue of establishing special conditions for the use of contaminated land in the floodplain of the Techa River.” Materials for the meeting of the Russian Scientific Commission on Radiation Protection, July 3, 2017 (in Russian).

18 S.V. Panchenko,IBRAE Institute, Presentation “On the Issue of Specific Conditions for the Use of Contaminated Land in the Riverbed of the Techa River”. Materials for the meeting of the Russian Scientific Commission on Radiation Protection July 3, 2017. (in Russian)

19 Rossyskoye Atomnoye Obschestvo, 19.10.2016, http://www.atomic-energy.ru/news/2016/10/19/69734 (in Russian)

20 Mayak annual report 2014, http://www.po-mayak.ru/wps/wcm/connect/mayak/site/resources/b97500804a222193b849bf46ed117988/OTCHET_2014.pdf (in Russian)

21 Report on research work “Investigation of specific aspects of state regulation of safety in the management of radioactive waste accumulated in industrial ponds of the Mayak production association, the Siberian Chemical Combine and the Mining and Chemical Combine”, Moscow, 2001. (in Russian)

22 V.M. Kuznetsov, M.S. Khvostova, S.P. Kolotukhin, V.A. Chuprov, B.A. Schukin, V.A. Moskalenko, V.V. Ponurovskaya. Final Report “Radiation Monitoring in the Rivers, Lakes in the Zone of Influence of «Mayak» Production Association”, 2013, http://bellona.org/assets/sites/3/2015/06/fil_report_3_Eng1.pdf p. 6, table 3.

23 Mayak annual report 2016, http://www.po-mayak.ru/wps/wcm/connect/mayak/site/resources/1a38e10041bc510b838a83dbc8f3c731/OTCHET_2016.pdf (in Russian)

24 Official note from Gosatomnadzor No. 3-13/701, dated 20 December, 2002. See as well: http://bellona.ru/2003/01/15/gosatomnadzor-otozval-litsenziyu-u-ma/ (in Russian)

25 Chelyabinsk regional court, 11.05.2006, www.greenpeace.org/russia/Global/russia/report/energy/nuclear/Sadovnikov-justice.pdf (in Russian)

26 Bellona, Duma demands an end to nuclear reprocessing at Mayak, 09.02.2006, http://bellona.org/news/nuclear-issues/radwaste-storage-at-nuclear-fuel-cycle-plants-in-russia/2006-02-duma-demands-an-end-to-nuclear-reprocessing-at-mayak

27 Geographical and Statistical Dictionary of Perm Gubernia, 1873, Volume II, http://zz-project.ru/glossarij/1653-kyzyltash-ozero (in Russian)

28 Ozersk74.Ru, 18.10.2011, http://www.ozersk74.ru/news/city/17454.php (in Russian)

29 The further argumentation presented by environmental lawyer Andrei Talevlin (For the Nature /Decomatom Network, Chelyabinsk)

30 NP-058-04 “Safety of handling radioactive waste. General Provisions “(Minutes of the interdepartmental meeting on the activities of FSUE PA Mayak No. 1-2 / 2-pr / 03-16 / 146-pr / b / n dated 02.07.2010). (in Russian)

31 Nasha Versia, 11.01.2016, https://versia.ru/radionuklidnoe-ozero-karachaj-poxoronili-no-gremuchij-rassol-pod-zemlyoj-ishhet-vyxody ; Za Prirodu, 27.11.2015, http://za-prirodu.ru/page/ozero-karachaj-problemy-ostajutsja (all in Russian)

32 ProAtom, 23.03.2017, http://www.proatom.ru/modules.php?name=News&file=article&sid=7383 (in Russian)

33 Mayak annual report 2016, http://www.po-mayak.ru/wps/wcm/connect/mayak/site/resources/1a38e10041bc510b838a83dbc8f3c731/OTCHET_2016.pdf (in Russian)

REFERENCES

34 http://www.mineco174.ru/htmlpages/Show/protectingthepublic/2015/25RADIACIONNAYAOBSTANOVKANAT (in Russian)

35 Results of poll conducted by Greenpeace Russia with inhabitants of Muslyumovo, 2002.

36 Copy of letter of Administration of Chelyabinsk District of 18 December, 2000, No. 08/3653

37 Citogenetical Research of inhabitants of Muslyumovo', Institute of General Genetic Russian Academy of Science, Moscow, 1998.

38 On the quality of construction in the new village, see Regnum, 28.01.2011, https://regnum.ru/news/1369264.html (in Russian). On radon concentrations in villages along the Techa river, see e.g. Yarmoshenko, I., et al., Geogenic and anthropogenic impacts on indoor radon in the Techa River region, Sci Total Environ (2016), http://dx.doi.org/10.1016/j.scitotenv.2016.07.170 (in English)

39 http://www.president-sovet.ru/documents/read/568/ (in Russian)

40 http://www.president-sovet.ru/documents/read/568/ (in Russian)

41 Ozersk74.Ru, 8.08.2017, http://www.ozersk74.ru/news/it/363760.php (in Russian)

42 ProAtom, 04.02.2016, http://www.proatom.ru/modules.php?name=News&file=article&sid=6544 (in Russian)

43 Analysis of arrangements and efficiency of works on the fulfillment of applicable international agreements of the Russian Federation related to import, storage and reprocessing of irradiated nuclear waste of foreign nuclear reactors. Prepared by the Government of the Russian Federation for the fulfillment of the instruction of the President of the Russian Federation of 4 February, 2002, No.Pr-251. (in Russian)

44 U.S. Department of State. Fact Sheet U.S.-Russia Agreement for Peaceful Nuclear Cooperation (123 Agreement), 15.05.2008, https://2001-2009.state.gov/p/eur/rls/fs/104917.htm (in English)

45 Bellona, US Congress ratifies 123 agreement, opening nuclear cooperation and environmental defilement between the US and Russia, 10.12.2010, http://bellona.org/news/nuclear-issues/radioactive-waste-and-spent-nuclear-fuel/2010-12-us-congress-ratifies-123-agreement-opening-nuclear-cooperation-and-environmental-defilement-between-the-us-and-russia (in English)

46 Ozyorsk town administration, EIA of SNF shipment from Paks, http://www.ozerskadm.ru/upload/iblock/4cd/pr_ovos_aes_paksh_hungary.pdf (in Russian)

47 Ozyorsk town administration, 21.03.2013, http://www.ozerskadm.ru/about/info/messages/17308/?sphrase_id=154944 (in Russian)

48 Ozyorsk town administration, EIA of SNF shipment from Paks, http://www.ozerskadm.ru/upload/iblock/4cd/pr_ovos_aes_paksh_hungary.pdf , p. 4 (in Russian)

49 Article 48 of the Law "On nature protection" no.7-FZ, issued 10.01.2002 (in the current form, amended by other laws) http://www.consultant.ru/document/cons_doc_LAW_34823/ (in Russian)

50 Supreme Court of the Russian Federation, case no.KAS02-225, 21.05.2002, http://www.supcourt.ru/stor_pdf.php?id=8454 (in Russian)

51 See more on this shipment Rossiyskoye Atomnoye Obschestvo, 1.09.2014, http://www.atomic-energy.ru/news/2014/09/01/51147 , and on the earlier Supreme Court decision: Bellona, 4.03.2004, http://bellona.ru/2004/03/04/oyat-iz-vengrii-pravovaya-storona-vopro/ (both in Russian)

52 This article describes the nature of damage: World nuclear news, Damaged Paks fuel sent to Russia, 20.08.2014, http://www.world-nuclear-news.org/ENF-Damaged-Paks-fuel-sent-to-Russia-2008145.html (in English)

53 Nuclear Transparency Watch, Opinion: Spent fuel transported from Hungary to Russia, 5.09.2014, http://www.nuclear-transparency-watch.eu/activities/transparency-and-public-participation/opinion-spent-fuel-transported-hungary-russie.html (in English)

54 Kozloduy NPP annual report 2015 p. 11. «Part of the spent fuel from Kozloduy NPP… is returned to Russia for reprocessing and longterm storage". http://www.kznpp.org/uf//anual_reports/en/KozloduyNPP_AR_2015_en.pdf (in English)
Russia's agreement with Bulgaria states secondary radioactive waste from Kozloduy should be returned to Bulgaria: http://mddoc.mid.ru/api/ia/download/?uuid=6608dba4-6446-4630-84d8-1018ca24879d (in Russian)

55 Hvylya, 28.09.2015, http://hvylya.net/news/digest/ukraina-gotovit-kontrakt-s-rf-po-vozvratu-otrabotannogo-yadernogo-topliva.html (in Russian)

56 UNIAN, 28.09.2015, https://economics.unian.net/energetics/1135975-minenergouglya-gotovit-kontrakt-s-rossiey-po-vozvratu-v-ukrainu-otrabotannogo-yadernogo-topliva.html (in Russian)

57 Ozyorsk town administration, EIA of SNF shipment from Paks, http://www.ozerskadm.ru/upload/iblock/4cd/pr_ovos_pr_vvoz_otbs_hungary.pdf (in Russian)

58 Green Patrol, Ecodefense press-release, 19.06.2012, http://www.greenpatrol.ru/en/node/251690 (in Russian)

59 Bellona, Germany refuses to ship radioactive waste to Mayak pending safety evaluations, 5.12.2010, http://bellona.org/news/nuclear-issues/radioactive-waste-and-spent-nuclear-fuel/2010-12-germany-refuses-to-ship-radioactive-waste-to-mayak-pending-safety-evaluations (in English)

60 Russian Research Reactor Return Program (RRRFR) is performed within the frame of Global Initiative of Nuclear Threat Reduction. Russia receives SNF from research reactors from Belarus, Bulgaria, Czech Republic, , Hungary, Kazakhstan, Latvia, Libya, Poland, Romania, Ukraine, Uzbekistan, Vietnam and Yugoslavia (now Serbia). China and North Korea who have Soviet-built research reactors refused to participate; Germany refused after a campaign in 2011; Egypt refused because it has low enriched fuel only. Majority of shipments went to Dimitrovgrad.

61 Sosny Research and Development Company, Participation on the RRRFR Program. History of transport operations, http://sosnycompany.com/performed-projects/participation-on-the-rrr-fr-program.-history-of-transport-operations.html (in English)

62 Yuldashev, B.; Salikhbaev, U., et al., The experience of shipping spent nuclear fuel from Uzbekistan to the Russian Federation, http://www.rertr.anl.gov/RERTR28/Abstracts/S14-2_Yuldashev.html (in English)

63 World nuclear news, Uzbek research reactor fuel shipped to Russia, 28.09.2015, http://www.world-nuclear-news.org/WR-Uzbek-research-reactor-fuel-shipped-to-Russia-28091501.html (in English)

64 Novy Den, 14.10.2010, https://newdaynews.ru/chel/304581.html (in Russian)

65 World nuclear news, Mayak receives nuclear sub fuel from Andreeva Bay, 17.08.2017, http://www.world-nuclear-news.org/WR-Mayak-receives-nuclear-sub-fuel-from-Andreeva-Bay-17081701.html (in English)

66 The Independent Barents Observer, Andreeva Bay cleanup: Activist in exile says Norway's nuclear waste support is irresponsible, 07.06.2017, https://thebarentsobserver.com/en/node/2460 (in English)

67 NRPA reports: http://www.nrpa.no/dav/1fbb52ea04.pdf , http://www.nrpa.no/filer/19bdfc616e.pdf (in English)

68 Dhaka Tribune, 18.03.2017, - http://www.dhakatribune.com/bangladesh/power-energy/2017/03/18/dhaka-moscow-approve-spent-nuclear-fuel-draft-deal/ (in English)

REFERENCES

69 The agreement with Bangladesh stating that spent nuclear fuel is to be returned to Russia: http://mddoc.mid.ru/api/ia/download/?uuid=e3d646f7-c773-4403-b563-3248bba2d7db (in Russian).
The agreement with Belarus stating that spent fuel is to be returned to Russia for reprocessing and secondary waste and products of reprocessing are not to return to Belarus: http://mddoc.mid.ru/api/ia/download/?uuid=b4dac014-0f57-4b64-b722-52ab7ee31335 (in Russian).
The agreement with Hungary stating that spent fuel should be sent to Russia for interim storage and reprocessing with secondary waste to be returned to Hungary: http://mddoc.mid.ru/api/ia/download/?uuid=033219b5-1ba8-4bc8-bf1b-04909fd6c2b2 (in Russian).
The agreement with Turkey stating that spent fuel may be reprocessed in Russia: http://mddoc.mid.ru/api/ia/download/?uuid=19bd454d-1e53-4899-b321-6e101feba083 (in Russian).

70 Russian Ministry of Foreign Affairs, http://www.mid.ru/foreign_policy/international_contracts/2_contract/-/storage-viewer/bilateral/page-113/45623 (in Russian)

71 See map: http://www.elemash.ru/upload/files/map.pdf (in Russian); http://www.elemash.ru/en/produktsiya/produktsiya-yaderno-toplivnogo-tsikla/toplivo-dlya-reaktorov-pwr-i-bwr/ ; http://rosatom.ru/en/press-centre/industry-in-media/234-msz-completed-nuclear-fuel-assembly-line-for-areva-np-/ (both in English)

72 http://www.nccp.ru/products/fuel_for_nuclear_power_plants/fuel_for_vver/ (in Russian)

73 RIA Novosti, 19.06.2017, https://ria.ru/atomtec/20170619/1496819983.html (in Russian)

74 Letter of Rosatom 16.06.09 no.17.1/0513 to Greenpeace

75 Share of enriched uranium in fuel rods production in Lingen: 2011 -31% ; 2012 -12%; 2013 -21%; 2014 - 27%; 2015 - 43%; 2016 - 40%. See: Deutscher Bundestag Drucksache 18/12710 18. Wahlperiode 12.06.2017 Antwort der Bundesregierung auf die Kleine Anfrage der Abgeordneten Hubertus Zdebel, Eva Bulling-Schröter, Caren Lay, weiterer Abgeordneter und der Fraktion DIE LINKE. http://dipbt.bundestag.de/doc/btd/18/127/1812710.pdf (in German)

76 http://www.fennovoima.fi/userData/fennovoima/doc/yva/yva2013/ElAreport2014.pdf_ See: " Fennovoima plans to use also reprocessed uranium as fuel. " "There are reprocessing plants in France, Great Britain, Russia, and Japan." "fuel for the 1,200 MW plant planned by Fennovoima is currently only produced in Russia, it is feasible that in the future, the fuel will be produced in other locations as well." (in English)

77 https://www.stuk.fi/documents/12547/273805/suomen-kansallinen-selonteko-stuk-b180.pdf/6f3b-c26d-b4ae-4742-8ec1-858b6ade27c7 page 17, An amendment to the Nuclear Energy Act was passed in 1994, stating that spent fuel and all other nuclear wastes generated by the Finnish NPPs have to be treated, stored and disposed of in Finland. Spent fuel shipments to Russia were terminated at the end of 1996, and since then the spent fuel generated at the Loviisa plant has been stored at the plant site.(in English)

78 http://www.world-nuclear-news.org/RS_Axpo_says_no_to_uranium_from_Mayak_1411107.html; http://www.swissinfo.ch/eng/russian-nuclear-site-fuels-controversy/31570908 (in English)

79 Petabecquerels; 1 PBq = 10 (upper index) [15] Becquerels; The source of the figure is Atlas of the East Ural and Karachay radioactive trace including forecast up to 2047 / Editor-in-chief Yu.A. Izrael, – Moscow.: IGCE Roshydromet and RAS, «Infosphere» Foundation, 2013. – 140 p. http://downloads.igce.ru/publications/Atlas/CD_VURS/about.html. The Atlas refers to 20 MCi.

80 According to the IAEA it was an INES 6 accident. https://www.iaea.org/sites/default/files/ines.pdf (in English)

81 http://base.garant.ru/179742/ (in Russian)

82 http://www.greenpeace.org/russia/Global/russia/report/2008/1/50-2.pdf p.17 and further

83 Atlas of the East Ural and Karachay radioactive trace including forecast up to 2047 / Editor-in-chief Yu.A. Izrael, – Moscow.: IGCE Roshydromet and RAS, «Infosphere» Foundation, 2013. – 140 p. http://downloads.igce.ru/publications/Atlas/CD_VURS/about.html (in Russian). The Atlas gives 2.8 MCi of radioactivity.

84 Atlas of the East Ural and Karachay radioactive trace including forecast up to 2047 / Editor-in-chief Yu.A. Izrael, – Moscow.: IGCE Roshydromet and RAS, «Infosphere» Foundation, 2013. – 140 p. http://downloads.igce.ru/publications/Atlas/CD_VURS/7-12.html (in Russian). The Atlas gives 0.6 MCi; the estimation of the area affected is from the same source.

85 http://www.osatom.ru/mediafiles/u/files/VIII_reg_forum_2015/1_2_5_Mokrov_Radioekologicheskaya_bezopasnost.pdf p. 16 (in Russian)

GREENPEACE

www.gereenpeace.org