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Valence, May 6, 2011.

CRIIRAD Report No. 11-18 D¹

Radioactivity in the vicinity of the Mayak nuclear site in Russia

An analysis commissioned by GREENPEACE Switzerland

1 / Context, Objectives, and Methodology

The Mayak nuclear site

The military-nuclear site at Mayak, south-east of the Urals in Russia, was built with great urgency on the eve of World War II to produce the plutonium needed for the development of Soviet nuclear weapons.

The first Soviet nuclear bomb, detonated in 1949, was built here. North of Mayak a secret city (Chelyabinsk-40) materialized to accommodate the workers involved in the project.

Much like the American nuclear site at Hanford where the Nagasaki bomb was produced, Mayak and its plutonium extracting reactors have, over the years, discharged a steady stream of radioactive emissions into the environment and accumulated large amounts of radioactive wastes without sufficient protective measures.

From 1949 until 1951 the installation's liquid radioactive emissions were directly discharged into the surface water system of the **Techa River's** watershed and into Lake Karatchaï where they caused a devastating and lasting contamination.

Realizing the extent of the problem, the Soviet authorities eventually took steps to drain **Lake Karatchaï**, create a series of artificial reservoirs that came to be known as the «Cascade of the Techa », and prohibit the exploitation of the Techa's resources downstream of the site.

Unfortunately, even today, numerous inhabitants of the area do not have the means to respect this ban.

The partial draining of Lake Karatchaï in **1967** brought with it a new large-scale contamination resulting from the wind-borne dispersion of highly contaminated sediments from the shores of the shrinking lake.

Mayak was also—long before Chernobyl—the site of the first large-scale nuclear accident. In 1957 a radioactive waste tank exploded, contaminating several hundred square kilometers. The disaster of Kytchym, after the town closest to the site, remained a secret until it was revealed in 1977 by Jaurès Medvedev, a Russian scientist who had since gone into exile in London.

Even today it is difficult to know the precise extent of the environmental contamination and its effects on the health of the local population.

¹ The current version constitutes the final document, a preliminary version was addressed to Greenpeace on February 4, 2010



A Mission Organized by Greenpeace Switzerland in November 2010

The nuclear site of Mayak performs commercial services such as the reprocessing of spent fuel from nuclear power plants, much of it for customers from abroad. According to Greenpeace [GP 1], Mayak customers include : Bulgaria, Hungary, former Czechoslovakia, Finland, Germany, Ukraine, Iraq. According to Greenpeace Russia, by the end of 2001 the site had reprocessed more than 1540 tons of spent fuel from abroad [GP 1].

Greenpeace Switzerland enlisted the scientific and technical services of CRIIRAD laboratories for its mission to Mayak, which was designed to raise public awareness for the problem of radioactive contamination caused by the site's nuclear activities past and present and its reprocessing operations in particular.

Some of the nuclear materials imported by several operators of nuclear power plants in Switzerland are in fact reprocessed at the Mayak site in Russia [GP 2].

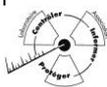
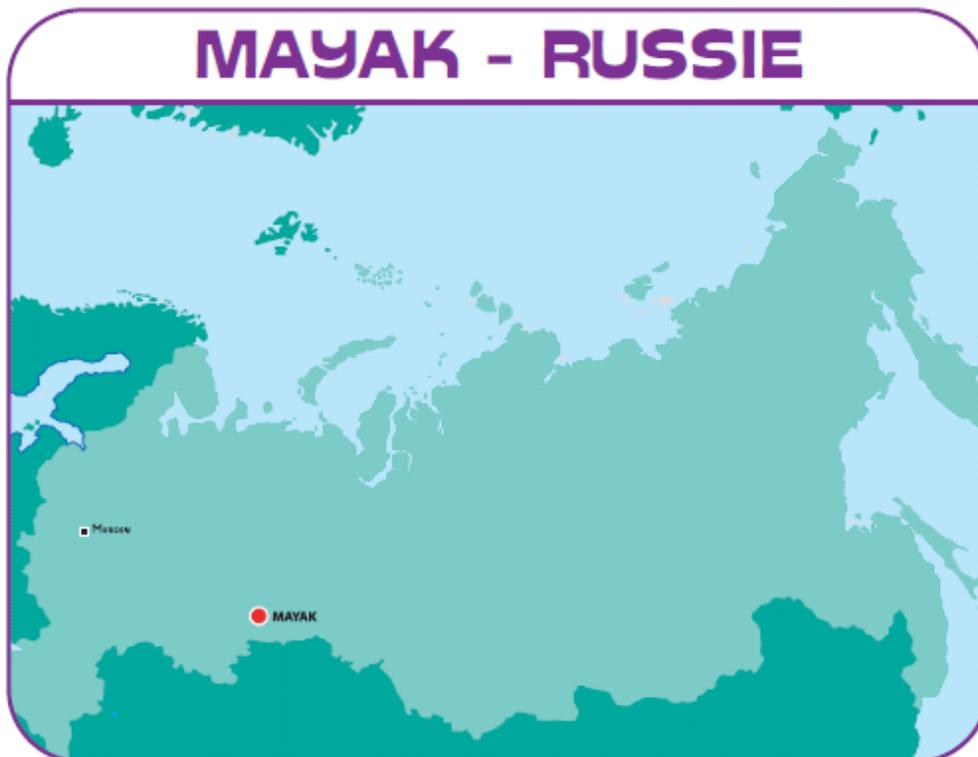
In May 2008, CRIIRAD laboratories had performed radiation measurements and taken samples along the banks of the Techa River and in the village of Muslymovo [CR 1]. Their measurements confirmed elevated levels of environmental contamination involving several artificial radioactive substances (cesium-137, strontium-90, plutonium). A summary of their findings is reproduced in Appendix 1.

A working meeting between Greenpeace Switzerland (Mr. Florian Kasser, nuclear campaign coordinator) and CRIIRAD (Mr. Christian Courbon, the specialist who led the Mayak mission in May 2008, and Mr. Bruno Chareyron, the engineer and nuclear physicist who had coordinated the analyses) was convened on October 21, 2010 in Valence, France.

At the end of the meeting a plan for sampling and analysis had been drawn up.

The team of Greenpeace Switzerland collected the samples in November 2010 and mailed them to CRIIRAD laboratories between Mid-November 2010 and Mid-January 2011.

C1 / the location of the Mayak nuclear site



Types of samples collected

Greenpeace never intended to produce an in-depth study but simply wanted to conduct a number of specific tests to determine if the environmental contamination in the area had evolved since the sampling carried out by CRIIRAD in May 2008.

Among the specimens Greenpeace submitted to the CRIIRAD laboratories were a sample of cow's milk, three samples of river water (2 of them from the Techa River) and 2 samples of well water:

- E1 / running water from the Techa River sampled at the M5 bridge, downriver from the cascades that collect the radioactive discharges from the Mayak site and upriver from the village of Muslymovo.
- E2 / water from a private well in Muslymovo.
- E3 / stagnant water from the banks of the Techa in Muslymovo, near the ruins of the boarding school.
- E5 / water from a public well in Muslymovo.
- E6 / river water collected from an upstream site roughly 26 km north of Mayak that may be safely considered out of range of the liquid radioactive emissions from the nuclear site (see map page 5 for locations of sampling sites).

CRIIRAD laboratories performed **gamma spectrography** measurements for cesium-137, cesium-134, manganese-54, cobalt-58, cobalt-60, ruthenium-rhodium-106, silver-110m, antimony-125, iodine-131, iodine-129, americium-241, etc.) and determined the dosage of free tritium by means of liquid scintillation. CRIIRAD is accredited by the French Nuclear Safety Authority (see appendix 2).

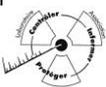
The samples were treated by the lab technician Jocelyne Ribouet, the analyses were performed by the metrologist Stéphane Patigeon, and the final results were validated and interpreted by Bruno Chareyron, engineer and nuclear physicist. It is important to point out that in its investigation of the gamma spectrums the CRIIRAD interpreted all detected gamma rays. However, the present report does not list all detection thresholds but only those of a small selection of gamma-emitting radionuclides in order not to burden the resulting tables with too much information.

The dosage of other pure beta-emitting radionuclides (strontium-90, carbon-14, organically bound tritium) and the measurement of the total alpha and beta activity indices in the water were entrusted to other specialized labs².

For budgetary reasons not all types of radionuclides could be measured.

Preference was given to the running water of the Techa (E1).

² Subatech (strontium-90 in the milk), RCD Lockinge (OBT and C14 in the milk), EICHRUM (indices of total alpha and beta activity and of strontium-90 in the water).



2 / Official Data on Current Radioactive Discharges from the Mayak Plant

Greenpeace Switzerland obtained an official document from Rosatom [MOK 1] containing some details on the current radioactive discharges from the Mayak plant.

Atmospheric radioactive discharges

For the period from 2004 to 2008 information about atmospheric radioactive discharges is given for 4 radionuclides (plutonium-239, strontium-90, iodine-131 and caesium-137).

Unfortunately this document cannot really be used because it expresses actual discharges as percentages of permitted discharges (they are below them) but never tells us how big the permitted discharges are.

Also, surprisingly, these tables do not address discharges of other radioactive substances known to be predominant in the atmospheric discharges of reprocessing plants in the Western hemisphere such as tritium, carbon-14, iodine-129, krypton-85 etc. (see study by CRIIRAD Lab, LHC1]).

Liquid radioactive discharges

No figures are given for current liquid radioactive discharges. The document simply indicates that some portion of the liquid radioactive effluents is directed to storage in special artificial reservoirs isolated from the open hydrographic system.

There are 8 such reservoirs:

- Reservoirs for water recycling: R-2 (Lake Kyzyltash) and R-6 (Lake Tatysh),
- Four « storage reservoirs » for low level waste (LLW): R-3, R-4, R-10 and R-11 (TRC).
- Two « storage reservoirs » for medium level waste (MLW) : R-9 (Lake Karachai) and R-17 (Staroye Boloto).

See map below (C2).

C2 / Diagram of water use and liquid radioactive waste discharge management at the Mayak plant [MOK 1]

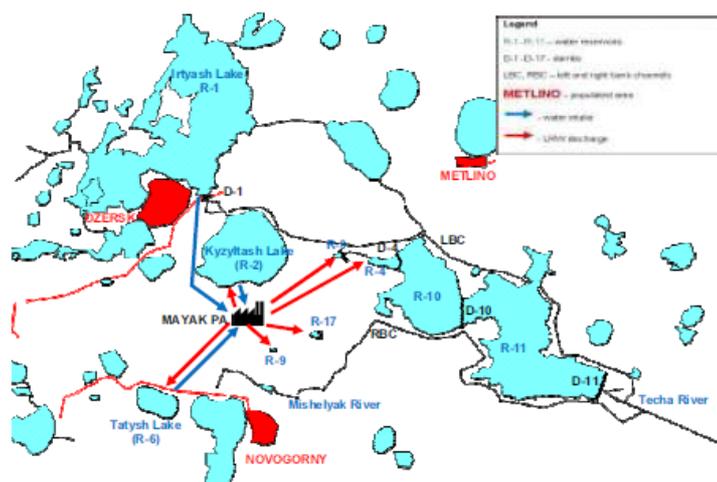
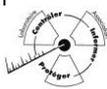


Fig.3 Layout of water use and liquid radioactive waste discharges from the Mayak PA

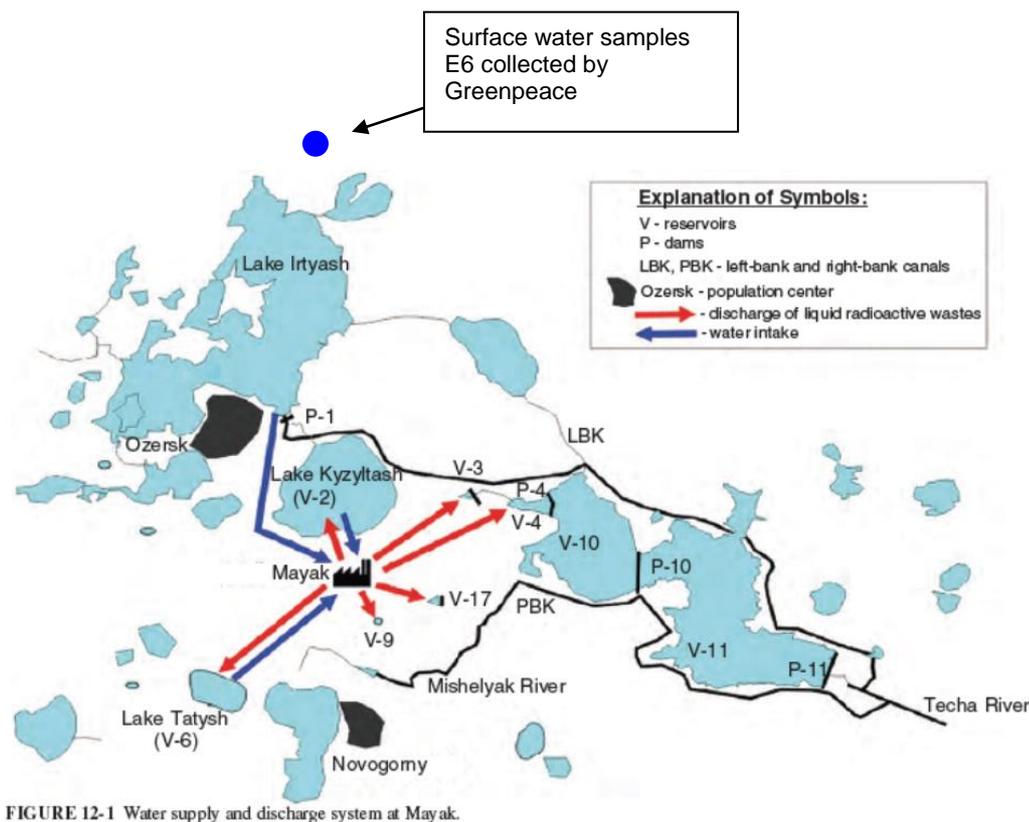


Given the poor resolution of map C2 we decided to reproduce map C3, below, from another official publication [GLAG 1]. The two maps provide consistent information.

These documents suggest that the « Techa Cascade » (TRC) consists of 4 reservoirs that are more or less isolated from the river.

Two networks of canals lead along this cascade of reservoirs and converge, downstream from the reservoirs, in the Techa River.

While there is no direct link between the disposal points of LLW-type radioactive waste and the water of the Techa River, there is however an indirect link via **the infiltration of contaminated water** through the bottom and the side walls of the reservoirs and the facing of the dams at the reservoirs (see dam called D11 and P11, respectively, on maps C2 and C3). This infiltration contaminates both groundwater and surface water and consequently the Techa.



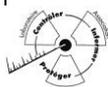
According to [MOK 1] the discharge permits are contingent on a guarantee that the activity concentration of the water in the reservoirs is not increased. However, the document does not specify the relevant limits.

Furthermore, according to this document, between 2002 and 2008 LRW-type (Liquid Radioactive Waste) radioactive discharges into the reservoirs did not exceed authorized limits and the activity concentration in the reservoirs remained constant with a downward trend.

The document contains two charts (see next page) that specify certain values of the activity concentration.

- **Reservoir R-17** designated to hold the most highly radioactive wastes (**MLW**).

Activity concentration – as shown in the chart – in 2008 was on the order of **50'000 Bq/l** for **caesium-137** and **300'000 Bq/l** for **strontium-90**.



Note that the activity concentration of cesium-137 has declined steadily from 2004 to 2008, while strontium-90 activity shows a sharp drop between 2004 and 2006 and then stagnation between 2006 and 2008.

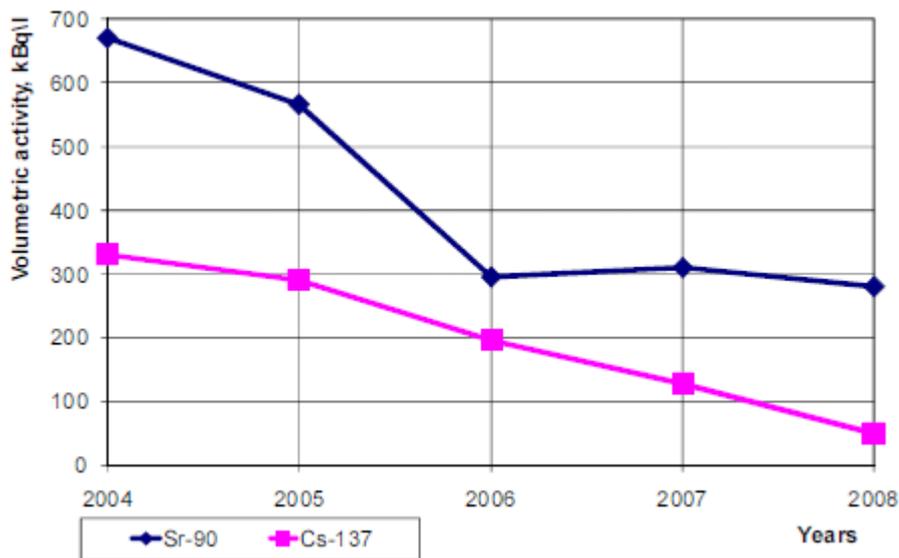
- Reservoirs R-10 / R-11 designated for **LLW**-type waste discharges

Activity concentration in 2008 – as shown in the chart – was on the order of **3000 Bq/l** for **strontium-90** in reservoir R-10 and about half that (1500 Bq/l) downstream in reservoir R-11. There is no mention of caesium-137 in that chart.

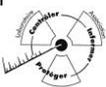
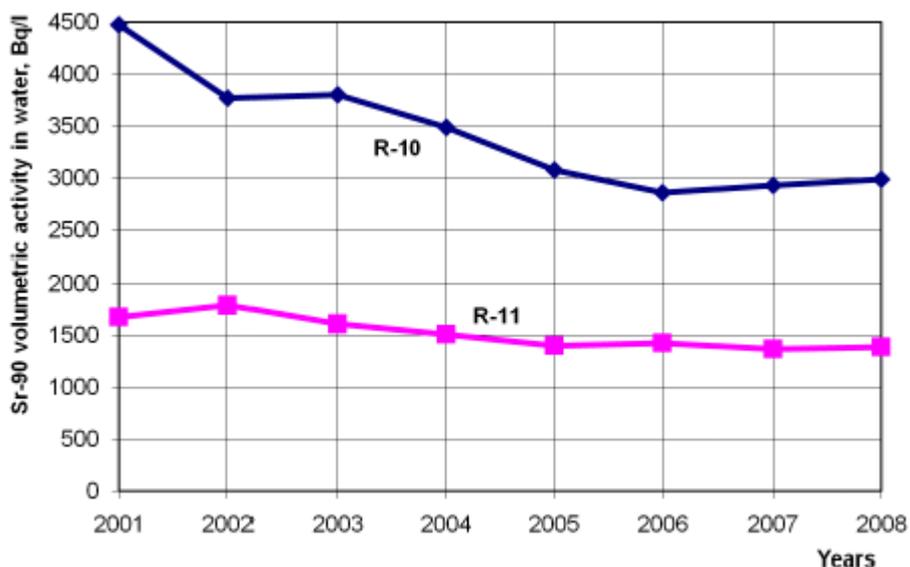
Note that the activity concentration of strontium-90 in reservoir R-10 generally decreased between 2001 and 2006 and then showed an upward trend between 2006 and 2008.

In reservoir R-11 values are more stable.

C4 / Changes in activity concentration of strontium-90 and caesium-137 (kBq/l) in the water of reservoir R-17 between 2004 and 2008 [MOK 1]



C5 / Changes in activity concentration of strontium-90 (Bq/l) in the water of reservoirs R-10 and R-11 of the cascade between 2001 and 2008 [MOK 1]



The document [MOK 1] raises many questions: it gives no figure regarding tonnage of reprocessed fuel nor the volume of the radioactive waste discharge nor of the annual activity in question.

It also contains no results of checks performed on Techa River water downstream from the reservoirs nor does it show activity concentrations of other radionuclides that certainly are present in those discharges such as tritium, carbon-14, cobalt-60, technetium-99, antimony-125, rhodium rhenium-106, iodine-129, iodine-131, europium-154 and 155, protactinium-233, the transuranics (isotopes of plutonium, neptunium, curium and americium) etc. [see CRIIRAD studies on discharges at the La Hague reprocessing plant: ref. LHC 1 to LHC 5].

The question of infiltration

The document [GLAG 1] provides interesting details about the technical problems arising from the reservoirs used for storage of LLW-type radioactive waste.

We learn that the region has recorded climate change since the early 80's that affects both annual rainfall and the level of evaporation of the water in the reservoirs. As a result, water levels in the reservoirs are approaching maximum authorized levels.

A situation analysis conducted for the last reservoir of the cascade (R-11) shows that between 1950 and the early 1980s, the rate of evaporation exceeded precipitation with a differential of 100 mm per year. **Between 1980 and 2006 the situation was reversed: precipitation exceeded evaporation loss by 90mm.**

The situation was « extremely critical » in 1999-2000 when the water level in reservoir R-11 rose by 1.5 meters in a year and a half.

The authors indicate that the recurrence of such a situation cannot be ruled out and that a 50-year action plan has been established. In the first phase that will last 6 to 8 years the volume of effluents released into the reservoirs will have to be reduced.

The increased water level in reservoir R-11 causes a **sharp increase in the infiltration rate of strontium-90** into the adjoining canals and consequently into the **Techa River** as shown in chart C6 below. Note that the rate of leakage of strontium-90 is in the dozens of Curies. And 1 curie = 37 billion Becquerels (Bq). This can therefore represent **more than one TBq per year** (1000 billion Becquerels).

C6 / correlation between the total amount of strontium-90 (in Curies) transferred into the surface water of the Techa and water level (in meters) in reservoir R-11 [GLAG 1]

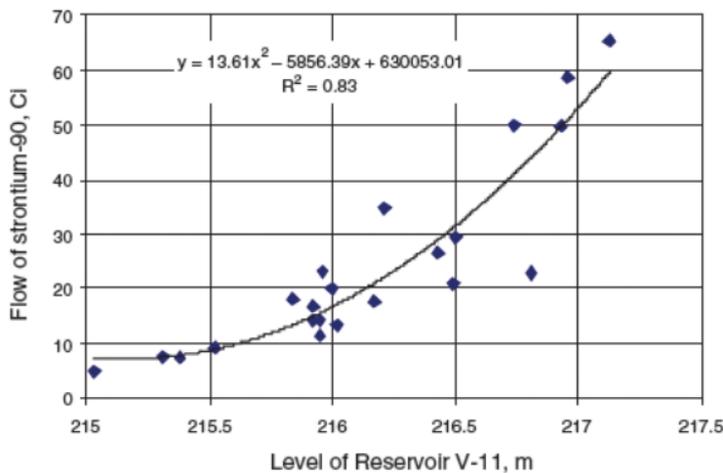
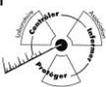


FIGURE 12-2 Correlation between total infiltration of strontium-90 into the surface levels of the Techa River and water level in Reservoir V-11.



According to [GLAG 1] the flow of the Techa at its mouth is typically 7 m³/s. One can calculate that an annual leakage rate of 60 Curies of strontium-90, diluted evenly in a stream with a flow of 7 m³/s, will correspond to an activity concentration of about 10 Bq/l.

3 / Contamination of the Techa River Water

The main results of the analysis of the water samples taken from the Techa in May 2008 (by CRIIRAD) and November 2011 (by GREENPEACE) are shown in chart T1 below. Activity levels are shown for the dates the samples were collected.

The samples from the Techa taken below the bridge on road M5 (point E1) are chronically contaminated by caesium-137 (1,45 Bq/l in November 2010), **strontium-90** (22 Bq/l) and **tritium**, a radioactive hydrogen isotope (451 Bq/l).

These three substances are released during reprocessing of spent nuclear fuel.

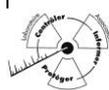
Note that in November, 2010 compared to May 27, 2008 there was an **increase in contamination** by

- **Caesium 137** (+ 38 %)
- Global **alpha** activity
- Global **beta** activity (factor 2,4) that stems mostly³ from **strontium-90**,
- **Tritium** (factor 5,8).

T1 / Analysis of the River Techa water samples

Code Sampling Date	E1 19/11/2010	E1 27/05/2008	E6 19/11/2010	E3 17/11/2010
Type	Techa, flowing water (bridge M5)	Techa, flowing water (bridge M5)	River water upriver from the Mayak site	Techa, stagnant water (near school ruins)
Cs 137 (Bq/l)	1,45 +/- 0,33	1,05 +/- 0,26	< 0,05	< 0,08
Cs 134 (Bq/l)	< 0,06	< 0,039	< 0,047	< 0,06
Co 58 (Bq/l)	< 0,07	< 0,043	< 0,08	< 0,07
Co 60 (Bq/l)	< 0,07	< 0,035	< 0,04	< 0,05
Mn 54 (Bq/l)	< 0,06	< 0,042	< 0,05	< 0,06
Am 241 (Bq/l)	< 0,09	< 0,09	< 0,1	< 0,13
Sb 125 (Bq/l)	< 0,19	< 0,12	< 0,14	< 0,19
I 131 (Bq/l)	< 0,09	< 0,1	NM	< 0,12
Ce 144 (Bq/l)	< 0,34	< 0,27	< 0,34	< 0,42
Ag 110 ^m (Bq/l)	< 0,06	< 0,042	< 0,05	< 0,06
I 129 (Bq/l)	< 0,11	< 0,08	< 0,09	< 0,13
Ru-Rh 106 (Bq/l)	< 0,6	< 0,4	< 0,47	< 0,6
H3 (raw water) (Bq/l)	441 +/- 44,1	91,4 +/- 9,1	16,7 +/- 1,7	11,4 +/- 1,8
H3 (distilled water) (Bq/l)	451 +/- 45,1	78 +/- 7,8	NM	13,1 +/- 1,6
Alpha total (Bq/l)	0,24 +/- 0,05	< 0,05		
Beta total (Bq/l)	52,57 +/- 7,75	21,65 +/- 2,1		
Residual total beta (Bq/l)	52,37 +/- 7,75	21,49 +/- 2,1		
Sr 90 (Bq/l)	22,0 +/- 1,8	NM		

³ For budgetary reasons, strontium-90 was not evaluated in May 2008. Instead an evaluation of total beta activity was done. The samples from November 2010 were evaluated for total beta activity and dosage of strontium-90 (a beta emitter). Its activity was 22 Bq/l. It quickly moves into balance with yttrium-90, its first descendant beta emitter. The global beta activity was therefore twice 22 Bq/l equals 44 Bq/l. 84% of the indicated value of total beta activity can be explained by the presence of the strontium-90/yttrium-90 couple. The rest of the beta signal comes from caesium-137 and possibly other artificial radionuclides or natural beta emitters. Given the uncertainties, it is possible that 100% of the residual beta signal comes from the Sr-90/Y-90 couple and from caesium-137.



As for **Tritium**, note there is contamination (16,7 Bq/l) found in river water samples collected upstream, about 26km north of the Mayak site.

However, this rate of contamination is significantly lower than the one found in the Techa downstream from the reservoirs that are used for the radioactive waste discharge (451 Bq/l). The upstream contamination could be linked to the release of tritium into the atmosphere.

In any case, the result shows that it is imperative to include tritium in the list of radioactive substances that should be controlled in the environment of the Mayak site.

Interpreting the variations between 2008 and 2010

Variations found in the activity concentration of the Techa water samples from May 2008 and November 2010 need to be interpreted with caution, as it is difficult to come to any conclusions based on just two sets of samples.

To determine the exact origin of contamination one should have more detailed knowledge of the present management of liquid and gaseous radioactive discharges from the Mayak site as well as on the transfers into the Techa watershed from:

- Liquid waste accumulated in the lakes and reservoirs of the watershed
- Contaminated sediments deposited at the bottom of those lakes and reservoirs
- Runoff transfer that affects the contaminated soil in the region

As for **strontium-90** with its half-life of 30 years the official document [GLAG 1] shows that most⁴ of the contamination transferred to the Techa is due to infiltrations from the reservoirs (the Techa Cascade) for type LLW radioactive discharges.

This leakage is certainly increased by the current liquid radioactive waste discharges of the nuclear site – as the operators indicate, the rate of strontium leakage that numbers in the hundreds of GBq per year is directly linked to the water level in the reservoirs and thus to the liquid waste discharges of the industrial site, among other things.

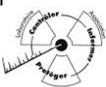
Tritium has a shorter half-life (12,3 years), a very high mobility in the environment and is usually the first radionuclide released when reprocessing spent nuclear fuel. The results of the Techa measurements probably reflect an increase in contamination of the river water linked to current discharges from the Mayak site and thus to the industrial activities conducted there. To be sure however, it would be necessary to have access to data on the tritium released in atmospheric or liquid form, the transfer rate of tritium from the reservoirs, the hydrodynamic characteristics of the Techa, etc..

In the Techa water samples taken on May 27, 2008 and November 19, 2010 no other artificial radioactive gamma emitting products were detected. Activity concentrations of iodine-129, iodine-131, manganese-54, silver 110^m, cobalt-58, cobalt-60, americium-241, etc. were below detection limits.

As for alpha emitting radionuclides note that total alpha activity was below the level of detection of 0,05 Bq/l on May 27, 2008 and well above this level on November 19, 2010: 0,24 +/- 0,05 Bq/l.

To determine if those alpha emissions stem from natural or artificial sources, would require additional analysis. It is possible that the source is plutonium, which is known to be part of reprocessing activities [LHC 1 to 5]. Its presence was also proven in soil samples from the bank of the Techa collected by CRIIRAD in May 2008 (plutonium-239 and plutonium-240: 2'200 Bq/kg sec, cf [CRI 1]).

⁴ It is possible that some of the contamination currently registered in the Techa river originates from erosion/leaching of soil contaminated by grave accidents in the past (particularly in 1957 and 1967).



4 / Radiological tests of well water in Muslymovo

The main results of the analysis of the well water samples from Muslymovo taken in May 2008 (by CRIIRAD) and in November 2010 (by Greenpeace) are to be found in chart T2 below. Activity levels are shown for the dates the samples were collected.

T2 / Radioactivity of well water in Muslymovo

Code	E2	E5	E2Bis
Sampling date	19/11/2010	19/11/2010	27/05/2008
Type	Groundwater / private well in Muslymovo	Groundwater / public well in Muslymovo	Groundwater / public fountain in Muslymovo
Cs 137 (Bq/l)	< 0,09	< 0,036	< 0,07
Cs 134 (Bq/l)	< 0,07	< 0,031	< 0,06
Co 58 (Bq/l)	< 0,07	< 0,06	< 0,07
Co 60 (Bq/l)	< 0,06	< 0,033	< 0,05
Mn 54 (Bq/l)	< 0,08	< 0,034	< 0,06
Am 241 (Bq/l)	< 0,15	< 0,044	< 0,09
Sb 125 (Bq/l)	< 0,2	< 0,09	< 0,16
I 131 (Bq/l)	< 0,11	< 3,4	< 0,13
Ce 144 (Bq/l)	< 0,47	< 0,18	< 0,32
Ag 110 ^m (Bq/l)	< 0,08	< 0,035	< 0,06
I 129 (Bq/l)	< 0,14	< 0,05	< 0,1
Ru-Rh 106 (Bq/l)	< 0,7	< 0,32	< 0,5
H3 (raw water) (Bq/l)	4,43 +/- 1,43	2,8 +/- 1,3	< 2,5
H3 (distilled water) (Bq/l)	NM	NM	NM
Alpha total (Bq/l)	< 0,02		< 0,04
Beta total (Bq/l)	0,13 +/- 0,03		0,23 +/- 0,1
Total residual beta (Bq/l)	0,10 +/- 0,03		0,09 +/- 0,1
Sr 90 (Bq/l)	< 0,04		

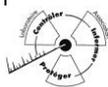
As for the controlled water samples from Muslymovo, the activity of gamma emitting radionuclides sought was below the limit of detection. The same goes for global alpha activity.

A residual global beta activity (that is, after subtraction of the contribution of beta emissions of natural potassium-40) is recorded (in the order of 0.1 Bq/l). This is well below the guideline values of the World Health Organization (WHO) of 1 Bq/l.

In two samples of underground water tested in November 2010, tritium was detected at levels of 2,8 et 4,4 Bq/l. Although these rates are well below the guideline values of the WHO (World Health Organization) they are higher than the natural level and indicate an **impact linked to nuclear activities**.

For a more complete diagnosis one would require hydrogeological data and would have to select the wells most vulnerable to contamination transported by the Tеча and likely to impact the groundwater.

It would be good to follow in particular the evolution of tritium levels in the groundwater since the detection of tritium in two wells at Muslymovo in November 2010 could be linked to the tritium loads in the Tеча. The contamination of the river, especially in the case of a radionuclide as mobile as tritium, can easily impact the groundwater close to the river's bed.



5 / Radiological tests of milk from Muslymovo

The main results of the analysis of the cow milk samples from Muslymovo taken in May 2008 (by CRIIRAD) and in November 2010 (by Greenpeace) are to be found in chart T3 below. Activity levels are shown for the dates the samples were collected.

T3 / Radioactivity of milk in Muslymovo

Code	L1	L1 bis
Sampling date	11-19-2010	05-30-2008
Sample taken by	GREENPEACE	CRIIRAD
Type	Cow's milk (formolized)	Cow's milk (formolized)
Cs 137 (Bq/l)	0,74 +/- 0,23	24,3 +/- 2,7
Cs 134 (Bq/l)	< 0,05	< 0,032
Co 58 (Bq/l)	< 0,06	< 0,036
Co 60 (Bq/l)	< 0,05	< 0,037
Mn 54 (Bq/l)	< 0,06	< 0,038
Am 241 (Bq/l)	< 0,08	< 0,05
Sb 125 (Bq/l)	< 0,14	< 0,1
I 131 (Bq/l)	< 0,08	< 0,06
Ce 144 (Bq/l)	< 0,29	< 0,19
Ag 110 ^m (Bq/l)	< 0,05	< 0,038
I 129 (Bq/l)	< 0,11	< 0,07
Ru-Rh 106 (Bq/l)	< 0,48	< 0,33
Tritium OBT (Bq/l combustion water)	13,0 +/- 0,9	14,7
Sr 90 (Bq/l)	< 0,28	34 +/- 9
C14 (Bq/kg C)	241 +/- 2,0	237

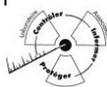
The specific activity of carbon-14 (237 and 241 Bq/kg of carbon) is classic and does not indicate any influence by discharges from the Mayak nuclear site.

On the other hand the following contamination was detected in the cow milk samples:

- **Caesium-137** (24,3 Bq/l in the sample from May 2008, and 0,74 Bq/l in the sample from November 2010)
- **Strontium-90** (34 Bq/l in the sample from May 2008) and
- **Organically bound tritium** (13 to 14,7 Bq/l combustion water).

The two milk samples did not come from the same property. The sample collected in May 2008 by CRIIRAD came from a property where cows had easy access to the highly contaminated banks of the Techa, which explains the transfer of artificial radionuclides to grass and milk. In May 2008, CRIIRAD actually measured a caesium-137 activity of 55'000 Bq/kg wet in the soil from the banks. The sample from November 2010 came from cows that were – according to observations by Greenpeace when collecting the sample – fed on hay.

The two series of sampling and analyzing milk confirm the importance of not neglecting tritium contamination. Tritium is one of the main radionuclides released during reprocessing operations, and one about which official documents of Mayak contain no information.



6 / Conclusions

In its report about the measurements of 2008, CRIIRAD noted:

«If one considers only the cesium-137, strontium-90, and tritium measured in the milk, the annual dose of radiation received from the consumption of one liter of milk per day is 463 microsieverts for an adult resident of Muslymovo and 1013 microsieverts for a small child of 1-2 years.

For small children, then, the simple fact of drinking a liter of milk per day may expose them to an amount of radiation in excess of the maximum permissible annual dose established by the International Commission on Radiological Protection (1000 microsieverts a year).

These dose estimate calculations were based on official risk factors which tend to significantly underestimate actual risk.

The radiological contamination of the natural environment and of the principal food sources (fish, milk) exposes the local population to external radiation and internal contamination.

The resulting doses make protective measures for the inhabitants of Muslymovo indispensable. In fact, these people should have been evacuated a long time ago or at the very least supplied with untainted foodstuffs—especially those most at risk, such as pregnant women and young children. »

The measurements taken from the samples collected by Greenpeace in November 2010 show that the contamination of the Techa River with cesium-137, strontium-90, and tritium had actually increased since CRIIRAD took their samples in the very same locations in May 2008 (by a factor of 2 for strontium-90 and a factor of almost 6 for tritium). Moreover, in November 2010 tritium was also detected in the two controlled wells in Muslymovo.

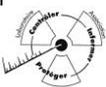
Official documents show that the greater part of the contamination actually reaches the **Techa** through **infiltration from the reservoirs** (of the Techa Cascade) that hold the **radioactive wastes** (type LLW) from the reprocessing plant.

This leakage is further compounded by the current liquid radioactive discharges from the nuclear site because, as the operators admit, the leakage rate of strontium, which is in the hundreds of GBq per year, is directly linked to the water level in the reservoirs, i.e. to the waste water discharged by the industrial site, among other things.

While the contamination of the environment continues all around Mayak, the impact of the radioactive legacy of past accidents alone brings with it such significant exposure to ionizing radiation as to justify the evacuation of the village of Muslymovo.

The documents produced by the people who run Mayak do not fully account for the intensity of this contamination. The levels of radioactivity for certain important radionuclides in the wastes of the nuclear site (both air and water borne) seem⁵ to have been left out. For instance, the impact of certain radionuclides commonly associated with reprocessing (like tritium, carbon-14, krypton-85, or iodine-129) appears to receive no mention; yet these radionuclides have a very long half-life. Therefore, the estimated exposure dose for the population is probably undervalued.

⁵ In order to give more weight to this assertion Greenpeace would need at its disposal all the public documents concerning the impact of the Mayak site as well as an English translation of the annual report for 2009 [MK2009].



7 / The Case for Additional Information

To fully appreciate the evolution of the radioactive wastes at the Mayak industrial site and assess their impact on the environment and human health, additional information from the operators of these nuclear installations and the supervising authority will be needed. A non-exhaustive list of questions that require an answer includes the following:

1 / Detailed data about the **atmospheric and liquid wastes** of all pertinent radioactive and chemical substances

For the radioactive elements, given what one knows about the impact of reprocessing plants, it is necessary to have accurate results concerning, for example: tritium, carbon-14, cobalt-60, krypton-85, technetium-99, antimony-125, ruthenium-rhodium-106, iodine-129, iodine-131, europium-154 and 155, protactinium-233, the uranium isotopes (uranium-232, 234, 236, 235, 238), the trans-uraniens (isotopes of plutonium, neptunium, curium et americium), etc.

2 / Detailed descriptions of the systems implemented to limit both atmospheric and liquid radioactive wastes (including devices for the pre-discharge treatment of liquid wastes).

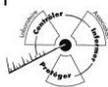
3 / Detailed description of the management circuit for liquid wastes. Chemical composition, monthly volume, radioactivity balance in each reservoir of the Techa cascade, estimate of **monthly flows of radionuclides into the Techa**.

4 / Facts regarding the contamination of the environment by all the radionuclides listed below. These facts should relate to:

- The radioactivity of rare gases, tritium, carbon-14, aerosols, and gaseous halogens in the ambient air.
- Precipitation (rain, snow)
- Bio indicators for atmospheric pollution (lichens, terrestrial mosses)
- Surface layer of soil
- Foodstuffs susceptible to contamination by atmospheric fallout.
- Groundwater
- Surface waters, sediments, samples of aquatic flora and fauna at different levels of the Techa Cascade, in the canals alongside the reservoirs and at points downstream in the Techa, both near and far.
- The soil on the banks of the Techa, the fauna and flora impacted by the contamination of the Techa downriver from the waste cascade.

5 / Detailed description of the models used to evaluate the doses incurred by the people living in the neighborhood of the site (selection of critical groups, transfer parameters, dose coefficients, etc.)

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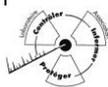
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APPENDIX 1 / Excerpt from note CRIIRAD N°09-102 of September 15, 2009 :

Synthesis of CRIIRAD's role in the shooting of the documentary «Déchets, le cauchemar du nucléaire» / B. Chareyron

Mayak Nuclear Site (Ural, Russia)

The radiometric measurements in situ and the analysis of samples collected by the CRIIRAD laboratory in May 2008 along a 35-kilometer stretch of the River TECHA downstream from the Mayak nuclear site in the Urals and farther downstream in the inhabited village of MUSLYMOVO document the persistence of radiological contamination by various artificial radioactive elements.



Plan of the sampling and measuring sites (CRIIRAD)

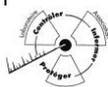
On the river bank gamma radiation levels at ground contact reach 16'000 c/s (at bridge M5 upstream from the village of Muslimovo) and 7500 c/s in the village; these values are, respectively, 160 and 75 times higher than the natural levels of radiation (from 65 to 100 c/s).

On the banks to the right of the village the dose rate is 4,6 μ Sv/h at ground contact and 2,1 μ Sv/h at 1 meter above ground; these values are 15 to 25 times higher than normal.

This contamination probably dates back to the accidents at the Mayak site (including the disaster of 1957) but a contribution from the nuclear installation's current radioactive waste discharges should not be ruled out.

The **soil** sampled by CRIIRAD under the bridge in the course of the shooting is highly contaminated by cesium-137 (183 000 Bq/kg fresh), strontium-90 (2 700 Bq/kg dry) and plutonium (plutonium-239 and plutonium-240: 2 200 Bq/kg dry). These concentrations are such that the soil may be considered as radioactive waste. Note that plutonium is a highly radio-toxic element with a very long half-life (it takes 24,100 years for the radioactivity of plutonium-239 to be reduced by half).

The inhabitants of the village of Muslymovo, some distance downstream, live in contaminated territory. According to CRIIRAD's measurements the soil on the banks of the River Techa is highly contaminated (55 000 Bq/kg) by cesium-137.



The **fish** are contaminated by cesium-137 and strontium-90 (640 and 909 Bq/kg, respectively, for a grand total of more than 1 500 Becquerels per kg of dried fish). The daily consumption of 60 grams of fresh fish adds up to a dose of 370 μ Sv/year for an adult.

Never mind the other radionuclides likely present in the fish as well, such as the tritium measured in the water and the plutonium detected in the soil of the riverbank: merely by eating fish one easily surpasses the 300-microSieverts-threshold recommended by the ICPR (International Commission on Radiological Protection) to limit the health risks caused by exposure to a single nuclear site.

The **milk** collected from a farmer during the shoot was also contaminated by radioactive elements (cesium-137: 24,3 Bq/l; strontium-90: 34 Bq/l; and tritium: 14,7 Bq/l). Note: the cows commonly graze on the banks of the river.

In terms of radioactivity ingested, considering only the cesium-137, strontium-90, and tritium measured in the milk, the annual dose for the consumption of 1 liter of milk per day comes out to 463 micro Sieverts for an adult and 1 013 microSieverts for an infant of 1-2 years.

For a small child, the simple fact of drinking a liter of milk per day means being exposed to an amount of radiation in excess of the maximum permissible annual dose (1 000 microsievarts a year) established by the ICPR.

These dose estimate calculations were based on official risk factors, which tend to significantly underestimate actual risk. The radiological contamination of the natural environment and of the principal food sources (fish, milk) exposes the local population to external radiation and internal contamination. The resulting doses make protective measures for the inhabitants of Muslymovo imperative. In fact, these people should have been evacuated a long time ago or at the very least supplied with untainted foodstuffs—especially those most at risk such as pregnant women and young children.



Russia, contaminated banks of the river Techa
near Muslimovo (CRIIRAD, C Courbon, May 2008)

APPENDIX 2 / Agréments du laboratoire de la CRIIRAD

The CRIIRAD laboratory is accredited by the Nuclear Safety Authority for measurements of radioactivity in the environment. The detailed terms of accreditation are available on the internet site of the Nuclear Safety Authority.

Here is an updated⁶ list:

1 / **Water** matrix: gamma emitters of energy below 100keV and of energy above 100keV (authorization valid until June 30, 2015) and tritium (authorization valid until June 30, 2014).

2 / **Soil** matrix: gamma emitters of energy above 100 keV (authorization valid until July 10, 2011), uranium and descendants, thorium and descendants, Ra 226 and descendants, Ra 228 and descendants (authorization valid until June 30, 2015).

3 / **Biological** matrices: gamma emitters of energy below 100keV and of energy above 100keV (authorization valid until June 30, 2014).

4 / **Gas** matrices: gamma emitters of energy below 100keV and of energy above 100keV and halogenated gases (authorization valid until February 01, 2012).

Moreover, the CRIIRAD laboratory is authorized to take radon measurements in locations open to the public (levels 1 A, 1 B and 2 ; valid until September 15, 2011).

⁶ Detailed list available on the website of the ASN. The list of laboratories accredited to take measurements of radioactivity in the environment, updated on August 1, 2010, with the dates of validity of the respective authorizations was established in conformity with the decree of August 11, 2006 (JO du 24 septembre 2006) and the decisions of the ASN n°2007-DC-023 du 29 janvier 2007, n°2007-DC-0064 du 10 juillet 2007, DEP-0009-2008-PRESIDENT du 28 janvier 2008, DEP-DEU-0544-2008 du 09/07/08, n°2008-DC-0120 du 16 décembre 2008, DEP-DEU-0099-2009 du 06 février 2009, DEP-DEU-0373-2009 du président du 23 juin 2009, DEP-DEU-0704-2009 et DEP-DEU-0705-2009 du 8 décembre 2009, CODEP-DEU-2010-031543, CODEP-DEU-2010-031549 et CODEP-DEU-2010-031551 du 15 juin 2010 (official bulletin of the ASN).

