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EXPERIENCE IN ELIMINATING THE CONSEQUENCES OF THE 1957 ACCIDENT AT THE MAYAK PRODUCTION ASSOCIATION

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IAEA, Vienna, Austria,
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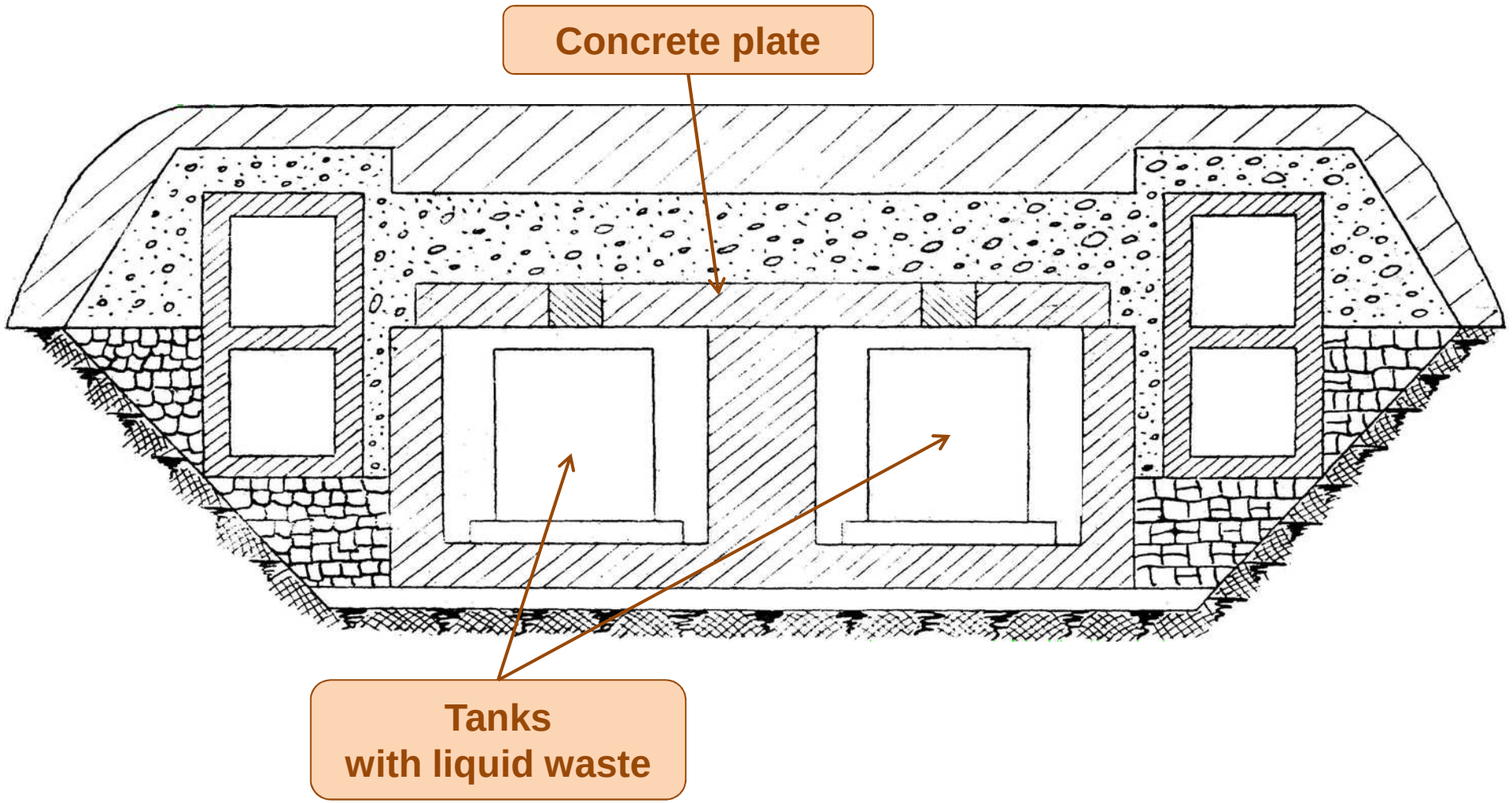
Mayak PA Location

Tank Design for Liquid HLW Storage



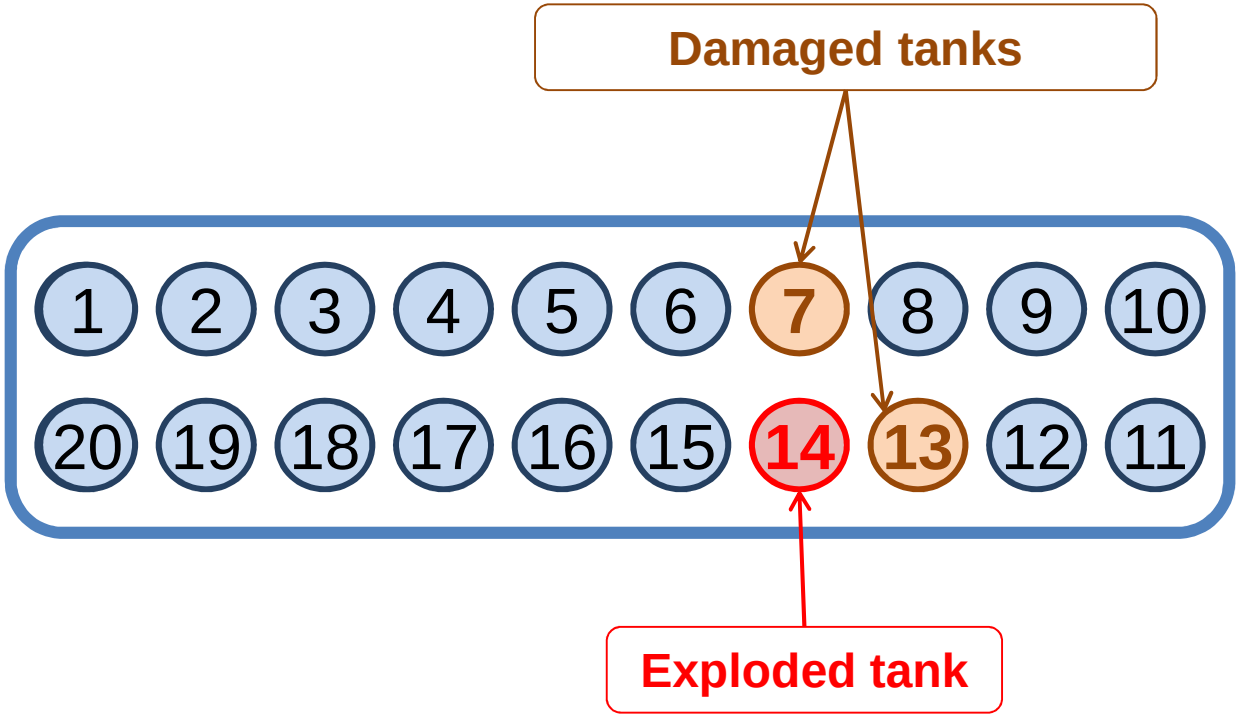
Causes of the Accident

Accident was caused by technical failures coupled with violation of the tank cooling regime following the below described event chain:

- failure of devices monitoring temperature and cooling water level
- cessation of cooling water feed
- evaporation of water out of liquid saline solution followed by formation of dry nitrate and acetate salts
- chemical explosion of the dry residue due to spontaneous ignition

Later on, during laboratory-scale studies with simulators, it was determined that the ignition temperature for the dry residue containing nitrate and acetate salts was 340° C.

Main Consequences of the Explosion for Waste Storage Facility

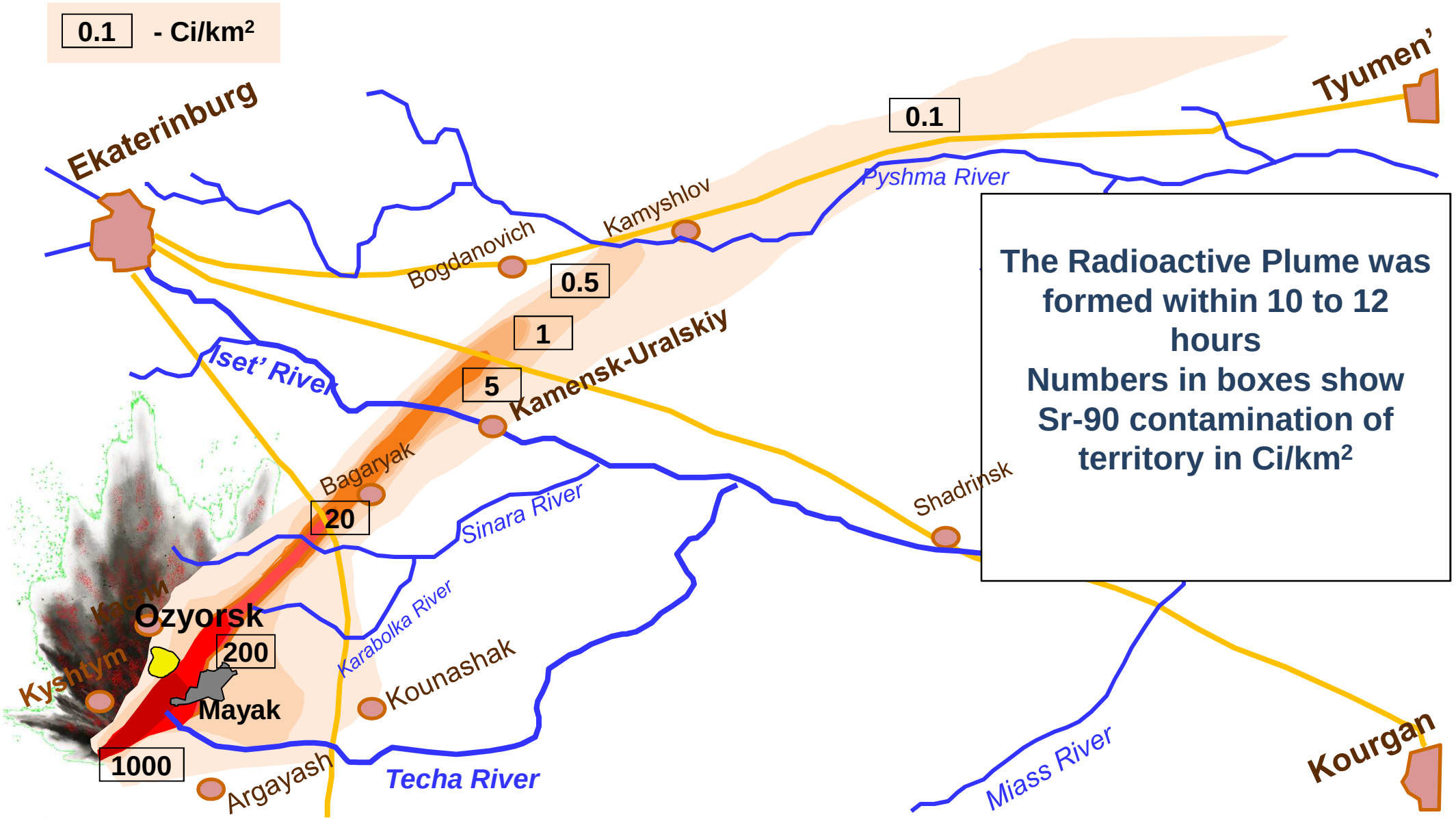


- Tank 14 was completely destroyed
- Overhead covers of neighboring cells 7 and 13 were partially damaged
- Total C-3 cooling system broken
- Buildings, roads, territory, vehicles contaminated
- No deaths

Estimation of Accident Consequences in Terms of Contamination Levels through the Facility Adjacent Areas

- Next day after the accident major consequences were assessed in terms of adjacent areas contamination levels. Radiation measurements were carried out with portable radiometers
- Seven radiation measurements of territory were carried out within the first year after the accident (four with motor vehicles and three with airplanes)

Radiation Accident 1957 (29.09.1957, 16:20 local time) and East Urals Radioactive Trace (EURT) formation



Radiation Parameters
(3 to 5 days after the accident)

Area	Distance to explosion point, km	Exposure dose rate, μR/s
Complex C-3, production site	0.1	100 000
Plant territory, production site	2-3	1 000
Along the Trace axis, outside the production site	12-20	100-300
Ozyorsk (outside the Trace)	10-12	0.1

Radioactive Trace Parameters

Radioactive contamination density (in terms of ^{90}Sr)	Trace parameters		
	Length, km	Width, km	Area, km^2
> 0.1 Ci/km^2	300	30-50	20 000
> 2.0 Ci/km^2	105	8-9	1 000

The contaminated area was named East Urals Radioactive Trace (EURT)

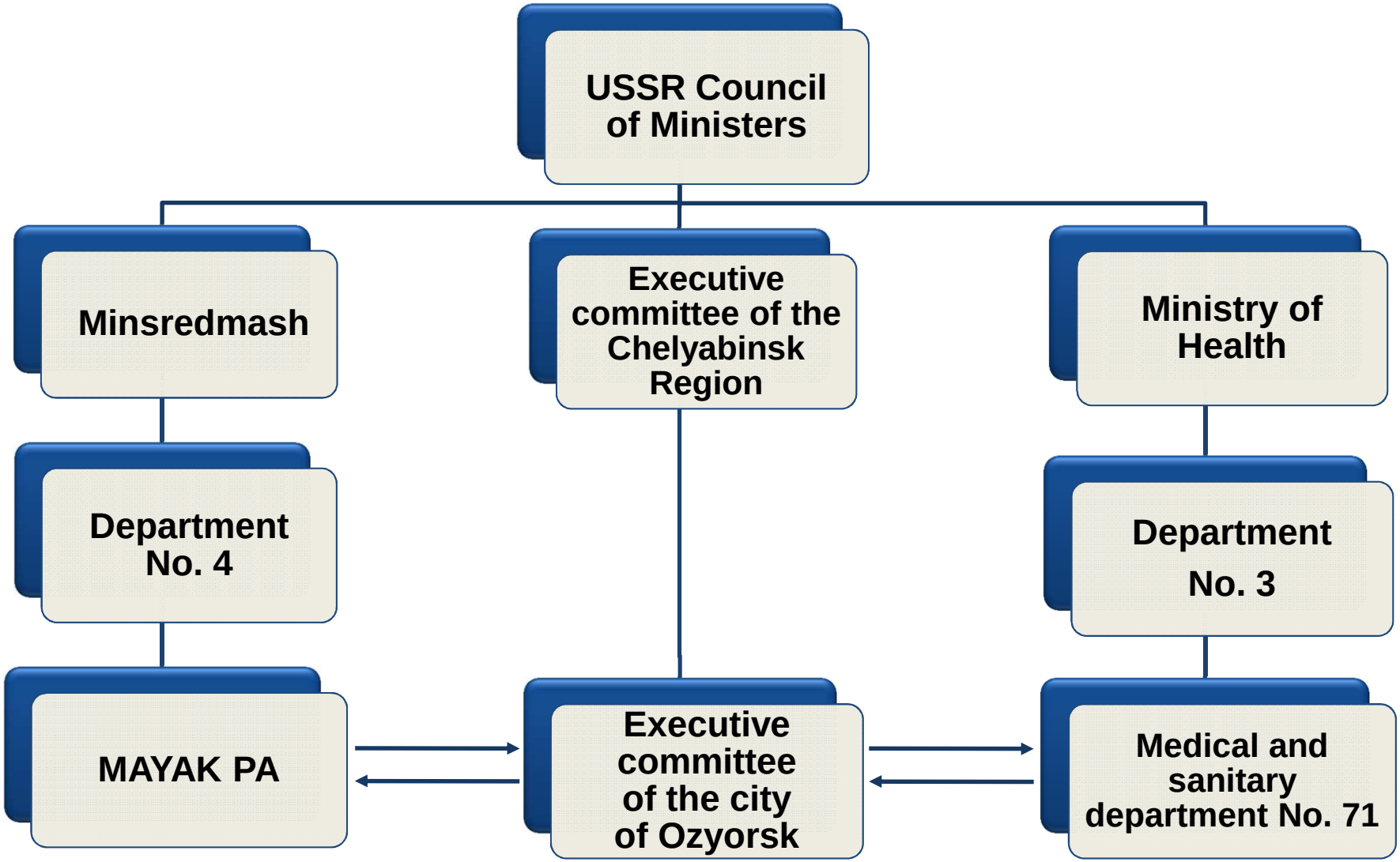
Radionuclide Composition in the Exploded Tank and Activity Inventory within the Trace Territory

Radionuclide	Contribution, %	Activity inventory within the Trace, kCi	
		Within the production site (90%)	Outside the production site (10%)
Ce-144 (+ Pr-144)	65.8	11 800	1 316
Zr-95 (+ Nb-95)	24.8	4 500	496
Sr-90 (+ Y-90)	5.4	490	54
Ru-106 (+ Rh-106)	3.7	670	74
Cs-137 / Ba-137m	0.35	63	7.0
Pu	0.0043	0.77	0.086
Total:	**100**	**18 000**	**2 000**

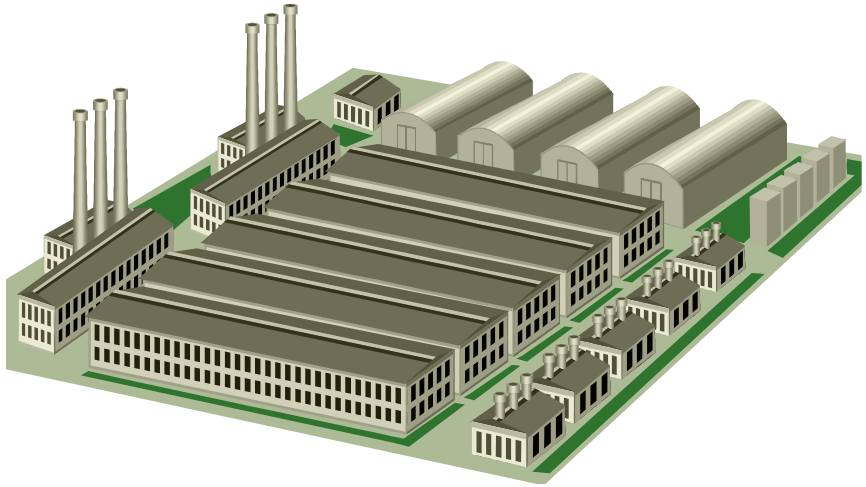
Urgent Management System Aimed at mitigation of the Accident Consequences

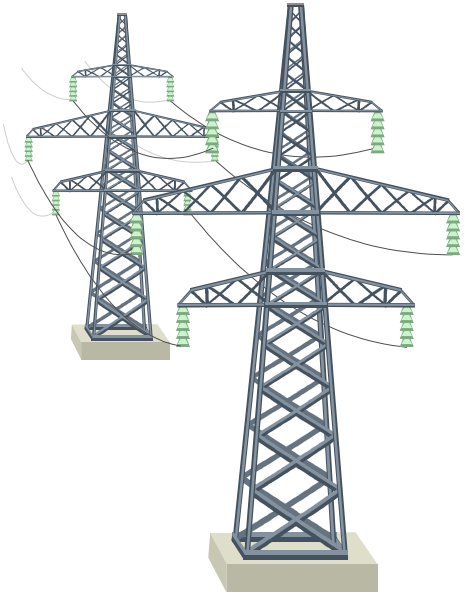
- Right after the accident, the enterprise established an emergency center to deal with the accident consequences. The emergency center consisted of senior management and experts representing the Mayak PA and the Ministry of Medium Machine Building (Minsredmash, currently the Rosatom State Corporation)
- Urgent emergency actions were taken to ease off the accident consequences
- The emergency actions were directly guided by Minsredmash and the Mayak PA senior management and appropriate medical authorities

General guidance and coordination of clean-up actions



Principal First-Priority Actions Planned for Elimination of Accident Consequences





- Restoration of cooling and ventilation systems of the damaged complex C-3
- Ensuring routine production activity of the Mayak
- Maintaining operating conditions of all energy, water and heat supply systems
- Ensuring radiation protection of the population and personnel

Restoration of Ventilation, Cooling and Monitoring Systems of the Damaged Complex

- The Waste storage complex ventilation, cooling and monitoring systems were restored by urgent drilling of special boreholes, in which tubes for water supply and temperature monitoring sensors were installed
- The spots for drilling had been preliminary covered with a protective layer of uncontaminated soil up to 1.5 m thick
- All activities for the complex restoration were completed within 2 to 3 months

Streamlining the Production Activities of the Plant

Within first 2 to 5 days the following measures were taken:

- **additional dosimetric equipment for the dosimetric service was delivered**
- **some work place locations of personnel were changed**
- **changes was provide for some traffic patterns for vehicles**
- **several buildings and facilities were closed**

Decontamination of the Territory in the Accident Area

- Heavily contaminated areas were covered with 1-meter thick soil layer, this decreased dose rate by 100 times and fixed radionuclides
- Less contaminated areas were decontaminated by removing the contaminated soil to the lower parts of the terrain (abandoned construction pits, ditches, etc.)
- About 320,000 m^3 of soil were removed and disposed of

Decontamination of the Concrete and the Asphalt Roads

- Decontamination of the roads was performed by washing them with water
- After cleaning the sides of the roads and the adjacent areas were contaminated considerably worse than before
- To reduce the external radiation the upper soil layer (~10 cm) was removed aside by 25 meters.
- The resultant bank of soil provided additional shielding for the traffic

Decontamination of the Motor Vehicles and the Railway Cars

- Decontamination of the motor vehicles and the railway cars was performed on the basis of the specially developed technique with the use of decontaminating, rinsing and fixing solutions
- Decontamination of the railway was carried out by intense washing of the entire railway track with water. In the most contaminated area the railway bed and the slopes were additionally covered with 10 cm thick soil

Radiation Monitoring of the Workers

- All the activities were performed applying strict radiation monitoring with fixed duration of work. Sometimes the work shift lasted for only 15 to 30 minutes
- With the permissible dose of professional exposure being 0.15 Sv per year at that period of time (or 0.2 mSv per shift), admissions to perform the cleanup activities were granted on the basis of single admissible radiation exposure of 8 to 10 mSv
- Maximum doses of the cleanup workers during 1957-1958 were as high as 0.6-1.2 Sv

Radiation Monitoring of the Population

- Radiometric monitoring of foodstuff was organized in the shops and the canteens. Radiation monitoring of the city area, roads, vehicles, public places, schools, kindergartens and dwellings was carried out
- Contaminated foodstuffs, personal clothes and footwear, banknotes and coins were withdrawn
- Digging of lawns in the city was carried out. Fallen leaves and rubbish were removed
- Special instructions were developed and distributed among the population regarding effectiveness and technique of dwelling decontamination

Radiation remediation of the contaminated territory outside the industrial site

Radiation Protection of the Population

- More than 200 populated areas including several towns and workers' communities was contaminated
- Immediately after the receipt of the radiation monitoring data the USSR Minsredmash took first decision on urgent evacuation of the population inhabiting the area within 23 km from the explosion site with contamination density of more than 2 Ci/km^2 in terms of strontium-90
- Later on the Kyshtym accident of 1957 was ranked as Level 6 of the INES as a serious accident required implementation of the planned countermeasures

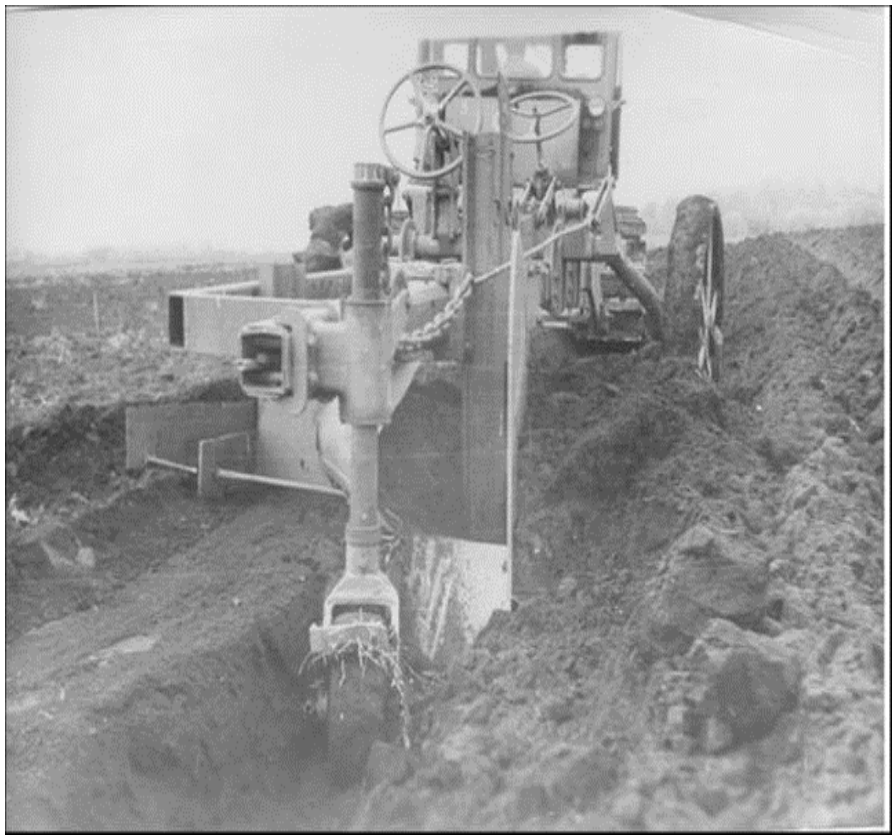
Resettlement of the Population from the Contaminated Territories

- The population of Berdyanish, Satlykovo, Galikaevo and Kirpichiki villages (1,383 persons) were evacuated in 7 to 10 days after the accident
- Local authorities were in charge of the population resettlement
- The people underwent complete decontamination procedure. The entire personal property of the evacuated people was disposed of with full reimbursement of losses from state budget
- A total of 12,763 citizens inhabiting 24 populated areas were resettled during the initial (urgent) and intermediate (scheduled) periods of evacuation

Organization of Scientific Research Center at the EURT (ONIS)

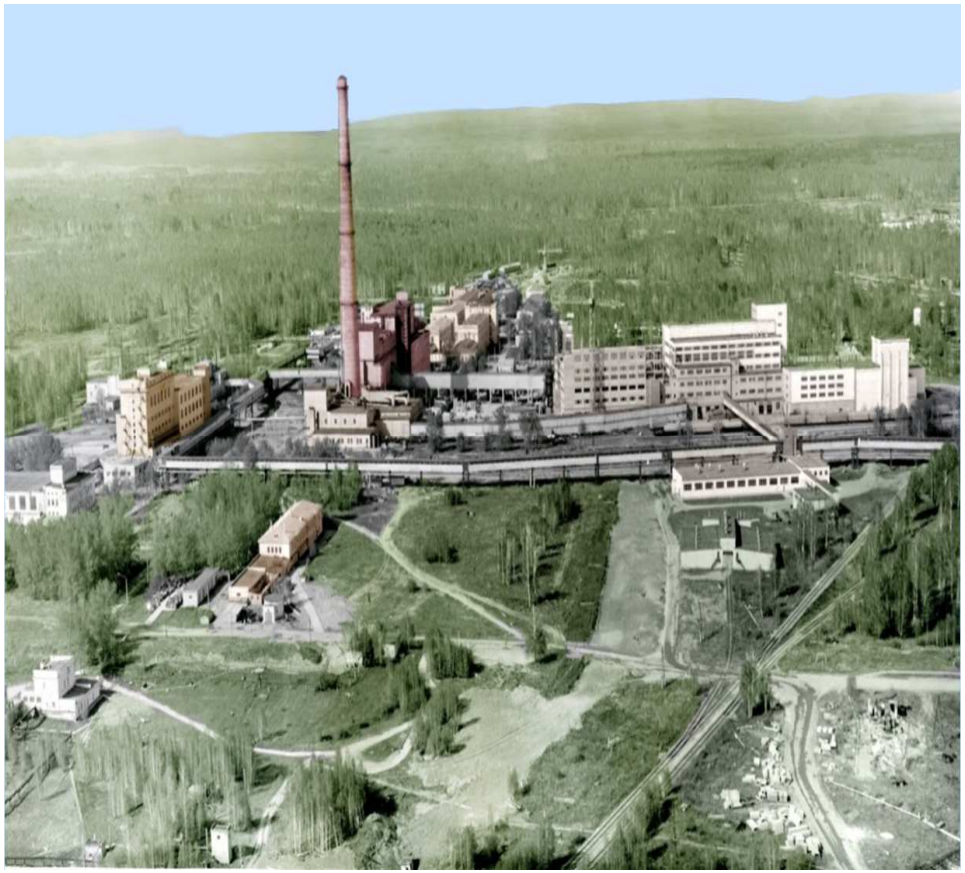
- In 1958 the most contaminated area of the EURT got a special status of “reserve” and the experimental research center (ONIS) was established. The ONIS Center was involved in large-scale scientific research activities
- The ONIS scientists studied problems of radionuclide migration in the environmental objects and within food chains, effects of ionizing radiation on living organisms and their adaptation. They also developed methods of soil decontamination and agricultural techniques for the contaminated territories

Decontamination of the Agricultural Lands (photo made in 1961)



- Systematic recovery of farming production was started in 1961
- The techniques of farming land restoration with the use of special plows were applied. It allowed inverting the upper soil layer with a thickness of 10 to 20 cm to a depth of 1 m

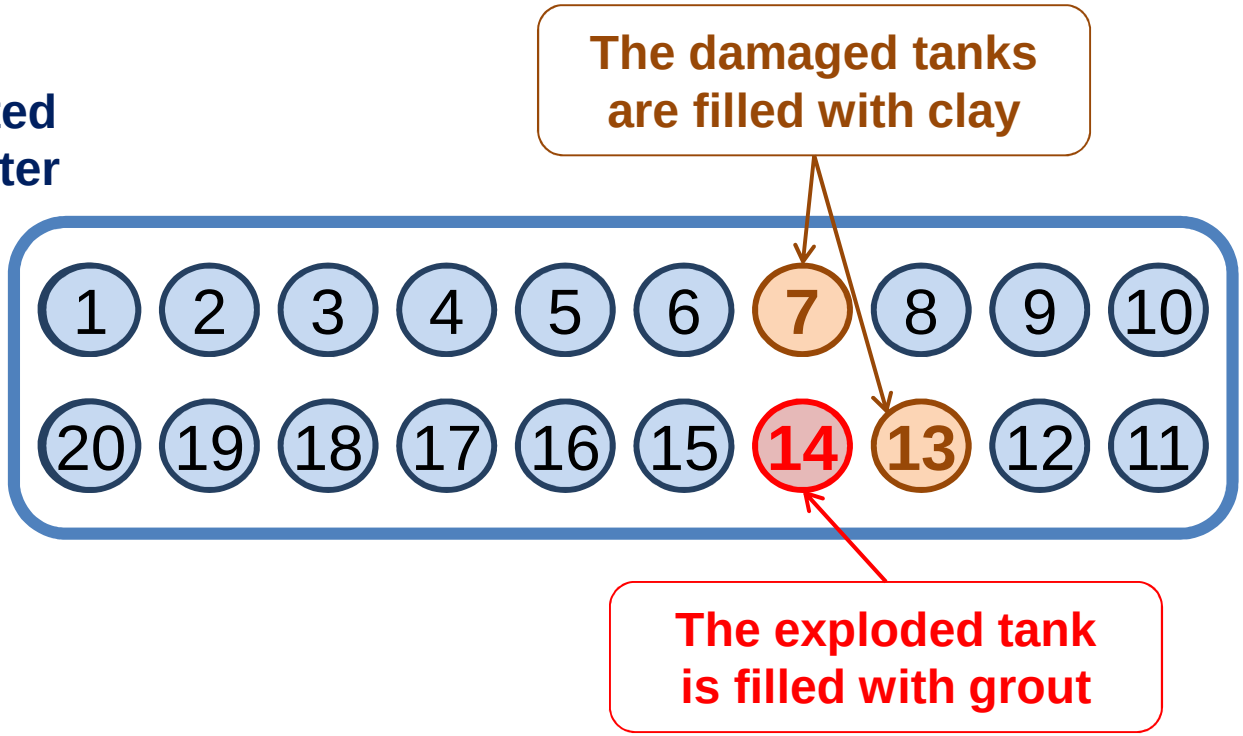
The Operating Radiochemical Plant RT-1



- In 1976 the old military radiochemical plant was reconstructed into the civil radiochemical plant RT-1 for reprocessing of the NPP spent nuclear fuel. The RT-1 plant is designed for operation at least till 2030
- The radiation situation at the plant is normal: average annual dose to the workers are not higher then 2-3 mSv
- Maximum individual dose does not exceed 15 mSv per year

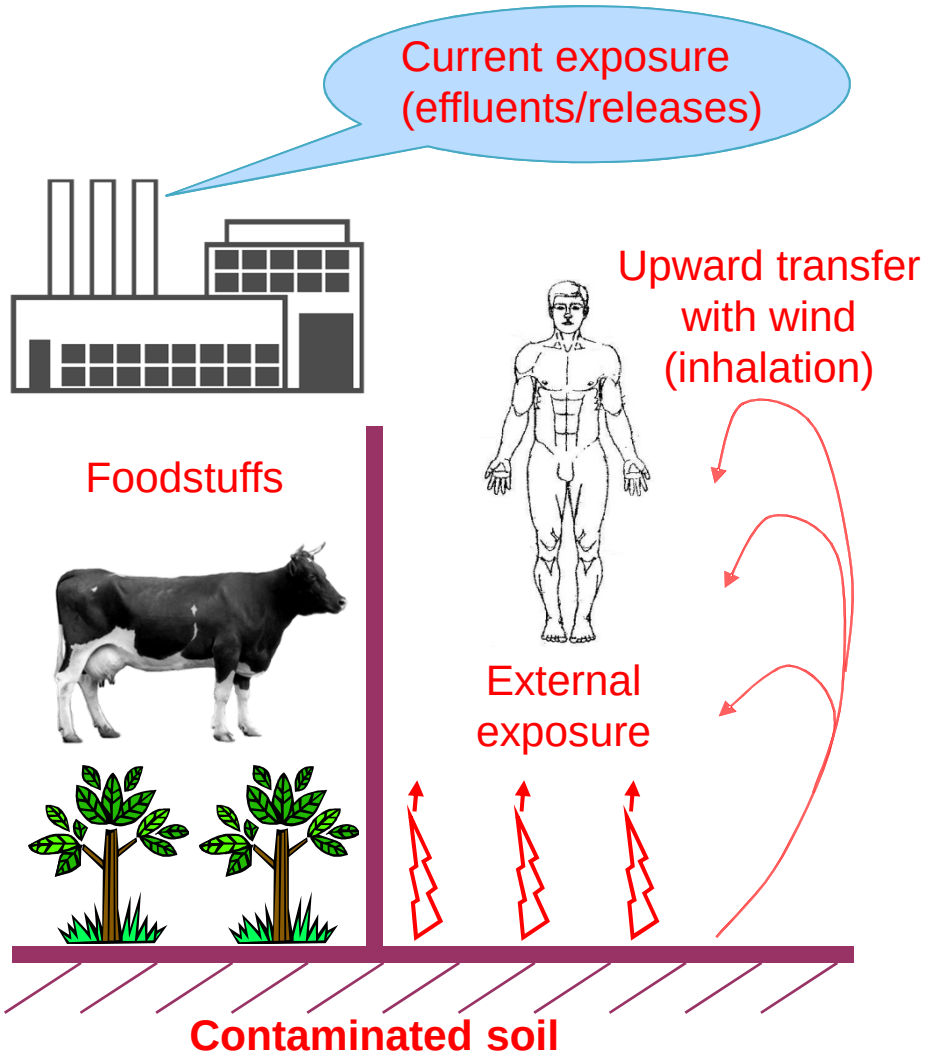
Decontamination of C-3 Waste Storage Complex

All tanks are decontaminated and filled with water



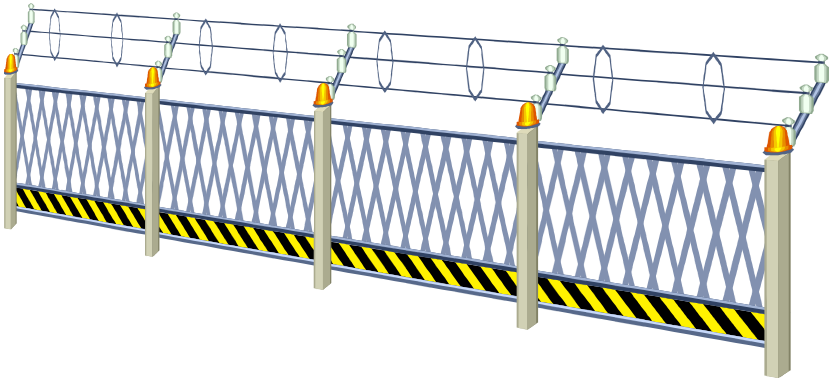
- The damaged C-3 complex was decontaminated, filled with clean water and shut down
- Decommissioning of the C-3 complex and other obsolete buildings and facilities is planned in the framework of the Federal State Program for 2016-2025 years
- All the Mayak PA facilities are operating on the routine basis
- The radioactive contamination and high dose rates of some areas within the plant site remains until now

Current Radiation Situation in the Mayak PA Vicinity



- **Based on the conservative estimates annual individual effective dose of anthropogenic exposure of the population critical group in Ozersk and other populated areas adjacent to the EURT, does not exceed 0.1 mSv**
- **The studies performed in the framework of the SOUL project demonstrated that during the entire period of Ozersk history (1948-2008) the total dose of external exposure from all types of radiation did not exceed 15 mSv**

The Use of the Contaminated Areas



- By 1982 about 87, 000 ha (or 82%) of the lands contaminated during the accident of 1957 were brought back
  to use for agricultural purposes

- The EURT area is isolated, protected from unauthorized entry and used only to perform genetic and general ecological studies

Flora and Fauna in the EURT Area (East-Urals State Reserve)

- Today the flora of EURT Reserve includes about 450 rare species recorded in the Red Data Books of the Russian Federation
- The Reserve is inhabited by 29 bird species recorded in the Red Data Books of the Russian Federation
- The Reserve fauna includes 5 species of amphibians, 4 species of reptiles, 219 bird species and 50 mammal species
- **Radiation exposure did not cause degradation of the ecosystems of the Reserve natural complex**
- Numbers and biodiversity of the Reserve flora and fauna exceed those at the adjacent areas

General Conclusions - Population

- Prompt evacuation (resettlement) of the inhabitants from the contaminated territory was timely carried out
- Conditions for safe residence of the population in the adjacent territories were provided, panic among population was prevented
- Not a single case of chronic or acute radiation disease resulted from the accident among the Mayak workers or the population was recorded
- Radiation situation in the populated areas adjacent to the EURT meets all the sanitary requirements and obviously tends to improve

Safety Relevant Conclusions

- The storage facilities of heat-generating radioactive wastes should always be cooled and monitored. Dry residue of HLW should be fire-safe and explosion-proof
- Mitigation of the consequences of large-scale radiation accidents requires adequate and prompt reaction from the centralized system of emergency response including operating organization (utility), public authority and governmental body
- The operator/utility should be involved in a local radiological survey for urgent decisions on the population resettlement from the contaminated areas. All possible measures should be taken to prevent panic among population
- The “General Plan of Mitigating the Accident” should firstly provide safe operation of the plant and all safety relevant systems in order to not aggravate the consequences of the primary accident

Thank you for your attention!