ECODEFENSE!

RUSSIAN PLUTONIUM PROGRAM: NUCLEAR WASTE, ACCIDENTS, AND SENSELESS HUGE COSTS

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1. Introduction

Plutonium in History

The large-scale extraction of plutonium had been developed by the military industry for the production of nuclear weapons. Over the past 50 years, the world produced about 950 tons of plutonium. This is sufficient to destroy the entire population of the world with no nuclear explosions.

Plutonium, Pu, is an artificial radioactive chemical element, atomic number 94, belongs to the actinides. It was discovered in 1940-41 by American scientists G. Seaborg, E. McMillan, J. Kennedy and A. Valem, who received the isotope ^{238}Pu as a result of irradiation of uranium with heavy hydrogen nuclei, deuterons. The known isotopes of plutonium have mass numbers from 232 to 246. Traces of ^{247}Pu and ^{255}Pu isotopes were found in dust collected after the explosions of thermonuclear bombs. Already by 1958, according to the UN, from eight to ten tons of plutonium were released to the atmosphere.

Among the isotopes of plutonium, the alfa-radioactive ^{239}Pu ($T_{1/2}$ = 2,4×10^{4} years) is the most important one. Nuclei of ^{239}Pu are capable of a fission chain reaction. In the USSR, the first experiments to get ^{239}Pu started in 1943-44 under the supervision of academicians I.V. Kurchatov and V.G. Khlopin. For the first time, plutonium in the Soviet Union was extracted from neutron irradiated uranium in 1945. In very tight deadlines, its properties were extensively studied, and in 1949, the first in the USSR plant for radiochemical plutonium extraction started operating.

Industrial production of ^{239}Pu is based on the interaction of ^{238}U nuclei with neutrons in nuclear reactors. Subsequent isolation of Pu from U, Np and highly radioactive fission products is carried out by radiochemical methods (coprecipitation, extraction, ion exchange, etc.). As a fissile material, ^{239}Pu is used in nuclear reactors and in nuclear and thermonuclear bombs.

Plutonium in Living Organisms

Plutonium in the environment is largely concentrated by marine organisms - its rate of accumulation (ie, the ratio of concentrations in the body and in the environment) for algae is 1000-9000, for plankton (mixed) - around 2300, for clams - up to 380, for sea stars - about 1000, for the muscles, bones, liver and stomach of fish - 5, 570, 200 and 1060, respectively. Terrestrial plants absorb plutonium mainly through the root system and accumulate it to 0.01% of their mass. In human body, plutonium is retained mainly in skeleton and liver, where it, for the most part can't be removed. The most toxic ^{239}Pu is a cause of hemodyscrasia, osteosarcomas, lung cancer. Since the 1970's , the proportion of plutonium in radioactive contamination of the biosphere is increasing (so, plutonium-caused irradiation of marine invertebrates is getting greater than that caused by ^{90}Sr and ^{137}Cs).

Plutonium is one of the most dangerous radioactive substances for human beings. Being released to the biosphere, it interacts in the natural biochemical cycles. Radiation hazard of plutonium is related to its alpha activity, the specific value of which is approximately 200 000 times greater than that of another alpha emitter, uranium-238.

Once inside human body, plutonium remains there forever, killing surrounding tissues with strong ionizing radiation. Even a paltry amount of plutonium can cause severe, even fatal, damage the body. Penetrability of alpha particles is small; they are detained by cloths and skin. However, plutonium can enter the body through respiratory or digestive tracts.

Plutonium that gets inside the body by inhalation partly settles on the surface of lungs and partly passes into blood. Then it gets into bone marrow, lymph nodes, liver and other organs. Alpha-active substance concentrated in a small amount in lung tissue destroys it forming foci of necrosis. This leads, depending on the severity of exposure, to respiratory dysfunctions and cardiopulmonary diseases, in the worst cases, to lung cancer.

Plutonium that enters the body thought the digestive chain (with contaminated food and water) affects mucous tissues of stomach and intestines, causing inflammation, erosion, hemorrhage and malignant tumors. Through the blood stream plutonium enters the liver, as well as surface of bones and bone marrow. Plutonium is mainly deposited in bone tissue (50% or more). It is virtually impossible to remove this plutonium (biological half-life period in the human body is 50-100 years). Alpha-radiation effect on cells located on bone surfaces may lead to periosteum damage (inflammation, necrosis) and other complications, as well as to osteosarcoma, a malignant bone tumor.

Up to 30% of plutonium deposited in the body through the blood will lodge in the liver. The biological half-life for plutonium in the human liver is approximately 20 years. Plutonium in the liver leads to serious dysfunctions up to development of cirrhosis. The half-life period exceeds 400 days. In blood-forming organs, alpha radiation can cause destruction of cell nucleus and DNA, leading to genetic changes of the next generations.

The greatest radiobiological hazard of plutonium for a human being is related to its ability to cause cancerous tumors and genetic changes.

Radiobiological Consequences of Plutonium in a Civil Reactor

The ways plutonium gets inside and affects the body are determined by such factors as type of chemical compound that contains plutonium, particle size, state of the organism and its organs. The most common and dangerous form of plutonium oxide which is produced in the process of spent nuclear fuel reprocessing and in production of mixed uranium-plutonium oxide fuel (MOX-fuel) used in some nuclear power plants. In Russia, plutonium fuel is not yet used on an industrial scale, but the Rosatom state corporation is developing plans to introduce MOX-fuel in some nuclear power plants. In particular, new power units of VVER-1200 type that are already under construction at several nuclear power plants of Russia, are able to use uranium-plutonium fuel (MOX) instead of conventional uranium fuel. In less than 10 years, several such reactors can be put into operation in the European part of Russia, the Urals and Siberia. In particular, the VVER-1200 units are supposed to be constructed at the Leningrad, Novovoronezh, Tver (Kalinin), Central (Kostroma or Yaroslavl), Baltic, Rostov, South Urals, Seversk nuclear power plants. In addition, according to Rosatom senior officials, within 4-5 years the BN-800 unit is expected to start operating at the Beloyarsk nuclear power plant; this unit has been under construction for over 25 years. This reactor will also use the MOX fuel.

According to Rosatom, within the next decade in Russia large-scale production of MOX-fuel is planned to begin, and also several new reactors using such fuel would be constructed. All nuclear plants in regular, accident-free operation emit radioactive waste in gaseous, liquid or solid form. The introduction of MOX fuel at Russia's nuclear power plant will inevitably lead to the fact that in the radioactive waste would contain [additional] particles of plutonium which will be regularly released into the environment, and then spread around uncontrollably. Also, in case of accidents at nuclear power plants using MOX, the amount of plutonium released from the reactor into the environment, may increase.

Plutonium tends to accumulate in the surface layers of soil. The danger posed by plutonium is redoubled by the fact that it is extremely hard to detect outside specially equipped laboratories, and is even more difficult to detect in the human body. As for the maximum permissible concentration of plutonium in the body, "one gram of reactor plutonium oxide corresponds to an annual inhalation exposure limit for 40 million people ... the maximum permissible amount of plutonium entering through the respiratory system is equal to one billionth gram (0.000000001 g) for the average person”. [6].

This report represents some basic information about most of nuclear power facilities in Russia which are involved in the Rosatom’s plutonium program. Among other things, it provides information about accidents at nuclear power plants and nuclear fuel cycle facilities which Rosatom brings as examples to the international arena calling them “absolutely safe". From the perspective of the report's authors, the gathered data clearly indicates that the use of MOX-fuel on an industrial scale at Russian nuclear power plants will lead to a surge of accidents and rapid increase of plutonium spread into the environment. This will create a massive threat to public health, and bring the problem of radioactive pollution of the environment to a new level. Russia's public services are not ready to clean up plutonium contamination, lacking trained personnel and large funds needed for plutonium monitoring which is an extremely expensive and technically challenging task.

Another serious concern is plutonium fuel transportation safety. In recent years, railway accidents are a regular occurance in Russia, and the radioactive freights are poorly protected. For example, at protest actions against the import of radioactive waste to Russia in 2007-2009, environmental activists in St. Petersburg have repeatedly come close to the containers with uranium "tails" coming from Europe. Given that under Russia's plutonium program, MOX-fuel containing weapons-grade plutonium which can be used for a nuclear bomb is expected to be transported over long distances, weak protection (risk of theft and terrorist attacks) as well as poor quality of Russian railways (risk of accidents) raise serious concerns.

Russia is not ready for large-scale production and use of plutonium fuel for nuclear power plants. In the current situation, the plutonium program is an adventure that could have a devastating impact on the environment and health of many generations of Russians.

2. Nuclear Reactors Research Institute (Dimitrovgrad, Ulyanovsk region)

2.1. History. Subdivisions

Nuclear Reactors Research Institute (NRRI) is located nearby Dimitrovgrad of Ulyanovsk region and was established in 1956. It was that time when, in accordance with a resolution of the USSR Council of Ministers, the construction of a pilot plant to test new research and experimental reactors began. Three years later, July 21, 1959, the government adopted the resolution "On production of experimental nuclear reactors and the development of the reactor research of the General Directorate for Atomic Energy under the Council of Ministers of the USSR," in accordance with which the pilot plant was named the Nuclear Reactors Research Institute.

One of the first large objects of the Institute, the SM-2 interneurone reactor, came into operation in October 1961. It is supposed to irradiate samples of reactor materials, study the properties of materials under irradiation of transuranic elements. In particular, “in this reactor with a very high neutron flux density, it is possible to investigate the behavior of ceramic and metal fuels based on uranium and plutonium at high burnup subject to design, technological effectiveness of fuel and its heat intensity” [28].

December 20, 1965, the VK-50 reactor was launched at the designed capacity in the Institute. It was a boiling water type with the water natural circulation contour inside the reactor vessel. In December 1988, the material research reactor, MIR, came into operation. “It is a heterogeneous thermal reactor of channel type, immersed in a water pool. It is designed to test fuel elements of the planned reactors” [28].

Studies in the field of materials science and radiochemistry are conducted in specially constructed buildings of the Institute. A laboratory for radioactive materials research was opened in January 1964. The Radiochemical Department began work with radioactive products in 1965.

In early 1969, physical launch of the BOR-60 fast neutron reactor with designed thermal power of 60 MW took place in the Institute, followed by its power-producing launch in December 1969.

In 2008, the Institute has been transformed into a joint-stock company State Scientific Center – Nuclear Reactors Research Institute and became a part of Atomenergoprom company with 100% state capital. At present, according to information from the Institute’s official Internet-site, it is considered to be “the largest research experimental complex of civil nuclear energy sector in Russia. The Institute has 6 research nuclear reactors operating, the Europe's largest complex for post-irradiation research of commercial reactor core elements, a complex of facilities for research and development on nuclear fuel cycle, a radiochemical plant, and a radioactive waste treatment system.”

The designed lifetime period for the majority of reactors currently operating in the Institute since 1960’s has been expired. However, lifetime of some facilities has been extended; and there are plans to extend the deadlines further. Thus, for the BOR-60 fast neutron reactor lifetime period has been extended until 2010. According to the Director General Alexander Bychkov, management of the Institute “is actively working to extend the operation until 2015 ... Representatives of the company do not exclude that “the BOR-60 would be required to operate for another year or two after 2015” [5].

A similar situation arises with respect to other reactors operating in the Institute for more than forty years – for some of them, lifetime period has been extended repeatedly.

2.2. Accidents and Incidents

According to official sources, “radiation monitoring data suggest that the exploitation of nuclear power plants is safe for the Institute personnel and the surrounding population” [2]. Nevertheless, information available in open sources refutes such assertions. It is known that in 1977, “at the MIR-M1 reactor (NRRI), fuel assemblies meltdown occurred in the reactor loop, resulting in leakage of the loop channel, contamination of premises, and damage to the reactor stacking"; as well as that, “on 17.07.1994, at the VC-50 reactor (NRRI) a case of exceeding the limit of activity of iodine-131 daily release in 1.7 times (5.65 mKu / day at MPE 3.3 mKu / day) took place due to leakage in fuel assemblies and shutdown of the radioactivity suppression installation at the reactor maintenance shutdown" [21].

January 31, 1996, a radioactive gas-vapor mixture was relesed in the atmosphere at the reactor VK-50. Information has become public thanks to an employee of the Federal Nuclear Regulatory Authority (GAN) local office who witnessed a vapor cloud escaping the reactor building. Next morning, the Institute was forced to hold a press conference, after which journalists were allowed access to the incident site, the VK-50 reactor building, including the radioactive traces in residue from the gas-vapor mixture. At that time, devices showed up to 485 microroentgens per hour, while the day before the exposure dose was about 11 thousand mcR/h, which is about a thousand times higher than background reading [30]. But no division of the Institute interrupted work time even after the accident. The Institute leaders claimed there was no need to stop operation and evacuate people.

The Dimitrovgrad GAN investigating committee found that the accident at the reactor VK-50 was due in part to “weakening of the technical discipline and neglect of maintenance duties of the staff ” [31]. Nearly 4 tons of radioactive steam-gas mixture were released to the atmosphere. No Nuclear center personnel were disciplined or received serious punishment.

The next summer, increased atmospheric release of radioactive iodine-131 occurred at the MIR reactor, and lasted for three weeks! The permissible emission limit for this radioactive substance which is dangerous to the thyroid gland, was exceeded by 15-20 times on some days. No information about the incident and radiation protection measures for the population were circulated. [33].

Ulyanovsk region is a zone of stable iodine deficiency; that is why radioactive iodine-131 is particularly dangerous there. Although incidents occur regularly in the Institute, proper measures to protect the inhabitants of the city of Dimitrovgrad and neighboring settlements are not taken. Most people do not know how to fight iodine deficiency, or how to take iodine preventive measures in the case of the increased release, nor were they provided with the means for such measures. At the same time, the extension of the Institute operation is planned which would increase emissions of iodine-131.

Underground Repository for Liquid Radioactive Waste

The repository began operating with the launch of “a pilot plant in 1966; up to 500 cubic meters of liquid radioactive waste a day had been removed underground” [46]. Later, amounts of liquid radioactive waste dumped underground increased. To date, it is nearly 3 million cubic meters [32].

Representatives of the nuclear agency offer assurances that the repository does not pose any danger to the environment. Some Institute’s officials sometimes even say that the repository “can serve as an example of successful placement of radioactive waste in permeable strata, and selection of a site for removal of waste unsafe for human from the surface" [13]. However, there are grounds to argue that the negative facts about the repository are withheld and kept unpublished.

Liquid radioactive waste is dumped to aquiferous layers. No expert can say precisely what the trajectory of water carrying radioactive substances will be. There is an assumption that "possible area of dumped radioactive waste unloading can be Zhiguli village, 140 kilometers away from the site". [32]. According to Center for Support of Civil Initiatives, a local nongovernmental organization, waste dumped to a great depth has already infiltrated to the upper aquiferous system (referred to as the fourth one in the repository documentation). Recently, liquid radioactive waste was pumped to a lower depth than before. Geologic layers under which liquid radioactive waste is pumped under high pressure, have proved to be unreliable, despite claims of designers.

Insecurity of the Institute repository is confirmed by studies carried out by organizations independent from the atomic agency. In particular, "a research carried out by the Research Institute for Geology and Ore in Kazan on interpretation of space images in the repository area discovered a dense network of relief faults related by deep cracks. In this regard, experts say that by cutting the sedimentary rocks, these faults may well contribute to the vertical migration of liquid radioactive waste. The researchers also presented a map which indicates two tectonic faults intersecting near the NRRI repository. Moreover, one of the faults crosses the Cheremshansky Gulf of the Volga River. According to Kazan specialists, it is in this place where dumped radioactive waste is likely to be already coming out from the deep layers, contaminating the Volga". [32]. Along with that, "underground water supply source ... for the western part of a town of about 50 thousand population operates in 2-2.5 kilometers from the repository" [34].

It is known that the direct disposal of liquid radioactive waste is more dangerous than of solid one. The 1996 IAEA recommendations also reflect the global trend to ban dumping of liquid radioactive waste [40]. Unfortunately, this has not led to a change in current NRRI practice.

2.3. Utilization of Plutonium

The first studies on the use of plutonium as a component of fuel for fast neutron reactors started in the Institute about 40 years ago. At that period an automated line for production of fuel elements with the mixed uranium-plutonium fuel, formerly called the Eagle installation, was designed and installed in a specially constructed building. According to the bulletin of the Minatom's Center of Public Information on Atomic Energy, "Creating the Eagle installation … began in 1969 in the GDR. Development of equipment for all four complexes of the Eagle installation was done at the GDR Academy of Sciences Central Institute for Nuclear Research. The special building to refine the technology for manufacturing nuclear fuel elements made from vibration compacted uranium fuel was constructed in this academic institution."

The German side has worked only with simulators of plutonium. It was shown that potent heterogeneity in the distribution of nuclear fuel in the vibration compacted fuel can occur along the length of a fuel element. After that, the work continued at the NRRI, with use of plutonium.

Thus, "with the participation of the GDR specialists the work of the complex was regulated, and the BOR-60 reactor core was constructed. Then the installation was reconstructed, and the work proceeded without German specialists; fuel elements and fuel assemblies were manufactured using the vibration compacted uranium-plutonium fuel, and the BOR-60 reactor was subsequently loaded with them" [7].

In addition, since the 1970's the NRRI, in conjunction with other institutions, developed an approach to utilization and recycling of plutonium of different quality for fast reactors, based on two technologies: pyroelectrochemical (for reprocessing in molten salt for the manufacture of MOX-fuel) and vibration compaction (for manufacturing of fuel elements for fast reactors). These technologies were later used by the NRRI for mixed uranium-plutonium fuel produced from weapon-grade plutonium and designed for fast reactors.

In his speech at the First International Energy Forum JNC "Energy Supply and Environment in the XXI century" in 1999, Director of NRRI A.F. Grachev reported that the scheme of pyrochemical reprocessing of the plutonium alloy allows produce either PuO2 powder or mixed oxide fuel. This particular characteristic of the process made it easy to adapt it to the task of military plutonium disposal [12].

For the last decade, MOX-fuel production has been considered by the Institute leaders as the most promising prospect for big financial benefits. This is particularly so for work on the use of weapons-grade plutonium in MOX-fuel pellets, covered by the framework of the intergovernmental agreements on utilization of weapons-grade plutonium that has been officially declared to be surplus in Russia and the USA - 34 tons on each side.

The task that NRRI is supposed to undertake, according to the director of NRRI A.F. Grachev, includes the development of the tablet MOX-fuel technology, which could in future be delivered to the plant, and research on licensing of this fuel for the VVER reactors. Undoubtedly, the most important sections of the planned work is safety, environmental issues, accounting and control of the material balance of plutonium, and many others that will be addressed in accordance with existing legislation and regulation. The work will start with that point if financing is determined" [6]. However, the development of the tablet MOX-fuel technology for the VVER reactors has not been deployed in the planned large scale due to lack of funding.

In 1999, in his interview to Rossiyskaya Gazeta, director Grachev claimed that the Institute "managed to find a mode of one hundred percent of plutonium burnout in fast reactors. This is the know-how". [37] But it turned out that this information was false. At the BOR-60 reactor, it was additional generation of plutonium instead of "one hundred percent of plutonium burnout" due to, in particular, the so-called "reproducing" screen.

In his response to the request of local environmentalists, Grachev said that in his interview to Rossiyskaya Gazeta he "was not talking about one hundred percent of plutonium burnout in fast reactors, but, apparently, about the possibilities for the closed fuel cycle; a correspondent interpreted this in his own way, and this interpretation is wrong" [35].

When fuel for fast breeder reactors was produced at the NRRI, a large amount of plutonium was handled in this process. Thus, the present NRRI CEO A.V. Bychkov said in an interview: "... for all the time we produced about 7 tons of fuel for the BOR-60, BN-600, BN-350, BFS, and of this number about 4 tons was MOX fuel" [5]. He also mentioned the volume of weapons-grade plutonium used by the NRRI for MOX-fuel production: "In the 1990-ies, of course, there was a strong decline, but nevertheless, we managed ... to adapt this technology to weapons-grade plutonium. Mikhailov gave us then 50 kg of real weapons-grade metal plutonium, and Evgeny Adamov gave another 100 kg, and from it we made a number of fuel assemblies for the BOR-60 and a series of experimental fuel assemblies for the BN-600" [5].

Recently, the NRRI leaders are making active efforts to launch production of vibration compacted MOX-fuel and use it in the BOR-60 reactors at the Institute and in the BN-600 at the Beloyarsk nuclear power plant.

"... The negative side of technology proposed by the NRRI is that the radioactive waste generated at reprocessing, though quantitatively much less than in other technologies, and qualitatively is secure, but still it is ... In the salt cycle, the value is 200 grams of salt per 1 kg of plutonium or 200 kg per 1 t. In terms of volumes, it is 100 liters." [35]. Nevertheless, the leadership of the nuclear industry does not respond to one of the most important questions - about the future of waste. Where will it be stored, where it will be disposed, how much will the entire cycle of further treatment with it cost?

A particular issue is the competitiveness of plutonium energy comparing to the uranium cycle. Here is the NRRI attitude: "With regard to the cost of kilowatt-hours of electricity with the use of weapons-grade plutonium, everything is determined by position of the government, the owner of weapons-grade plutonium, toward this product. If weapons-grade plutonium is considered as raw materials at its production cost, a kilowatt-hour is surely more expensive the one generated with the traditional uranium fuel, as plutonium does not exist in the nature and its production is costly. And if weapons-grade plutonium is viewed as a harmful product that actually exists in the world in large quantities, which the cost of storing alone is increasing with time, and which we have to get rid of for safety reasons, then its cost should be minimized. Then, the cost of kilowatt-hour can be lower than that of uranium fuel. Now, when research on weapons-grade plutonium utilization is being carried out, there are no regulations to set the cost of plutonium to be used in MOX-fuel in our country. At the stage of its industrial utilization, it will be certainly done" [35].

It's obvious that technologies associated with the MOX-fuel are designed not only for disposal of surplus weapons-grade plutonium owned by the United States and Russia. When weapons-grade plutonium is over, they will use plutonium extracted by reprocessing of spent nuclear fuel since the nuclear industry is planning further use of MOX-fuel in civilian reactors to generate electricity. So, a fair approach is the first one, which considers the production cost of plutonium as a raw material for electricity production. Thus, with equal approach to cost estimation, plutonium energy is economically infeasible, and it is recognized by the nuclear industry. However, the plutonium program is being developed.

The NRRI initiated activities on expanding the MOX production for fast reactors using vibration compaction technology. Speaking to the Dimitrovgrad newspaper December 31, 2008, the Institute CEO A.V. Bychkov said that "... construction of the facility is scheduled for next year, and will also continue in 2010. And its launch is scheduled for January 2011."

The institute has also planned to build a new fast reactor, named the MBIR, which stands for a multi-purpose fast research reactor. According to the NRRI, it would not be an exact copy of the BOR-60. If you define it in a simplified comparison with Russia's research reactors, it is a kind of mix of the BOR-60 and the MIR reactor – a sodium reactor with a number of loop installations. This reactor is supposed for a wide range of research, for example, with heavy coolant (lead, lead-bismuth), with helium, etc. The loops of the new reactor would be designed to create the same conditions as in water reactors with a thermal neutron spectrum.

A.V. Bychkov notes that "the new reactor should start operating in a closed fuel cycle straight away. The NRRI has a large stock of the BOR-60 reactor irradiated fuel based on highly enriched uranium and of MOX-fuel, and pilot plants to reprocess such fuel ... By the new reactor launch, they must be ready for regular operation" [5].

3. Beloyarsk Nuclear Power Plant (Zarechny, Sverdlovsk region)

3.1. History. Subdivisions

Beloyarsk Nuclear Power Plant (BNPP) started operation in 1964 and is located 38 km from the eastern border of Yekaterinburg (Sverdlovsk region) in Zarechny municipality. The plant uses the Beloyarsk Reservoir, which was formed by regulation of the Pyshma River (the Ob basin) as a cooling water body.

The Scientific Research and Design Institute for Experimental Engineering Sverdlovsk Branch (SF NIKIET) which has the IVV-2M research reactor, of 15 MW capacity, is located by the BNPP site.

The Beloyarsk NPP is the only Russiaian plant with units of different types, at which experimental engineering solutions for nuclear energy have been tried.

At the moment, the Beloyarsk NPP has three units: AMB-100, AMB-200, BN-600. The first unit AMB (Atom Peaceful Large) of 100 MW was put on line on April 26, 1964, exactly 22 years before the Chernobyl tragedy. Unit 2 of 200 MW with a single circuit was launched on December 29, 1967. The first two reactors of the BNPP operated for 17 and 21 years respectively and were stopped "in relation to non-compensable deviations from safety regulations" in 1981 and 1989.

The only currently operating reactor at the BNPP is the BN-600. Preliminary specifications for the BN-600 reactor development were prepared in 1963, and in 1980 the unit started commercial operation.

The BN ("Fast Neutrons") type is an experimental nuclear energy technology. Fast neutron reactors are also called breeders. Breeder reactors can produce plutonium.

The BN-600 is the only operating commercial breeder reactor in the world. All similar units in the western countries stopped their commercial operation long before their designed lifetime period was expired due to economic, safety and technical reasons.

The BN-600 uses liquid metal coolant. Sodium is used as a coolant in its first and second circuits, and the third circuit is water-steam with an intermediate (sodium) overheating of steam. The BN reactor core is very much different from the cores of thermal reactors. The main feature of the breeder reactor is that in its core a process of nuclear fission by fast neutrons is accompanied by a much higher yield (by 20-27%) of secondary neutrons than in thermal reactors.

3.2. Safety issues. Accidents and incidents

The BN-600 reactor was designed without taking into account the requirements of the contemporary safety regulations. It does not ensure the independence of control channels and power supply systems, nor equipment of a number of components of the first circuit with safety containment in the event of a leak of sodium.
One of the serious problems of the BN-600 operation is a possible leak of sodium. There were 27 leaks at the unit, five of them occurred in systems with radioactive sodium, 14 were accompanied by burning of sodium, and five were caused by improper maintenance or repair operations or by the unit input/output operations. Amount of the leaked sodium was in different cases from 0.1 to 1000 kg with an average weight of 2 kg.

The BN-600 unit has a number of non-compliances to the General Terms on Safety of Nuclear Power Plants (OPB-88/97):

- During designing and construction of the unit the BNPP site belonged to non-seismic zone, therefore, calculations to confirm its functioning in cases of earthquakes above certain levels were not done for all its systems and elements. This increases risk of accidents because the seismic impact to the increased intensity can cause possible failure of elements of the third circuit that is involved in unit shut-down cooling.

- The existing ionizing radiation measurement network does not allow control all the areas of the sanitary protection zone and the surveillance zone. Evaluation and prediction of the radiation situation in the surrounding areas in case of both the designed and the beyond design-basis accidents cannot provide a full assessment of radiation impact on the population in all areas of the sanitary protection zone and surveillance zone [20].

The most serious incidents at the Beloyarsk NPP:

• From 1964 to 1979 disintegration of fuel assemblies repeatedly occurred in the first unit core. In 1977, a half of fuel assemblies melted down in the second unit core. Repairs took about a year. December 31, 1978, a fire occurred at the second unit. The fire was caused by the floor slab in the machine room falling on the turbo-generator oil tank. The entire control cable burned out. The reactor was left without control systems. Eight people got irradiated during emergency cooling water supply operations.

• January 21, 1987, accident occurred at the BN-600 reactor: in result of exceeding the permissible operating temperature in the reactor core a massive break of fuel elements hermeticity happened. This led to the release of radioactivity with total activity of about 100 thousand Ci. By all its characteristics it was a 4 level accident by the INES.

• In August 1992, the expedition of the State Chernobyl Committee of Russia in the Beloyarsk NPP area found anomalous concentration of cesium-137 and cobalt-60. Maximum radiation was registered at about 1200 mcR/h and formed mainly by radiation of cobalt-60.

• December 22, 1992, due to personal negligence of staff a liquid radioactive waste storage pumps service room was flooded. Water reached soil under the storage, and then, by special drainage network, the cooling pond. Total amount of liquid radioactive waste leaked was about 15 m3 with total activity of 6 Ku. The total activity of cesium-137 entered the cooling pond, about 6 mKu. This incident was assigned to the 3rd level on the INES.

• January 29, 1993, due to the increased number of failures in the technological process at the Beloyarsk NPP the sanitary-protective zone of the plant was expanded. Its radius has grown from 8 to 30 kilometers and became equal to the size of the Chernobyl zone.

• October 7, 1993, at 11:19 am, the third unit of Beloyarsk NPP was stopped on the grounds of the increased radiation background in the ventilation system. The reason was a coolant leak in one of the auxiliary systems. Also, according to director of the plant, there was a small fire. The incident was rated a 1st level on the INES.

• June 6, 1994, during the major repair non-radioactive sodium leaked from the second circuit, causing the fire. The plant personnel was unable to manage the situation on its own and called the fire brigade. The brigade also did not have means extinguish sodium. Once the leak was stopped the released sodium burned out, and the fire stopped by itself.

• In 1995, radiation levels in groundwater under the liquid radioactive waste storage was found to exceed the allowable concentrations of cesium-137 by 1.2-4.4 times and of strontium-90 by 1.8 -11.5 times at the Beloyarsk NPP.

• June 9, 1999, one of the three turbo-generators was shut down because of the risk of ignition of the turbine. There was an alarm system signal. Two other generators were shut down automatically.

• September 9, 2000, due to personnel errors an accident occurred in the Sverdlovenergo power grid that supplies the plant with electricity the station. In result the Beloyarsk nuclear power plant was disconnected from the power supply. 3 seconds later the BN-600 reactor was shut down by emergency system. As a result, the plant's capacity reduced to 0. The station was de-energized for 9 minutes. Emergency situation of this kind is not described in the special instructions. According to independent experts, the BNPP was only a few minutes away from a disaster comparable with Chernobyl .

• July 9, 2007, one of the three BNPP power generators was cut off in result of a lightning hit to the overhead power line.

• In June 2008, due to some faults of one of the main circulating pump system the reactor capacity was reduced from 600 to 400 MW. In result, one of loops in which the coolant circulates was automatically shut down.

Operation of the Beloyarsk nuclear power plant has left its long term traces in the region:

The accumulation of radionuclides and their release to the environment

Even an accident-free operating nuclear power plant emits dangerous isotopes. Radioactive substances go from nuclear power plants to the environment by air and with water. There is a constant radionuclide contamination of vast areas around the BNPP going on. According to official information, aerosol emissions from the nuclear power plant do not occur. However, monitoring conducted by independent experts has shown an increase of cesium-137 content in arable soils on the leeward side at a distance of 50 km from the NPP. Plutonium (not a natural substance) was found in forested parts 3 km outside the sanitary protection zone. The density of plutonium-239 contamination exceeded the background values by 5.1 times (36 Bk/m2), at a distance of 5 km - by 3.5 times, 10 km - by 3.2 times. In other words, the closer to the plant the more contamination.

The highest density of contamination is found near the landing of the emissions plume, on the leeward side. In 1998, concentration in arable soils of Yekaterinburg exceeded the background by 1.5-2 times. According to the Institute of Geophysics of the Russian Academy of Science Ural Department, "background pollution of the Ural region in the vicinity of Yekaterinburg with radioactive isotope cesium-137 has been repeatedly detected. The level of cesium-137 fallout in some places has been 2-2.5 times higher than the norm".

Russia's laws prohibit dumping of liquid radioactive waste in the open hydrographic network. Despite this, it takes place at the Beloyarsk NPP over many years. During the operation of the plant's three units, radionuclides have been accumulated in sediments of the Olkhovsky wetland (the BNPP water dump site) and removed by the Pyshma river to 180 km downstream. In fact, the Olkhovsky wetland and the Olkhovka river have turned into an illegal dump-site of radioactive waste and become a secondary source of pollution. More than 100 Ku of long-lived radionuclides have been dumped to the Olkhovsky wetland. According to the Institute of Geophysics, in terms radionuclides content, muddy bottoms of the Olkhovka river are close to the category of radioactive waste - the concentration of radionuclides in them is more than 30 kBq / kg. Increased level of activity has led to the need for closure of the wetland area (about 40 ha). Independent studies carried out by the Radiation Safety Committee found multiple exceeding of cesium-134 and cesium-137 content in the water.

In addition, heavy hydrogen - tritium - emerged in result of the first two blocks operation. In water of the Beloyarsk Reservoir concentration of tritium 2-3 times exceeds natural background. According to the Institute of Geophysics, "tritium is found in the Elizavetisky underground water intake from which drinking water is taken to Yekaterinburg". Meanwhile, the existing system of radioactive monitoring does not take into consideration impact of tritium, radon and carbon-14 [60].

Accumulation of radioactive waste. Unsolved issues relating to storage and removal of spent nuclear fuel (units 1 and 2)

The current situation at BNPP: storage sites for liquid and solid radioactive waste are filled for more than 80%. The amount of solid radioactive waste is more than 35,000 m3, of liquid waste - more than 5,000 m3.

When shut down, whole reactors join the category of radioactive waste. The Beloyarsk NPP was the first nuclear power plant in Russia to face the need to solve the problem of decommissioning reactors that had worked to the end of their resource. Under existing regulations, the nuclear unit decommissioning project is required to be developed in detail 5 years prior to the unit being shutdown. It is about 20 years now since the units were shut down, but the reactors have not yet been dismantled. The whole complex of solid radioactive wastes (metal, concrete, graphite) is 33 m3.

Currently, these industrial units are not operating. Fuel is unloaded from the reactor and placed in special pools located in the same building with the reactor, which in itself is dangerous. Only safety systems remain in place.

Spent nuclear fuel is not removed from the BNPP. Removal is scheduled to begin in 2012, but as long as it is not done, the level of danger posed by improper storage of radioactive waste at the plant remains high.

In addition to the above mentioned problems, annual reports of Russian Federal Technology and Nuclear Regulatory Authority (Rostekhnadzor) repeatedly note the existence of an unsolved problem of "spillage of spent nuclear fuel from the units' equipment…".

3.3. Utilization of Plutonium

Despite many unresolved problems, another breeder reactor is currently under construction at the Beloyarsk NPP. The nuclear industry plans to dispose Russia's plutonium extracted from nuclear weapons by burning MOX-fuel in civilian reactors provides a new impetus to construct the BN-800. Plutonium can be recycled in fast reactors by "burning" it in the reactor core (it's necessary to take into account that this does not at all mean that all the plutonium "burns out": spent fuel contains just a little less plutonium than fresh one) . Along with this, we should not forget that the breeder is capable to "burn" plutonium as well as to breed it.

For the first time as a candidate for "burning" plutonium the BNPP was designated in 1992. According to calculations, modification of the BN-600 to the plutonium program costs 73.6 million dollars. According to the American side (data of the STAND, Inc), "the Beloyarsk nuclear power plant sought cooperation with the U.S. in the development of safety conditions for the BN-600 reactor coolant (sodium). In 1997-1999 the US Department of Energy (DOE) has allocated U.S. $ 1,780,000 for a joint program of the reactor conversion and announced the intention to assist obtaining the necessary licenses, even if the designed lifetime of the unit ends in 2010" [59].

The new plan signed in November 2007 by the U.S. Secretary of Energy and the Head of Russia's Federal Agency for Atomic Energy approves the following procedure: both countries build similar MOX production plants, then Russia uses MOX-fuel in its two breeder reactors. The program to use weapons-grade plutonium to generate energy will at the initial stage draw on the BN-600. This reactor is supposed to be used in the program until the end of its lifetime period, and the BN-800 reactor would be involved as soon as its construction is completed.

Rosatom representatives argue that the BN-800 reactors can fully operate on MOX-fuel. The concentration of plutonium in MOX-fuel for breeder reactors is significantly higher than for the VVER reactors. According to a joint Russo-American research, breeder reactors of the Beloyarsk NPP can utilize 50 tons of plutonium in 30 years. The use of weapons-grade plutonium in the BN-600 was scheduled to start in 2012, and soon after that in the BN-800. It was expected to "burn" at two BNs approximately 1.5 tons of plutonium per year.

Russia announced its intention to implement this program with the U.S. contribution of 400 million dollars which was promised earlier in the intergovernmental agreement between Russia and the United States. Along with that, it was pointed out that the U.S. Department of Energy and Rosatom will work together to search for other donor funding to "reduce the costs of Russian plutonium disposition in the BN-800” and to meet the program timetable.

According to recent data, Rosatom plans to build a MOX plant in 2014 simultaneously with launch of the fast breeder BN-800 at the Beloyarsk NPP. [16]

The BN-800 reactor of 880 MW capacity is called a pilot model for serial production of commercial breeder units. Nuclear industry says that the breeder reactor of this type “should help to address the following global challenges: development of the close nuclear cycle technology, expansion of fuel resources for the national nuclear energy, utilization of weapons-grade plutonium released in result of conversion.” The BN-800 is one of the nuclear world’s "long promises". Designing of the unit was begun in 1981. After the Chernobyl accident the project implementation was suspended. Then the project BN-800 had two upgrades: in 1987 and in 1993-m.

In 1990, the Ural Ecological Union, the Committee for Radiation Safety, Sverdlovsk Branch of the Russian Society for Nature Conservation collected about 40 thousand signatures of residents against the construction of the BN-800 unit. Then, under public opinion pressure, the Sverdlovsk region parliament adopted a moratorium on the construction of the reactor. The resolution pointed out the reason: "significant deficiencies that could affect the safe operation of the plant have been found in the project". Before this decision was adopted, there were 5 major assessments of the BN-800 project conducted. In particular, Gosatomnadzor presented a 24-sheet list of comments. It’s interesting that until now the majority of deficiencies are not solved. The main reason for this situation is the high cost of the necessary changes: it would cost as much as the BN-800 itself to remove all shortcomings.

Although the decision of the regional legislative authorities has not yet been cancelled, construction of the breeder reactor was approved in 1992 by the President of Russia Boris Yeltsin. Soon after that, Minatom has approved the project, and in January 1997, construction of the unit 4 of the Beloyarsk NPP with BN-800 reactor was licensed by Russia’s Gosatomnadzor. In fact, construction of another breeder reactor in the Urals resumed in 2002.

Plans for construction of the BN-800 continue raising public protest. During the period from 2002 to 2009 NGOs and the public held dozens of pickets and protest actions.

The BNPP unit 4 project which caused a lot of criticism on security issues, was listed among the "state innovation projects." It should be noted, for the years of "adjustment" of the project, construction of ancillary facilities for the BN-800 were constantly going on at the plant.

The scientific leader of the BN-1800 reactor project is the Physics and Power Engineering Institute (Obninsk), the general designer is Atomenergoproekt Institute (St. Petersburg). A joint stock company was established to finance construction of the BN-800. The company is owned by Rosenergoatom, the Government of Sverdlovsk region, JSC Sverdlovenergo, JSC Uralenergostroy, and the Beloyarsk NPP. General contractor is the managing company Uralenergostroy. The scheduled start of operation the reactor has been already delayed from 2009 to 2014.

According to the BNPP Public Information Center, "according to the federal program, launch of the BN-800 is planned for 2012. According information which has not yet officially confirmed, the deadline may be postponed until 2014. Which calls to question the competence of the Government of Russia "[58].

BN-800 is being built in 2.5 km from the existing NPP. Construction site and all auxiliary facilities are designed to serve not only for the unit 4 of the BN-800, but also for unit 5 of the BN-1800 reactor.

Construction continues at the BN-800 site. As of July 2009, the power turbine hall in the main unit building is made at level 0, the walls of steam generator' compartment came up to a mark of +11.8, reactor compartment - to the +7.8 mark, covering the reactor shaft - to the +16.65 mark. Bulky equipment (e.g., the 1st circuit sodium tanks) is installed to the "minus" levels. The task for 2009 was to construct the entire reactor compartment to a mark of +16.65m and begin assembling the reactor vessel in its shaft.

The new nuclear technology program for 2010 – 2010 includes the MOX –fuel and development of fast reactors with the total program cost of 128 billion rubles. Approximately 75% of the program costs would go for fast reactors and the fuel cycle for them. A similar joint project between the U.S. and the French Areva at the Savannah River site was estimated in 2008 to 4.8 billion U.S. dollars.

The program of irradiation of sample MOX assemblies at the Beloyarsk NPP started in 1988. For 12 years (from 1988 to 2000) 34 fuel assemblies with mixed fuel were used on the BN-600 (annual consumption of uranium assemblies is 246). The report of the BNPP management presented in 2000 at the US-Russia plutonium hearings, said that "from 2000 to 2004, it was planned to irradiate 36 assemblies (up to 18 assemblies at the same time) and, since 2004, to get a fuel zone permanently supplied with 25% of mixed fuel assemblies, and from 2008 to switch to the mixed fuel entirely".

According to the BNPP Center of Public Information, "at the moment, the BN-600 runs on uranium fuel. By request of the MOX-fuel developers, custom-made samples of uranium-plutonium fuel are used at the BN-600 for research purposes. Figures related to nuclear materials represent information protected by the state".

3.4. Possible Implications of the Plutonium Program

About 180 thousand people live in the 30-kilometer zone around the BNPP. Depending on weather conditions, possible radioactive contamination may affect all or part of 11 municipalities, 76 settlements, and 170 economic bodies with a total population of about 2 million people.

Most air movements are directed northeast in the direction of the Tyumen region. Westerly winds prevail throughout the year. Therefore, probability of contamination of western districts of the south part of the Tyumen region is higher than of Yekaterinburg. Water flows from the area through the Pyshma river system and enters the Ob River basin.

Long-term radiation monitoring has shown that there is an almost linear positive correlation between the density of cesium-137 fallout and the wind frequency plotted by azimuths of the location of monitoring site. Evidence suggests that above-background figures caused by the BNPP emissions are traced beyond the 30-km zone. Consequently, 1.5-million people in Yekaterinburg become an object of the BNPP emissions even during normal, accident-free operating.

It is important to note that in Yekaterinburg, Asbest, and in other cities there is no health monitoring system to determine the effect of small doses of radiation on human health, while global data of sickness incidence of people living near nuclear power plants show a stable relationship of these indices with the proximity to a nuclear object.

A switch to the ongoing construction of breeders is complicated by the many unsolved problems.

Sodium is used in breeder reactors as a coolant. It burns in air or other oxidizing environments. Burning sodium produces smoke which can cause damage to equipment and devices. The problem becomes more complicated if the smoke is radioactive. When in contact with concrete, hot sodium can react with components of concrete and evolve hydrogen, which is, in turn, explosive. Sodium is very likely to react with water and organic materials. This is especially important for the design of a steam generator, as leakage from the water circuit to the sodium one leads to a rapid increase in pressure. In addition, in the BN reactor core a positive sodium "hollow effect" is very likely to occur that could lead to a thermal explosion. It takes more than four days after reactor shutdown before the staff could enter an area with a large amount of sodium coolant.

In general, implementation of fast neutron reactor projects can hardly be called successful. In Russia, France, Japan, the United States - the reasons are the same: unavailability of the technology for large-scale application, including poorly-studied question of sodium reactivity, and the unsolved problem of radioactive waste.

Handling with industrial plutonium, including fuel fabrication and transportation, is a very complicated technological process. It is important to note that the existing federal rules and regulations to ensure nuclear and radiation safety for many processes are unavailable, and the existing departmental regulatory framework cannot be used as it is closed and covers a range of weapons-grade technologies that does not involve use of plutonium as fuel for nuclear power plants.

If the MOX program is implemented, plutonium (half-life of 24 thousand years; impossible to be detected with traditional measurements of gamma-background is very likely to be a component of radioactive emissions from nuclear power plants. Not to mention transportation of plutonium across the country, both in pure form and in the form of fresh, and then spent MOX-fuel. Radioactive waste is generated at nuclear power plants as well as at the manufacture of fresh MOX-fuel and reprocessing spent one.

The only unit operating at the Beloyarsk NPP will runs out of its project lifetime in 2010, but it may be extended for another 15 years. Obviously, the extension of lifetime does not reduce risk, but increases it. Due to temporal, technical and technological difficulties, it is impossible to diagnose all the nuclear power plant systems. If, moreover, one takes human factor into account, the danger of nuclear power plants with extended service life only grows with time.

Dangerous impact of the nuclear industry on the environment in the Sverdlovsk region is worsened by the presence of other dangerous objects: the Ural Monazite company, the Ural Electrochemical Plant (UEIP), and Lesnoy the closed city. The objects located in the neighboring Chelyabinsk region should also be taken into account – the Mayak industrial complex is recognized as the most "dirty nuclear plant in the world".

About 70% of the population of Sverdlovsk region live in conditions of the exceeded maximum allowable concentrations of toxic substances in the air. Under the concept of "The Capacity Development and Distribution in the Sverdlovsk Region up to 2015", the main object of which is the Beloyarsk nuclear power plant, the industrial production will raise by 230-276% of 2000, *which can increase technogeneous impact on the region at 2-2.5 times* [60].

One of the arguments of supporters for expanding the capacity of the Beloyarsk NPP was the creation of jobs for residents of the region. According to the BNPP public information center, "at the BN-800 site around 2100 construction workers are employed, all of them are from the Ural region". At the same time, numerous local media reports that construction workers employed at the nuclear power plant are mostly from neighboring countries. Thus, in summer 2008, it was reported that the builders from Kazakhstan, engaged in the construction of the BN-800, had not been paid for a long time.

3.5. *The BNPP Capacity Built-up and Plutonium Utilization Expediency Assessment*

3.5.1. Energy Expediency

The Sverdlovsk region is Russia's 5th energy producer. It is important to bear in mind that in Russia in general, supply exceeds demand for electricity for at least a third. To date, the Sverdlovsk region is able to fully ensure its own needs. According to the Minister of Industry, Energy and Science of the Sverdlovsk region Y.P. Shevelev, the growth of electricity consumption in the region over the past 8 years has been supplied only by existing system capacities. At present, the installed capacity in the Sverdlovsk region exceeds 9 MW. Consumer load at winter peak period does not exceed 6.5 MW, while in summer falls below 4.5 MW [60].

The only BN-600 reactor operating at the BNPP provides 8-11% of electricity production in the Sverdlovsk region. If we compare this figure with data on losses (losses due to inefficient use of energy are 35-50%), then the answer whether such a dangerous object as a breeder reactor needs to be constructed, is obviously negative.

In addition to the above mentioned, the Sverdlovsk region is adjacent to the major energy donor - the Tyumen region and Khanty-Mansiysk Autonomous Region. The power system of the northern regions allows the export of about 20 billion kilowatt-hours of electricity from the Tyumen region where energy is produced inexcess. According to the Ural Industrial - Ural Polar Corporation Energy Department Director Andrew Kasyanenko [59], capacities of the neighboring northern regions "can provide any amount of generation and transmit, by the eastern corridor along the Ural Mountains, electricity to the industrial centers of the Urals – to the Sverdlovsk region it can deliver up to 1,000 MW". According to official statistics of companies, 6.2 billion cubic meters of by-product casing-head gas is burned annually. In fact, only two sites of the Priobskoye field burn more than 2.5 million cubic meters every day, or about 1 billion cubic meters a year. This gas would be enough to heat a one million population city over winter period [59].

3.5.2. Financial Expenses

Construction of new power units requires billions of dollars of investment. The initial cost of the BN-800 construction was estimated as 1.2 – 1.3 billion dollars. Today, this figure is exceeded at least 3 times. Breeder reactor cost is several times bigger than investments in other types of power plants of the same capacity. It is important to note also that weapons-grade plutonium (the main fuel for breeders) is 4 times more expensive than uranium fuel. Expert evaluation of the BN-800 construction business plan showed that the calculations underestimated the funds needed in the early years of operation for maintenance and loan repayment, as well to pay tariffs charged for electricity.. [20]

Former Russian Minister of Atomic Energy Vladimir Mikhailov: "The cost of weapons-grade plutonium is 4 times more expensive than the 90%-uranium-235, with 1 kW • h, generated at a reactor on fast neutrons, 2 times more expensive than at the light water reactor. .. [20]

The calculation of electricity cost generated at the BN-800 does not include the following components [20]:
• the total cost of radioactive waste management (storage, reprocessing and transportation);
• cost of initial download of uranium-plutonium nuclear fuel;
• cost of delivery and storage of fresh fuel, as well as transportation and reprocessing of spent nuclear fuel;
• inflationary rise in the cost of nuclear fuel for the period of the BN-800operation;
• decommissioning of nuclear power plants with BN-800;
• cost of risk insurance and compensation for possible radiation damage associated with the NPP with BN-800 operation at all stages of the life cycle of the plant (cost of a nuclear electricity is very high, if you include the insurance fund for the population living near nuclear power plants and the radioactive waste management).

Scientists estimated that if the Beloyarsk NPP paid for discharges and emissions, as enterprises in other sectors do, then, to a very modest estimate, this amount annually will be: on tritium - at least 30 million rubles, on cesium-137 - 150 million. [60].

Examination of the BN-800 project suggests that implementation of projects such as the BN-800 cannot be guided by, for example, only knowledge of projected need for additional generating capacity or destruction of weapons-grade plutonium. The full range of social, ecological, economic factors prevailing in the region should also be taken into account.

Construction in the densely populated industrial region of the Urals inspires serious concerns. It must be noted that the nuclear scenario for the region's development dictates an approach based on economic growth that at the samem time introduces new threats and negative impacts on the environment at the expense of the health of the population of the Urals.

The development of nuclear facilities with their "long term" (in thousands of years) effects, consequences and the need for major monetary investments is inefficient. Quite small amount of energy generated by nuclear energy is not a benefit commensurate with the risks, losses and danger for the region it creates.

4. Krasnoyarsk Mining and Chemical Complex (Zheleznogorsk, Krasnoyarsk region)

4.1. History. Subdivisions

Construction of the Krasnoyarsk Mining and Chemical Combine (MCC) started in 1950 with the decision of the Council of Ministers of the USSR on the right bank of the Yenisei River in 50 km downstream from Krasnoyarsk. To ensure the infrastructure of the plant, the closed (secret) administrative municipality, Zheleznogorsk city, was built next to it. The MCC has been constructed at a depth of 200 meters underground in the rocks to protect against possible attack from the air. The underground facilities of the plant occupy about 7 million cubic meters.

The main function of the Mining and Chemical Combine is extraction of plutonium from natural uranium irradiated in reactors.

The MCC operating facilities include:
- Reactor plant, with two shut-down reactors that used to produce weapons-grade plutonium from natural uranium;
- Radiochemical plant for the reprocessing of natural uranium irradiated in reactors;
- Structures in mines for temporary storage of intermediate and high-level level (HLW) waste, as well as preparing it for disposal;
- Solid radioactive waste storage site, located outside the radiochemical plant;
- The isotope-chemical plant (reprocessing and disposal of radioactive waste from the reactor and reprocessing plants, the RT-2 plant);
- The North landfill for the underground disposal of liquid radioactive waste;
- Open surface pools 2.5 km from the edge of the Yenisei River;
- Auxiliary plants.

The first AD reactor was put on line in August 1958, the second one (ADE-1) - in 1961, the third (ADE-2) one - in 1964. The reactor plant originally consisted of three operating reactors, two of which (AD, ADE-1) worked in the so-called "flow regime" - water from the Yenisei River which was then discharged back into a river was used to cool their cores. The radioactivity of this water reaches 3000 mR /h (150-200 times higher than natural background).

The third reactor is energy-generating, dual-purpose, and has a closed cooling circuit and in addition to plutonium produces heat and electricity for Zheleznogorsk. It produces 150-200 megawatts of electricity and 350 Gcal of heated steam used for heating water, which since 1966 supplies hot water and heating network. All reactors at the MCC are uranium-graphite, on thermal neutrons, channel-type, with water cooling. Now only the ADE-2 reactor is operating. The first AD was decommissioned in June 1992, and the second, the ADE-1, was closed two months later. Nuclear fuel from the first two reactors was unloaded; the dismantling of equipment has been carried out.

The ADE-2 reactor operates at thermal capacity of approximately 2000 MW with fuel burnup of 500 watts per day per ton, while it produces about 0.5 tons of weapons-grade plutonium per year [44]. Plutonium produced at the ADE-2 is reprocessed at the Complex, and then sent to the repository in the form of plutonium oxide.

The radiochemical plant designed to extract plutonium from natural uranium irradiated in reactors, was launched in 1964. The plant operations include dissolution of metal uranium in nitric acid, extraction multi-reprocessing to separate uranium and plutonium, their purification from radioactive fission products, and deep cleaning of plutonium with sorption method. The products in reprocessing of fuel assemblies irradiated in the reactor are the uranium salt (uranyl nitrate) and the compound of plutonium. The complexity of the plant's technological scheme is demonstrated by the very low concentration of plutonium in uranium (less than one weight percent) and high radioactivity of solutions.

Liquid high-level waste produced during reprocessing of irradiated uranium is stored in special stainless steel containers. Medium and low liquid waste is sent to the Northern underground repository.

The MCC uses a technology of underground repository of liquid radioactive waste (LRW). This activity is performed at the Northern landfill and represents dumping of liquid radioactive waste into deep aquifers. The Northern landfill is used for deep disposal of non-technological low-level waste (LLW) of the plant since 1962, intermediate level waste - since 1967. The intermediate level waste is deposited in the first horizon (depth interval 355-500 m), the LWR is dumped in the second horizon (depth interval 180-280 m) through specially equipped wells.

The common western border of underground LRW storage sites is a vertical plane of a tectonic fault. The hydraulic isolation of technological solutions injected at a site is possible only with simultaneous evacuation of an equivalent volume of reservoir water from the discharge wells. The pumped water is used for industrial and household needs of the landfill; there are no other sources of water at the landfill. Technological salt solutions are transferred to the North site from the radiochemical plant by the underground steel pipeline packed in sealed concrete trays.

The MCC receives, temporarily stores, and subsequently reprocesses spent nuclear fuel from nuclear power plants. In 1984, construction started on the RT-2 plant for regeneration of spent nuclear fuel (SNF) from the VVER-1000 reactors. However, initially because of public opposition, and later due to lack of funding, construction of the plant made little progress, though the SNF storage facility for it was built. The design capacity of the first stage of the RT-2, the SNF storage facility that was constructed in 1985, is 6000 tons. To date, the storage site is filled with spent nuclear fuel assemblies from the VVER-1000 reactors from Russia, Ukraine and Bulgaria to 60%. When filled, its activity will be 6 billion Ku. Each year, the MCC accepts about 10 trains with SNF [44].

The RT-2 complex includes a tunnel under the Yenisei River 2170 m long, which was designed for transportation of radwaste (including high-level) via pipelines to be dumped at one of the sites located on the opposite bank of the Yenisei River, 16 km from the tunnel.

4.2. Environmental impact issues. Accidents and incidents

Over fifty years of operation of the military production at the Mining and Chemical Combine the following problems have accumulated:

1. Problems associated with the continuation of the ADE-2 reactor operation
For more than a decade spent fuel units have not been sent for recycling, but stored in cooling ponds, where about 28 thousand spent units have accumulated. The prolonged storage of units in with no reprocessing can lead to their corrosion, and accumulation of uranium-235 in the cooling ponds and cooling water.

Since the State defense order was cancelled in 1995, the plant has to store plutonium dioxide it generates on site, in a temporary storage. The storage capacity is exhausted.

2. Problems associated with the operation of the radiochemical and isotopic-chemical plant

Over the operation period of the radiochemical plant, in containers, 6700 m3 of pulp has been accumulated in storage tanks with total activity of more than 100 million Ku. Moreover, it is necessary to process the pulp accumulated in the storage tanks (700 m3 of pulp for high level waste, with total activity of more than one million Ku) and in the outdoor pools (20 thousand m3 of pulp of approx. 80 thousand Ku of total activity).

3. Problems associated with the generation of solid radioactive waste
Decommissioning of the main production plant produces large quantities of solid waste; in this regard construction of new storage facilities is needed..

4. Problems associated with the generation of liquid radioactive waste (LRW)
LRW produced in the technological process of the MCC were sent to open surface storage as well as stored in special facilities, in deep absorbing geological horizons. Total activity of liquid radioactive waste, in both surface and underground (geological) storage facilities, is estimated at 450 million Ku. At the North dump site there are about 4 million cubic meters liquid radioactive waste dumped with total activity of 700 million curies of [15]. Design and launch of the dump site coincided with a difficult time of deficit due to the Cold War. In these circumstances it was impossible to do all the research and work necessary to ensure environmental safety.

Liquid waste is coming to the North dump site via the pipeline, along which local (up to several thousand square meters) areas of radioactive contamination are identified. Levels of cesium-137 and plutonium-239, 240 contamination are hundreds and thousands of times higher than global fallout. Public access to a part of the liquid waste pipeline from the village of Great Baltschug and the Yenisey River is no way restricted.

One of the consequences of the MCC operation is the pollution of the Yenisey River basin. Independent studies have shown 150-180 so-called ‘point sources’ of radioactive anomalies with high (up to 200 curies per square kilometer) level of radioactive contamination.

Contamination the Yenisei bottom with radionuclides up to the Kara Sea stretches for 1.500 kilometers. Radioactivity accumulates in algae and in fish, and is delivered by movement of fish over hundreds of kilometers down and up the Yenisei.

Because of the special secrecy of the MCC operation relating to weapons-grade plutonium, numerous cases of emergencies and incidents which occurred at the main production site are still at hidden by the nuclear agency. This mainly concerns incidents related to the industrial reactors and the radiochemical plant. Information about some "emergency situations" is given below:

- 21.09.87, the accident at the radiochemical plant resulted in radioactive contamination of drainage channels of industrial buildings. Radioactive contamination of the Yenisei traced to a distance of 800 km from the place of discharge; floodplain and bottom sediments were contaminated to a distance of 1500 km down the location of the plant.

- In 1999, seven workers of the ADE-2 reactor staff got external exposure target level (25 mSv) exceeded.

- 27.07.2000, during the reloading of containers with spent VVER-1000 fuel elements (from a transport to a storage container) at the MCC, a case fell on a metal structure. There were also technological operations carried out that are not foreseen by the regulations and instructions. The event was categorized as a «I» category violation.

- In 2000, during transportation of spent nuclear fuel from nuclear power plants in Russia and Ukraine to the MCC, inner surfaces of the car-containers were contaminated up to 1500 beta-particles/sm2 per minute.

- In the first half of 2001, the ADE-2 reactor of the MCC was shut down due to some shortcomings. While recovering the shortcomings, 8 employees received a radiation dose exceeding the annual allowable dose, and were suspended from work.

- November 5, 2003, the ADE-2 reactor was shut down due to a channel failure.

- January 5-6, 2004, the ADE-2 reactor was shut down thrice due to failures in three channels.

4.3. Utilization of Plutonium. Granulated MOX-fuel Production.

According to various estimates, since its establishment the Complex has produced about 45 tons of weapons-grade plutonium [19]. Plans for further development and existence of the MCC are closely related to the implementation of the plutonium program.

In summer 1994, U.S. Vice-President and Russian Prime Minister signed an agreement committing the Russian government to complete Russia's plutonium production at the remaining industrial reactors no later than in 2000, which was never fulfilled.

It was scheduled to launch a spent nuclear fuel regeneration plant (the RT-2 plant) after decommissioning of the reactor and the radiochemical plants. A "rational" scheme of conversion - to gradually transfer the staff from the decommissioned plants to the RT-2 – was developed.

Initially, the plant RT-2 was designed for receiving, temporary storage and subsequent reprocessing of spent nuclear fuel from nuclear power plants. The technological scheme of the plant RT-2 operation was based on a technology of extraction and purification of uranium and plutonium. The designed capacity of the plant was supposed to be 1500 tons of spent fuel per year, and the area was planned as about 140 hectares. It was planned that final products of the plant should have been mixed uranium-plutonium fuel assemblies.

The first phase of the plant, a spent nuclear fuel complex, was put into operation in 1985 Due to the lack of funds and people’s protests the construction of the plant was halted in 1990. By that time it was not more than 5% of the entire RT-2 plant built. Since 1992, the only operation taking place at the RT-2 plant is maintenance work to prevent the destruction of the constructed buildings and facilities. The initial estimated cost of the RT-2 plant was $ 3 billion (from 5 to 7 billion dollars, according to independent estimations). After 30 years of operation it is supposed to be decommissioned, similar to nuclear power plants, including dismantling and disposal of thousands of tons of nuclear waste of all kinds.

Under current plans of Rosatom, the MCC should be one of the basic platforms of the MOX program. Rosatom plans to distribute the production of mixed fuel between the two sites. In particular, the initial preparation of the granulated material (pellets) consisting of uranium and plutonium should be done at the Mining and Chemical Complex [45].

The MOX-fuel pellets

The nuclear industry claims launch of the MOX-fuel pellets production to be one of the major projects "of the future". One of the possible starting dates of production is 2012 [16].

Uranium-plutonium pellets will be used in thermal reactors and in fast reactors. One of the components of the raw material must be plutonium dioxide, which is currently stored at the Mining and Chemical Complex.

Technology of pellet production is as follows: in the so-called dry method of processing (as unlike the water method, when the spent weapons-grade plutonium is first placed in the aqueous acid), plutonium is first placed in salt melted to 600 degrees Celsius. Through the thermal processes and salt washing-out, small pieces of plutonium-containing nuclear fuel appear. Uranium-plutonium pellets have different weight and size. In the special boxes, the pellets are loaded into the tube-type cladding, maximally condensed, and sealed, resulting into a fuel element. The final stage of the operation is a production of a fuel assembly, which is then placed in a nuclear reactor. Therefore, weapons-grade plutonium is suitable for use as fuel for nuclear power plants.

According to Rosatom, in December 2008, preparatory work for equipment complex and systems of the MOX-fuel pellets manufacturing plant pellets for the BN-800 reactor resumed. In 2010, the MCC should begin to produce the first batches of the substance. Vibration compacted fuel elements and fuel assemblies of these pellets will be produced at the NRRI, which already produces experimental MOX-fuel assemblies with for the Beloyarsk NPP BN-600.

According to recent statements of the nuclear industry, a nuclear waste reprocessing facility in Zheleznogorsk is to be built by 2025. A pilot plant for reprocessing of nuclear waste is planned to be built in 2010-2013. It is also scheduled to begin construction of a new dry storage at 33 thousand tons capacity, which is necessary for spent nuclear fuel from Russian RBMK and VVER-1000 reactors. The Russian government decided to build a demonstration radiation safety technology center at the Mining and Chemical Combine to start operating by 2015. It is supposed to be offering the potential clients a full range of services from project development to construction of high-tech facilities related to reprocessing of radioactive waste [49].

Due to the active protests of the Krasnoyarsk region residents, in 1989, the Ministry of Atomic Energy of the USSR decided to cease all work at the RT-2 site. Since January 1991, the leadership of the Ministry decided to freeze the RT-2 construction for five years. In autumn 1994, after the visit of the Russian President Boris Yeltsin in Krasnoyarsk-26 and the signing of the Presidential Decree "On state support of the restructuring and conversion of the nuclear industry in Zheleznogorsk, Krasnoyarsk Region", it was decided to continue the construction.

In August 1996, the State Environmental Assessment expert commission reviewed “The Adjustments to the Feasibility Study for Construction of the RT-2 Plant at the Krasnoyarsk Mining and Chemical Complex”. The document contains 29 comments and each of those essentially "puts an end" to the project ("Environmental Impact Assessment Section" does not meet the necessary requirements, ... the proposed basic technical equipment for spent nuclear fuel still has to be designed and developed anew", and many other things).

Numerous challenges to ensure the safety of the already existing storage site at the MCC and plans for the development of additional production was the basis for continued local public protests. In 1996, the initiative group was registered to collect signatures for a referendum in the Krasnoyarsk region on acceptance of the law “On Prohibition of Construction (continued construction) in the Krasnoyarsk region of spent nuclear fuel reprocessing facilities, including the RT-2 plant”. In 1997, the initiative group has gathered more than 100 thousand signatures for a referendum to ban the RT-2 construction. In 2000, the number of signatures for an environmental referendum increased to 2.5 million.

However, the Krasnoyarsk regional parliament rejected the initiative to hold a referendum. Hearings on this were carried out behind closed doors, with a secret vote. The conclusion of the hearings referred to the fact that the RT-2 plant is subject to federal jurisdiction, therefore, local lawmakers have no authority to make decisions regarding the termination of the construction.

4.4. Possible implications of utilization of plutonium

The feasibility of the RT-2 plant construction is questionable. There is no need to build such a large object in order to reprocess (or dispose) spent nuclear fuel from Russian nuclear power plants. What does the intention of the nuclear industry to continue constructing the spent fuel regeneration plant come from? Only 20% of its design capacity will be used for reprocessing spent nuclear fuel from Russian nuclear power plants. Most likely, the rest of spent nuclear fuel will be imported from abroad. Otherwise, this project will not make any sense.

It is important to note that reprocessing of spent nuclear fuel does not at all mean reduction of the enormous danger that this most dangerous of all the existing type of nuclear waste represents. A radiochemical plant is the dirtiest of all nuclear facilities. It produces hundreds of times more radioactive waste comparing to the amount of spent fuel reprocessed. A relatively less dangerous way of the spent fuel treatment is dry storage, although in this case, it would be difficult to guarantee complete safety for people and the environment as well.

4.4.1. The plutonium program impact on human health

According to official data, more than 100 thousand people live in the 30-km zone of the Krasnoyarsk Mining and Chemical Complex. Slightly less than one million people live in Krasnoyarsk. Deputy Chief Physician of the Center for State Sanitary and Epidemiology Regulation of the Krasnoyarsk Region Vitaly Kovalenko told to a local television and radio that "in the contaminated by the MCC radioactive emissions 500-kilometer zone of the Yenisei river, one can find areas where the density of cesium-137 is 40 Curies per square kilometer. By the so-called "Chernobyl classification", contamination of soil from 10-15 Ku per square kilometer, should already be considered as an ecological disaster zone" [56].

The Krasnoyarsk Radiological Center started its radio-ecological studies to determine connection between human health and the Mining and Chemical Complex operation only in 1996. Until that time, data on the MCC activities since the mid 50's when it started producing weapons-grade uranium, were classified as secret.

Analysis of Zheleznogorsk demographic data from 1989 to 1995 shows that mortality increased from 6.2 to 9.1 during this period. The birth rate for the same period decreased from 15.7 to 7.6. Since 1989, there is a rising trend in the proportion of deaths in age from 30 to 59 years. Analysis of health indicators showed growth of tumors from 26.3 in 1993 to 74.5 in 1995, respiratory diseases - with 348.2 to 389.3, diseases of the genitourinary system - from 56.3 to 125.3, diseases of the skin and subcutaneous tissue - from 31.3 to 61.7, diseases of the musculoskeletal system and connective tissue - from 84.7 to 160.7 [56].

In general, the above mentioned data indicate the need for independent regular special medical research on the impact of the MCC on health of local populations. In addition, the obvious need for special programs to protect the population, introduction of insurance payments to be made by the nuclear industry which creates these problems. But despite the obvious extremely negative impact on human health, the plant continues to operate. Rosatom plans to develop this facility, and negative impact of the MCC on human health and the environment is ignored by both the political leadership and the nuclear industry. Apparently, the main reason for this situation is that issues of negative impact of the MCC have not received the attention they deserve. Otherwise, there would be no doubt the facility should be shut down.

4.4.2. Financial expenses

The completion of the first stage of the RT-2 is estimated by Rosatom as about $2 billion. However this figure is likely greatly underestimated. For example, the cost of a similar plant in France reached 30 billion francs (~ $5-6 billion), while in Japan it cost about $ 20 billion dollars.

Economic calculations have shown that replacement of the decommissioned reactors with gas power plants will cost between $700 million to $1 billion [64], while replacing them with new nuclear units will cost significantly more [70]. For example, the cost of the new VVER-1200, production of which Rosatom is trying to establish, is between $2.5 and $4 billion dollars, depending on a specific project.

The amount required for the construction of new facilities has not been made public. But fast reactors and MOX fuel are planned to be included in the program to develop new nuclear technologies in 2010-2020 with a total cost of 128 billion rubles. It is assumed that 110 billion rubles will be provided by the government, and the remaining sum is expected to contributed by funds from Rosatom structures. According to the Atompromresursy company, a similar project in the Savannah River (USA) was estimated in 2008 to $ 4.8 billion (148.8 billion rubles). According to the NIRS, the cost of MOX fuel could be significantly higher in comparison with conventional fuel for light water reactors.

The potential market for Russian MOX fuel could be China, which is going to build a fast reactor with a help of Russia [14].

There are serious concerns on physical protection of the MCC in connection to non-proliferation security of nuclear materials. Initial works to secure physical protection, funded by the U.S. Department of Energy, focused on the plutonium oxide storage which is located in a zone of improved security. According to Minatom, the plant has a high level of protection against penetration. However, these allegations have been refuted several times; a member of the Russian State Parliament with a group of local environmental activists freely got in the plant site and shot photo-and video footage. A low level of physical protection of the storage was also confirmed by the Krasnoyarsk Region Prosecutor's Office [44].

Implementation of the plans for the MOX pellets production at the MCC is unlikely to improve the environmental situation, rather the opposite. According to representatives of the nuclear agency, a "dry" method of processing plutonium is much safer than a “water-base” one: "the requirements for the concentration of fissile elements in aquatic environments are very stringent and require constant monitoring. And then it is just a step from an uncontrolled nuclear reaction to an explosion. While the method developed by the NPPI virtually eliminates the occurrence of such emergencies"[11]. However, preference for the "dry" method of processing to the "water-base" one does not improve the “environmental indicators” of the technology. In both cases, large quantities of radioactive waste are produced. And the fact is that weapons-grade plutonium used in civilian facilities presents more minuses than pluses. Nuclear plants are even less protected than military sites, and, consequently, provide fewer guarantees for weapons-grade material safety.

5. Siberian Chemical Complex (Seversk, Tomsk region)

5.1. History. Subdivisions

The Siberian Chemical Complex (SCC) which history began in 1949 with the title Glavpromstroy Zauralsky Office (the Plant No 816) is located in the largest enclosed city of Seversk (former names Tomsk-7, Pochtovyi) with a population of 120 thousand people. The borders of the regional center of Tomsk and Seversk are adjacent to each other.

The facilities of the SCC are only 1 km away from houses on the edge of Seversk and 5-6 km from homes on the edge of Tomsk houses in the villages Shtamovo and Kuzovlevo. This is unprecedented case of placement of such facilities in such close proximity to a regional center. 700 thousand people, representing almost 70% of the total population of the Tomsk region live in the 30-kilometer zone of the SCC.

The Siberian Chemical Complex is the largest nuclear fuel cycle facility in the world. The only component of the uranium cycle not present at the SSC is uranium ore mining and processing. For the production of nuclear weapons in the 50's and 60's of the 20^{th} century a uranium hexafluoride production plant, a isotope separation plant (uranium enrichment), a reactor plant (weapons-grade plutonium production), a radiochemical plant (uranium and plutonium extraction from irradiated uranium rods of DAV-90 type), a chemical metallurgical plant (metallic weapons-grade uranium and plutonium production) were established at the SCC.

At the SCC reactor plant, five uranium-graphite reactors were stepwise built and put into operation. Their names and periods of operations are: Ivan-1 (I-1, 1955-1990), Power Ivan (EI, 1958-1991), Atomic Dual-Purposeful Power - 3 (ADE-3, 1961-1992), Atomic Dual-Purposeful Power - 4 (ADE-4, 1964-2008), Atomic Dual-Purposeful Power - 5 (ADE-5, 1965-2008).

Since 1963, the world's largest liquid radioactive waste underground dumping site is operating at the SCC. To date, more than 1,1 billion Ci of initial activity of long-lived radionuclides, including isotopes of plutonium, are dumped to the underground aquifers at a depth of 320-460 m at sites No. 18 and 18a.

Since all nuclear reactors have been shut down, the SCC production consists of the isotope separation plant, the uranium hexafluoride production plant and ancillary facilities.

5.2. Impact on the environment. Accidents and incidents

The first nuclear reactor at the SCC, the I-1, had a direct flow cooling; hot water left the reactor went through the channels system and entered the Tom River. Before the I-1 was stopped in 1990, river ecosystems were exposed to the greatest impact from the SCC. Until now, there are no publicly available data on radiation doses received by residents of the settlements Chernilschikovo, Samus, Kizhirovo, Orlovka, Iglovsk and others, located on the banks of the Tom and Ob rivers downstream from the SCC discharge mouth over the period the I-1 operation.

Given the lack of awareness of local residents about the nature of the plant’s discharges and their attachment to the river (year-round fishing and eating fish that accumulate radionuclides, primarily phosphorus-32, mowing on the flood plane where long-lived radionuclides have been accumulated in soil, the traditional summer vacation on the river), we can expect significant additional exposures of the public as a result of the SCC discharges into the Tom river that exceed the current radiation safety standards by many times. A retrospective assessment of doses received by residents of settlements located on the banks of the lower Tom and Ob below the mouth of the Tom is currently uncertain.

For over 50 years of operation, the SCC produced a huge amount of radioactive waste (RW). More than 1.1 billion Ku of initial activity of liquid radioactive waste were dumped in the underground aquifers. In 2001, the public hearing on the Seversk liquid radioactive waste underground dump site lifetime extension took place under the state environmental assessment of this project. Despite the large number of comments concerning, above all, legal aspects of dumping liquid radioactive waste into underground aquifers, the state environmental assessment has made a positive decision on the project feasibility study and extended its operation period until 2015.

An expert of the State Commission for Mineral Reserves A.V. Ivanov, in his generally positive conclusion on the "Justification for the SCC liquid RW disposal safety” and "Project of the sites No. 18 and 18a operation in connection with the extension of the utilization period of deep underground storage sites of liquid RW at the SCC” notes the following: “The significant influence on the rate of contamination distribution and its range entering the upper layers used for water supply, is made by water intakes (underground water intakes of Tomsk and Seversk). Operation of the intakes accelerates the speed of the contamination front and increases the amount of income in the IV and V aquifers. It is therefore **necessary to find alternative sources of water, and stop water intakes operation after 2015**". It turns out that it is not liquid RW underground dumping that poses a threat to the water intakes but the water intakes interfere dumping (!).

In addition, in the SCC area there are the partially covered open pools for liquid radioactive waste, storage and disposal sites that contain about 125 million Ku of man-made radionuclides.

For more than half a century of activity, more than 30 incidents and accidents of various kinds and scales took place at the SCC; five of them are officially classified at level 3 by the international nuclear events scale, INES.

The most well known accident occurred on April 6, 1993, when due to outdated equipment and human errors in the SCC radiochemical plant an accidental release of radioactive substances to the plant site took place. The radioactive fallout, by fortune went to the northeast in the opposite direction from the cities of Tomsk and Seversk, while on their way covered the regional road Tomsk – Samus, and Georgiyevka and Chernaya Rechka villages as well as farmland of Naumovka village.

Traditionally, the residents were informed about the radiation accident only after a long delay. For several hours, while the decision had been taken, radioactive dirt was delivered on the wheels of cars to Samus village.

The accident was assessed with level 3 of the INES. Total activity of all radionuclides fell out outside the plant site is estimated at 500 Ku. However, according to an expert assessment [4], if it was south wind direction and, accordingly, it was fallout in Tomsk and Seversk, it would have been necessary to evacuate the residents of these cities. Then the accidents would have been assessed as level 5 0r 6 on the INES. What would have changed to the accident essence? Nothing but the wind direction.

The debates on the consequences of the 1993 accident are still going on. The SCC management and a number of concerned scientists argue about the insignificance of the consequences for nature and people. In contrast, some independent researchers point out the gravity of the accidents consequences. Thus, studies conducted by a professor of the Siberian State Medical University T. Matkovskaya show strong impact of the accident on health of children in Naumovka and Georgievka villages, as well as the premature death of several of them.

Tomsk lawyer Konstantin Lebedev went through all levels of the court hierarchy to the Supreme Court of Russia and managed to get compensation for Georgiyevka villagers affected by the accident at the SCC in 1993 of 25 thousand rubles per person. Later, Naumovka villagers who did not believe in the success of the cause, tried to argue in the Russian courts that they are also, as Georgievka residents, affected by emissions from the SCC and the accident of April 6, 1993 (the majority of the mechanics of Naumovka worked in the contaminated areas; some products from the contaminated area was also used). The Russian courts dealt with the case for a very long time and didn't satisfy their claims. Then, Konstantin Lebedev sent to the plaintiffs' claims to the European Court of Human Rights. The European Court of Human Rights ruled that 29 plaintiffs from Naumovka, Tomsk region, should receive compensation of 2000 euros each for the violation of their right to have their case considered within a reasonable time.

The accident of 1993 at the radiochemical plant excited the residents of Tomsk region and initiated a public discussion on socio-economic impacts of the SCC operation. Meanwhile, before and after the accident, the environmental movement and the general public in the region has been and remains focused on plans to place new radiation-hazardous industries in Seversk.

5.3. Utilization of plutonium

A few years ago the SCC site was the main one among possible locations for a plant to produce MOX fuel. April 7, 2003, Russian Minister of Atomic Energy A. Rumyantsev with the order No. 150 instructed the Siberian Chemical Complex Federal State Enterprise, the TVEL Joint-Stock Company, and the Nuclear fuel Cycle Department to organize the work on the justification of the construction of a MOX fuel plant at the SCC site.

Initially, a prototype of the Russia's manufacturing MOX fuel plant was a Siemens-owned plant in Hanau, Germany, equipment from which was planned to be free of charge transported to Russia. The Hanau plant was completely built but hasn'tworked a single day because of Germany's decision to ban its own plans for the MOX program. However, under pressure from Russian and German environmentalists in 2001, the German government abandoned the idea of transferring the plant to Russia, proceeding from the fact that exploitation of this equipment may cause huge environmental damage. The plant in Hanau still stands in the same place, and its equipment is not used by anyone. At the moment, it's decided to use the COGEMA technology which is applied at the Melox plant in the south of France for the Russian MOX plant.

January 28, 2004 TVEL submitted to the Tomsk Region Administration and Seversk Municipality its declaration of intent to build a plant MFFF-R (MOX Fuel Fabrication Facility-Russian), also signed by the heads of Russian Ministry of Atomic Energy Nuclear Fuel Cycle Department, the SCC, and other enterprises and organizations within Russian nuclear industry. According to the declaration of intent, the MFFF-R is planned to be located on the territory of SCC site in the eastern part of Seversk near the radiochemical plant on an area of 35 ha (area of 500 x 700 m), in 6 km from the residential areas of Seversk and 7 km from the first houses of Tomsk (Kuzovlevo village).

This construction site option is explained by necessary technical communications (electric and thermal networks, industrial and drinking water, sewerage, railway) available near the radiochemical plant, the proximity of the underground waste dumping site and the possibility for the enclosure to ensure a separate entry to the area, as well as an autonomous access to the plant for foreign specialists without obtaining special permissions to get in the closed municipality of

Seversk. According to the declaration of intent, the MFFF-R is designed for the production of fuel assemblies with mixed uranium-plutonium fuel for Russian and foreign power reactors of VVER and PWR types.

The declaration of intent identified TVEL company as an ordering organization and the SCC as a builder; the exploiting organization is not defined. It is assumed that the plant would not be a part of the SCC, and will be operated by TVEL.

Tomsk Oblast Administration approved the declaration of intent with the following major conditions: to work over such issues as the plant operation lifetime, the decommission procedure, population risk insurance, and construction a diversion railroad around Tomsk for transportation of hazardous radioactive and chemical materials for the MFFF-R. Seversk Municipality endorsed the declaration of intent subject to the mandatory consideration of public opinion when deciding on the MFFF-R location.

According to the declaration of intent, the SCC had to start construction of the plant as early as in 2004 and finish in 2008, but the U.S. Congress postponed its decision on allocation of the part of funds for construction of the plant in Russia, the construction was postponed. According to the SCC, the plant was to start producing nuclear fuel based on uranium and weapon-grade plutonium in 2009 and operate in this mode for 15 years until 2024.

The cost of the entire Russian weapons-grade plutonium disposal program which includes, besides construction of the plant, improvement of the VVER-1000 reactors for MOX fuel, and organization and implementation of MOX fuel transportation within Russia, was in 2003 – 2005 estimated by Rosatom as $1.7 – 2.7 billion dollars.

There is no final price of the plant construction named. The figures from $ 400 to $ 1200 million have been mentioned. Under the declaration of intent, the MFFF-R construction cost is equal to 29 billion rubles in 2003 prices. The USA is considering allocating $ 200 million for Russia's MOX - program. Earlier, the USA has provided about $ 60 million on R&D on manufacturing and irradiation of MOX fuel based on weapons-grade plutonium. Allocation of the fixed assets to Russia's MOX program has also been expected from other G8 members.

The MFFF-R plant project, developed by a consortium of Duke Stone Cogema (DSC), which includes two American and a French companies, has been adapted for implementation in Seversk. The main problem faced by the international consortium is responsibility for damage in case of a nuclear accident at the MOX plant.

In 2004-2005, the MFFF-R construction contractor TVEL company has passed the approval of the declaration of intent and obtained a preliminary approval of the MFFF-R placement with the Seversk Municipality head. Another official document for discussion and assessment should have been a justification for investment in the construction of the MFFF-R. But in 2006, Rosatom withdrew its priority for the Tomsk site option to place the MFFF-R.

Despite this, in 2006, it was a construction site for a MOX fuel production plant prepared next to the radiochemical plant at the SCC.

5.3.1. The public opinion

Minatom’s plans to build a MOX plant at the SCC provoked the public protest. An initiative group of citizens appeared in Tomsk to collect signatures of protest against the construction of the MOX plant in Tomsk region. The negative attitude toward the plans for construction of the MFFF-R in Tomsk region was also shown by representatives of several business associations in

Tomsk. Over 10 thousand signatures of residents against the construction of the MFFF-R in Tomsk region were collected and sent to the regional government, Russian President, Russian government, and the U.S. Congress. Also, public appeals were sent to the state authorities of Tomsk region, municipalities, and parliamentarians of different levels.

In 2003-2004, Tomsk City Parliament discussed the proposed construction of the MFFF-R. At the initiative of several parliamentarians, in October 2003, a parliamentary commission was set, whose members unanimously believed that it is necessary to take into account opinions of Tomsk citizens in deciding on the MFFF-R construction. The public hearings held in the process of the Feasibility Study State Environmental Assessment do not ensure this right. With the assistance of lawyers, the commission developed a draft law of Tomsk region "On the procedure of discussion on nuclear energy use in the Tomsk region". Later, a draft regional law "On public nuclear energy commissions" was filed for consideration by the City Parliament committees by its Speaker Boris Maltsev. As of now, neither bills has support from the other MPs majority and neither has been reviewed by the Parliament committees.

Political parties did not remain aloof from the discussion on the MOX plant construction. Seversk city branch of the Edinaya Rossia (United Russia) Party decided to support the SCC development program, one of the main points of which is the construction of the MOX plant. Tomsk regional branch of the Edinaya Rossia's haven't taken a formal decision to support plans to build the MOX plant, but, at a regional conference of the Edinaya Rossia in November 2004, the Tomsk branch leader (of that time) Vladimir Zhidkikh outlined plans to support the MOX plant construction as one of the party's priorities.

In late February 2005, the SCC management approached the Tomsk right-wings with a request to listen to the nuclear industry's considerations on the construction of the MOX fuel production plant in the Tomsk region. The right-wings complied with a request of their pronuclear compatriots and invited the representative of the Complex to a joint meeting of the SPS (Soyus Pravykh Sil, Union of Right Forces) and the Yabloko regional branches. On March 3, at the joint regional SPS and Yabloko meeting, the SCC deputy general director Valery Mescheryakov failed to provide any weighty arguments in favor of the construction of the MOX plant. As a result, at the elections to the Tomsk City Parliament, the SPS-Yabloko bloc announced the struggle against the MOX plant as part of its election agenda, and has retained this issue even when the election campaign finished.

The SCC management has made statements that it will hold both mandatory public hearings on the construction of the MOX plant, and also conduct a public environmental impact assessment. However, at the moment it must be noted that there is no actual mechanism for accountability in the decisions made from the public environmental assessment and hearings in Tomsk region (as well as in other Russian regions).

5.3.2. Environmental impacts

The main argument provided by Rosatom and the SCC in favor of the environmental safety of the MOX-fuel production plant and the MOX-fuel loaded reactors is that several countries have similar plants and reactors operating for over 15 years, and Russia also has the Bor-60 and BN-600 reactors and the pilot MOX-fuel production in Dimitrovgrad [57, 10]. However, overseas there is very little experience in industrial production of MOX fuel using weapons-grade plutonium from dismantled warheads. And all Russia's experience consists of manufacturing just a few fuel assemblies using weapon-grade plutonium for the BN-600 at the NRRI in Dimitrovgrad. Yet, this was not dismantled warheads plutonium but freshly extracted plutonium dioxide of weapons-grade isotopic composition. A plutonium pit from a nuclear weapon has many other ingredients besides Pu 239 - the ingredients added to Plutonium to make a Pit are more secret than the ingredients in an American cigarette.

Current practice shows the unacceptability of the production and use of MOX-fuel made of plutonium extracted from spent fuel for more than 5 years ago. When decaying, the isotope plutonium-241 present in weapons-grade plutonium becomes the gamma-emitting radionuclide americium-241. When plutonium that has been separated is allowed to "age", the more dangerous and costly it is to deal with, because of the increasing ionizing radiation of the americium-241 [42].

The main environmental hazard of manufacturing of MOX fuel is related to the properties of plutonium. The natural environment around the SCC has over the years of the plant operation already accumulated a significant amount of plutonium. The accident of 1993 at the radiochemical plant has also contributed to the contamination of the surrounding SCC area with plutonium [42]. Today, in the zone of the SCC influence there has been no assessment of environmental risks caused by plutonium, americium and other radioactive and chemical elements entering the environment. Data available to date on the level of their accumulation in natural objects are insufficient for a full and objective evaluation of their risks and impact on biota and humans [52.54].

Maps of soil contamination including plutonium around plants analogous to the SCC - "Mayak" (Chelyabinsk region) and the Mining and Chemical Complex (Krasnoyarsk region) are available. No such maps have been made for the Tomsk region.

Nevertheless, some known data on the content of plutonium and americium in soils, sediments, biota objects suggest that their level is at least 4-5 times higher than the global background fallout resulting from nuclear weapon tests in the atmosphere, accidents and years of activity of nuclear fuel cycle enterprises [54].

In the production of MOX fuel and its use in nuclear reactors, plutonium inevitably gets into the environment. It is alarming that in early 2004, the DSC consortium proposed to organize the plutonium emissions control system no closer than 8 km from the perimeter of the MFFF-R.

According to the SCC estimations, the MFFF-R plant will annually produce about 2.5 thousand m3 of liquid radioactive waste, of which 20% of medium and high activity (MLW and HLW), and about 900 m3 of solid waste, of which about 50 % MLW and HLW[7, 8]. Along with that, so far the SCC has accumulated a record number of radioactive wastes. For 40 years of dumping liquid waste into underground aquifers at sites No. 18 and 18a, according to the SCC evaluations, more than 1.1 billion Ci of original activity of long-lived radionuclides have been dumped. The partially covered outdoor pools, pulp storages, water reservoirs, as well as solid radioactive waste disposal sites still contain about 125 million Ci of radionuclides, including plutonium.

The most significant concerns relating to the environmental hazards of the proposed placement of the MFFF-R at SCC site are the lack of plutonium contamination assessment in Tomsk region and the extreme congestion and activity of the selected construction site located in close proximity, just a few kilometers away from residential areas of cities of Tomsk and Seversk.

5.3.3. Probability of an accident with radioactive contamination of the area and evacuation of the population

The declaration of intent to build the MFFF-R plant states that the technical means and organizational protocols provided for preventing accidents and reducing their impact will result in a probability of 10^{-7} peryear that the maximum permissible accidental release will be exceeded.

It is well-known what such statements based on a probabilistic assessment of an accident possibility can mean in practice. Until 1986, a slightly less optimistic assessment of the likelihood - 10^{-6} reactor*years (one accident in 1 million years) for an accident of the global catastrophe scale at the RBMK-1000 (Chernobyl reactor type) was in use. After the Chernobyl catastrophe, the probability of an accident at the RBMK-1000 reactor was officially statistically increased by two degrees, i.e. to 10^{-4} (one accident per 10 thousand years).

Similarly, it would be difficult to discuss any project with the placement at the SCC of new large nuclear facilities with radiation hazard in the north wind of April 6, 1993.

The big drawback of a probabilistic assessment of accident potential is the impossibility of adequately taking into account human factors and external conditions such as meteorological situations.

The proposed estimate of expenditures from foreign donations to build the MOX plant in Seversk does not foresee dealing with the consequences of possible accidents with contamination of the areas and compensation to the affected population [48]. Along with that, the damage from the effects of a possible accident can be enormous and comparable to the effects of the Chernobyl accident.

Being aware of the long history of litigation of Georgievka residents affected by the accident at the radiochemical plant in 1993 with the SCC management, it is difficult to believe that the management of an exploiting organization will not contest the obligation to pay compensation. However, even if this is assumed, then the maximum upper limit of financial responsibility of the MFFF-R operating organization to the affected parties will be in accordance with existing regulations in Russia 40 million rubles only. [23]. No need to say how little this amount is.

In 1986, after the accident at the Chernobyl nuclear power plant the maximum amount of responsibility of the U.S. nuclear power plants has been raised from 500 million to $ 7 billion dollars [24]. However, this is not yet a sufficient amount. Total cost of Ukraine, Belarus, Russia and other countries to eliminate the consequences of the Chernobyl disaster from 1986 to 2015 will amount to at least $ 590 billion dollars [61]. Formally, in Russia only, 10 years after the accident annual payments to citizens who have become disabled and their families, as well as survivors, came to $ 240 million and exceeded the annual profit of the Russia's NPPs [17]. The relative costs of the main affected countries are also impressive: in 1994, costs associated with the aftermath of the Chernobyl disaster in Belarus reached 20% of the national budget, Ukraine - 4%, Russia - 1% [72]. This does not represent what was needed, only what was adopted as mandatory expenses. But the nuclear industry has its specific view of the damage that the Chernobyl disaster caused. For the development of the nuclear industry it is vital that the memory of the Chernobyl disaster is quickly erased or at least dimmed.

The Tomsk region does not have an effective system of early detection of accidental plutonium releases from the SCC. The system of automated radiation monitoring ASKRO, with observation posts located around the SCC, is not able to register releases of weapons-grade plutonium. Plutonium-239 is mainly an alpha-emitting, rather than (the more easily detected) gamma-emitting radionuclides. The most rapid way to detect plutonium in the air is the forced pumping of air with the subsequent complex radiochemical and hardware analysis of solid filtered sediment in a laboratory. Thus, the authorities have no independent monitoring system for emissions of plutonium. Like in the case of the accident of April 6, 1993, information about the accident can reach the regional authorities only several hours after the decision on the extent information to release is taken by Rosatom management. Moreover, in the event of a major accident with radioactive contamination it will be impossible to quickly evacuate the population of Tomsk and Seversk. Foreign experience of placing objects like the MFFF-R excludes proximity to major cities.

Indicators of the population around the nuclear fuel cycle facilities in different countries

	SCC, Russia	Marcuelle, France	Savannah River, USA
Number of residents in a 30-km zone	**700 000**	**150 000**	**50 000**
Presence of a major regional center in a 30-km zone	**Tomsk**	**No**	**No**
The nearest major settlement	**Tomsk, 7 km**	**Marseilles, 65 km**	**Augusta, 40 km**

In the case of the construction of the MFFF-R it would be easier for the nuclear industry to lobby for construction of other radiation-hazardous industries in Seversk. According to the former SCC CEO, and now director of the Tomsk Atomic Center Gennady Khandorin, a proposal to adjust the SCC radiochemical plant for reprocessing of spent nuclear fuel and build on its base the RT-3 plant is being discussed [74].

The responsibility towards the population of the regions where nuclear power plants in reactors of which Rosatom plans to use MOX fuel are located should not be forgotten. Reactors operating on MOX fuel, in comparison with conventional light-water reactors, have greater risks of accidents, and 4-fold greater possible extent of the effects of contamination and population exposure with plutonium [22]. A major reactor accident (core breech) would result in twice as many latent cancer fatalities than a similar event where uranium fuel only was in the reactor core. (Dr. Edwin Lyman, 1999)

The historical experience with nuclear energy proves the impossibility of giving "guarantees of not-exceeding a prescribed likelihood of an accident". Possible effects of large-scale accident at the MFFF-R exceed the asserted benefits of its location in Tomsk region. The main disadvantage of placing the MFFF-R at the SCC site is the threat of a major accident at a location in immediate proximity to the administrative center of Tomsk region, Tomsk city.

5.3.4. Economical risks for Tomsk region

Possible economic effects for the Tomsk region are considered assuming trouble-free operation of the MFFF-R.

England, Japan, France and Belgium have MOX fuel production and use experience, these were not profitable commercial projects but rather a way of getting rid of surplus plutonium rapidly that came from earlier decisions to reprocess spent nuclear fuel [51].

Arguments in favor of the MOX plant construction in Seversk may seem very significant. About a thousand jobs very to the point in Seversk in view of shutdown of the last two of the five nuclear reactors at the SCC, completion in 2012 of the he HEU-LEU program operations and cuts in military contracts. Some of Tomsk organizations may receive orders for manufacturing of equipment, building materials, and construction. Part of the taxes deducted by construction organizations, and then by an operating organization, will remain in the Tomsk region. It is asserted that the construction of the MFFF-R plant in Seversk will give a powerful impetus to the development of the Tomsk region economy, since the cost of construction, and, consequently, the amount of investment is about $ 1 billion in 2003 prices.

But the opposite effect can be no less expected. If the decision to build a plant to produce MOX fuel in Seversk is taken, Tomsk region may for many years lose much potential investments in science and education, the forest sector, and non-nuclear high-tech industries. Even with a loyal attitude of business to the fact of proximity to plutonium production, the inevitable strict regime in the surrounding areas will hamper the development of business [43].

An independent assessment of financial and investment risk for Tomsk region in the case of placing the plutonium production in close proximity to the regional center (7 km away from the residential area of Tomsk and 6 km from the residential area of Seversk) is needed. In order to avoid possible influence of Rosatom on the results of the audit, evaluation of financial and investment risk should be conducted by a foreign company with experience in similar evaluations. The audit should be commissioned by the Tomsk regional authorities, which is interested in obtaining an adequate assessment, but not in supporting the nuclear industry's position. The negative reaction of business to the operation of the Siberian Chemical Complex in the Tomsk region was clearly shown by the example of a joint Russo-German venture Romko. Despite the fact that Romko's timber cutting areas in Kargasok district were neither covered with the radiochemical trace of the accident at the radiochemical plant of April 6, 1993, nor fall within the zone of long-term impact of the SCC, the joint venture was liquidated on the initiative of the German side in summer 1993.

According to information of the SCC management, under the scheme of inter-budgetary relations of Tomsk region and Seversk of 2004 annual allocations to the regional budget as a result of the MOX plant operation, i.e. not earlier than 2010, should have counted for 105 million rubles. The relative contribution of the planned tax revenues to the regional budget from the activities of the MOX plant operation would amount to less than 0.3% of the regional budget.

According to the declaration of intent, total number of employees at the Seversk prototype of the Melox plant should be 850-1000 people. This would seem especially appropriate given that about 5 thousand people were employed at the reactors shut down in 2008. However, there is no such problem as lack of employment at the SCC and in Rosatom. The nuclear industry in Russia is suffering an acute shortage of qualified personnel. The average age of workers at nuclear power plants and nuclear fuel cycle facilities is approaching retirement. And the problem is not some sort of localized but systemic in its nature.

According to the SCC director general Vladimir Korotkevitch quoted in an interview to the Seversk weekly Novoye Vremya, in 2007, 4 thousand people more than 50 years old, and 2 thousand people aged over 60 were employed at the Complex. In 2008-2009, it was planned to retire from the reactor plant (this unit includes the stopped plutonium reactors) about 350 people only. And if Rosatom will allocate funds for long-term work on the decommissioning of the shutdown reactors, it would have to "decide on the promotion of retirement for men over 65 years". Speaking about the need for jobs for workers allegedly released after shutdown of the SCC reactors, the nuclear industry uses ideas that are easily understood by the people, but it is a false argument. A nuclear reactor cannot be just stopped, closed and left. It will take many years to put it out of the operation, with only a partial reduction of staff. And there is no tragedy in "the promotion to retirement for men over 65 years". On the contrary, it is too old to work at a nuclear reactor.

It is also necessary to mention the health of employees of the nuclear industry. Below are some data from the Federal Program "Medical care of the current stage of development of nuclear power complex and other high-risk industries in terms of missile, nuclear and chemical disarmament, as well as the conversion of the development of new technologies in 1997-1998", approved by the Russian government resolution № 191 of 22 February, 1997, and the materials of the Ministry of Atomic Energy Scientific Council that discussed an issue of "state of health of workers in the sector" in December, 1998 [1]:

- Frequency of diseases of the musculoskeletal system among workers exposed to ionizing radiation in 1997 was more than double the average for Russia.
- In 1997, the level of blood diseases among Minatom's professionals was more than 3 times higher than the average for Russia. The number of first identified patients with advanced stage of disease sharply increased.
- The primary incidence of mental disorders in a nuclear industry in 1997 exceeded the national average.
- The prevalence of congenital anomalies among children living in the closed municipalities attached to the nuclear industry objects was in 1995 more than double the average in Russia.
- Secondary immunodeficiency is typical for 80% of staff of extra-hazardous Minatom facilities.
- In the structure of disease incidence among professionals the first place is occupied by diseases caused by radioactive substances (45.1%).

Diagnostics in the nuclear cities and of employees of the nuclear industry is organized much better than in the country as a whole, and therefore more cases of abnormalities are detected. Along with this, the level of medical care and preventive treatment in the closed nuclear cities is also higher. Tighter control over the health of nuclear workers did not begin in the 90ies of the last century but much earlier. A more strict medical control helps to improve the health indications. It turns out that in the nuclear industry incidence rate should be significantly lower than the national average (due to better medical care), but in reality it is the opposite.

For an adequate assessment of plans to build the MFFF-R, it is important to understand why Rosatom, with the support of the large transnational nuclear corporations, refuses to consider other options for utilization of weapons-grade plutonium than to use it for production of nuclear fuel. There are two main reasons. The first one is that Rosatom is a contractor for utilization of weapons-grade plutonium, subject to foreign funding of the entire MOX program, i.e. it sells donated foreign funds or Russia's budget aid, providing its subordinate organizations with orders, jobs, and developing its own infrastructure. As a performer, Rosatom is interested in an expensive and long-term option for the plutonium treatment. The second reason is that the amount of uranium is reduced, and the MOX fuel would help avoid the exhaustion of nuclear energy fuel resources.

At the dawn of the atomic era, there was an extremely popular idea of "the discovery of an inexhaustible source of energy". Multi-year propaganda has resulted in the majority of our fellow citizens and, more importantly and dangerously, those responsible for making important strategic decisions, convinced that the only salvation from the impending exhaustion of hydrocarbon reserves is nuclear power. In fact, natural uranium is not only exhaustible, but may end sooner than hydrocarbons.

Annual consumption of natural uranium equivalent in 2003 was 67 thousand tons. At the same time, the production of uranium at the expense of its extraction practically has not increased and remains at 32-35 thousand tons [8]. Lack of production of uranium in the past 10-15 years is covered mostly by stocks and exports from the CIS countries and, primarily, from Russia. Important role in the temporary stabilization of the uranium fuel market played the HEU-LEU program under which Russia's stockpiles of weapons-grade highly enriched uranium are used for the manufacture of nuclear fuel.

At the current rate of consumption, world reserves of uranium will be exhausted by 2050. Russia is 5th in the world for uranium production and 7th for its proven reserves (180 thousand tons, of which only 30% are cost-effective for industrial development) [9]. The current production is not more than 30% of actual domestic consumption and less than 20% of exports.

According to the IAEA and Euratom, with the exhaustion of stocks of uranium the existing deficit of its production cannot be filled either by reprocessing spent nuclear fuel, or by installing new extraction capacities. At present, Russia is the leading supplier of uranium for nuclear power stations of the United States. In the framework of Russian-US agreement on the utilization of nuclear weapons stockpiles (the so-called HEU-LEU program), Russia undertook production of low-enriched uranium suitable for use as fuel for nuclear power plants out of 500 tons of Russia's weapons-grade highly enriched uranium (the isotope uranium-235). Then the fuel is sent to the U.S. nuclear power plants. However, the HEU-LEU program is close to its completion.

With the alleged date of commissioning and the rate of weapons-grade plutonium "recycling", the MFFF-R should have reprocessed 38 tons of metal plutonium by 2024. The prepared Russian-American agreement on the utilization of surplus weapons-grade plutonium has not determined what the fate of the MOX fuel production plant in Seversk will be after the end of the agreement in 2024. When answering questions from the Tomsk City MPs on the construction of the MOX plant, after his speech on October 21, 2003, the SCC CEO V. Shidlovskiy did not exclude the possibility that after 2024 the plant will produce MOX fuel using plutonium from energy reactors.

Despite the nuclear industry hopes, the "replacement" of ^{235}U fissile elements with ^{239}Pu in the nuclear fuel for light water reactors will not be a panacea for the looming fuel crisis for nuclear energy. Even if you do not take into account numerous difficulties and increasing risks of using MOX fuel in VVER-type reactors [17], or the rising cost of electricity generated with MOX, it is important to remember that light water reactors may only be partially loaded with MOX fuel in the so-called "hybrid zone" of these most common reactors (therefore uranium fuel must also still be in use).

6. Utilization of Plutonium: Public Opinion

At the end of December 2007, ROMIR (the Russia's largest independent research agency) held a public poll to determine public attitudes to the nuclear industry plans. The survey commissioned by the Ecodefense! group was conducted in nine regions of Russia. Speaking generally on the results of the study, sociologists noted that "in most cases, people are not indifferent to issues related to nuclear power plants operation and nuclear industry as a whole. Most often plans to construct new nuclear power plants and nuclear facilities cause a negative reaction from the population. So, responding to questions on the assessment of nuclear industry plans, the inhabitants of the studied regions and Russia as a whole more often give negative evaluations" [27].

Regarding to use of weapons-grade plutonium, the population's attitude is even more negative than to other plans of the nuclear industry.

Thus, in Sverdlovsk region, where the BN-800 which is planned to use MOX-fuel is under construction, 68% of the residents are negative to construction of new reactors, 73% are against use of fuel containing weapons-grade plutonium, and only 4% expressed a positive attitude to the plutonium program of Rosatom.

A ROMIR survey in Tomsk region gave similar results. According to the survey, only 5% of the Tomsk population responded the question "How do you feel about the fact that nuclear reactor fuel production with the use of weapons-grade plutonium may be placed in Tomsk region?" positively. The negative option was chosen by 71% of Tomsk residents. To the question "How do you feel about the planned construction of new nuclear power plant in your region?" Tomsk inhabitants responded as follows: 62% - negative, 11% - rather negative, 12% - positive, 5% - rather positive, 10% - no opinion. A similar poll in Chelyabinsk region revealed a similar disposition among the local population.

Tomsk region residents also believe that their opinion should be taken into account when deciding whether to construct the MFFF-R. According to an online survey conducted by the Tomsk state radio and TV company in December 2004, 789 of 861 respondents answered "Yes" to the question: "Does the opinion of Tomsk citizens have to be taken into account when planning the construction of the MOX-plant?"

According to an online survey conducted by the Tomsk TV-2 on October 18, 2004 (2537 respondents), 83% of respondents consider the 'peaceful atom' as environmental threat, 11% - as the future of energy, 6% as locomotive of the Tomsk science. Like the previous one, this survey is based on opinion of the active part of a specific TV company's audience.

The immediate attitude of the Tomsk residents to plans to construct the MFFF-R, independent of their affiliation to the consumers any specific media, is shown by a sociological survey conducted by TESI under the supervision of sociologist A.V. Konyashkin (Tomsk State University) in December 2004. Of 662 surveyed respondents, the question "Do you know that Minatom proposed to construct a new weapons-grade plutonium processing plant (the MOX-Fuel project) next to Tomsk?" 50% answered "Yes" and the same number replied "No". Regardless of this, the question "TESI opposes construction of the MOX-fuel producing plant. Are you ready to support the protest?" 83% of respondents answered "Yes" and pointed out various methods of the listed suggestions (protest signatures, participation in public action, etc.).

7. Utilization of Plutonium. Problem of Nuclear Non-proliferation

A need to construct new nuclear plutonium treatment facilities in Ulyanovsk, Sverdlovsk, Tomsk, and Krasnoyarsk regions Rosatom explains with Russia's international obligations to utilize surplus stocks of weapons-grade plutonium. One of the reasons for such utilization is to prevent the military use of weapons-grade plutonium, to prevent access to weapons-grade materials of non-nuclear weapons, as well as terrorist groups.

The total number of nuclear weapons produced worldwide is enough to destroy all life on the Earth multiple times. The United States, Russia, Britain, France, China, India, Israel possess nuclear weapons. According to Rosatom, about 270 tons of weapons-grade plutonium have been accumulated the world.

Rosatom insists on "the MOX option" for utilization of weapons-grade plutonium, which means to use it in production of nuclear fuel with irradiation of the latter in nuclear power plants' reactors. One of the conditions of the Russian-US agreement is a parallelism of their programs for plutonium utilization. The U.S. Department of Energy announced its intention to construct a MOX fuel production plant factory at Savannah River site in South Carolina.

Utilization of weapons-grade plutonium through the production and irradiation of MOX-fuel is presented as a solution to the problems of nuclear weapons non-proliferation. According to official statements, plutonium will be transformed to a form that is unsuitable for military use with another isotopic composition (so-called "reactor-grade plutonium"), while being a component of highly radioactive spent MOX-fuel. However, many of Russian and foreign scientists and specialists in the field of nuclear technologies conducted in the past 15 years prove the following:

1. Plutonium can be extracted from irradiated MOX-fuel. Technology for extraction of plutonium from spent fuel is already available in many countries.

Moreover, spent MOX-fuel is more attractive to potential buyers materials for making nuclear warheads than spent uranium fuel with the same degree of burnout.

Calculations carried out by the Kurchatov Institute showed that the degree of burnout 60000 MW × 24 hours / ton in a weapons-grade MOX fuel assembly of a VVER-1000 reactor will contain twice more plutonium than in a uranium fuel assembly [66].

Destruction of plutonium does not occur; there is only a change in its isotopic composition from the so-called weapons-grade to reactor-grade one taking place. In 1996, Russia's Minatom publicly declared its intention to reprocess spent MOX-fuel by extracting plutonium [73]. Radiochemical reprocessing of spent nuclear fuel is known to be the dirtiest part of the nuclear fuel cycle.

2. The main difference between reactor-grade plutonium and weapons-grade is the proportions of isotopes with mass numbers 239 and 240. The greater the proportion of ^{239}Pu in plutonium and the smaller the proportion of ^{240}Pu, the more effective it is for a nuclear explosive device.

Isotope proportion in weapons-grade and reactor-grade plutonium of uranium spent nuclear fuel [73]

Isotope	**Proportion %**	
	Weapons-grade plutonium	**Reactor-grade plutonium, exposure 33000**

		MW×24hours/tons
^{239}Pu	**93**	**56.5**
^{240}Pu	**6.4**	**23.4**
$\sum$ ^{238}Pu, ^{241}Pu, ^{242}Pu	**0.6**	**20.1**

The isotope ^{239}Pu ($T_{1/2}$ = 24 thousand years) is the most suitable because it is fissionable in result of thermal neutron capture and is quite stable in contrast to other fissile isotope of plutonium, ^{241}Pu ($T_{1/2}$ = 14 years), which also forms a strong gamma emitter 241Am while decaying. Isotopes ^{240}Pu and ^{238}Pu (the proportion of this isotope is low, so often only of ^{240}Pu is considered) are a hindrance for production of effective nuclear weapons, since they spontaneously emit neutrons able to cause the so-called "pre-initial ignition" which leads to significantly lower intensity of nuclear explosion.

Although pre-initial ignition reduces explosive capacity of a nuclear explosive device made from reactor-grade plutonium, "explosive capacity of a relatively simple explosive device with reactor-grade plutonium, similar to a bomb exploded in Nagasaki, is equal to about one or several kilotons, even if pre-initial ignition occurs at the least opportune moment" [65].

In Japan, Russia and some other countries, advocates of the use of plutonium in energy generation continue arguing that because of pre-initial ignition reactor-grade plutonium cannot be used in nuclear weapons, and that the plutonium programs in these countries should not be considered contrary to nuclear non-proliferation goals. But this is just PR-abstracts denied by facts recognized by the international scientific community. The U.S. National Academy of Sciences report of 1994 on disposal of nuclear weapons materials claims that "plutonium of virtually any isotopic composition can be used in nuclear weapons" [69].

Moreover, mechanisms to compensate for pre-initial ignition and other effects of using reactor-grade plutonium in nuclear weapons have been developed. Thus, pre-initial ignition problem is solved by accelerated implosion (convergence of blocks of fissile materials that together constitute a critical mass). For the diversion of excess heat generated during absorption of particles released at ^{240}Pu isotopes decay, plutonium charge is made in a shell shape (instead of a solid sphere) [28].

The difference of critical masses of reactor-grade and weapon-grade plutonium is low. If the material has the shape of sphere, then for α-phase critical mass of weapons-grade plutonium will be equal to 11 kg, and of reactor-grade plutonium – to 13 kg. For more convenience in reprocessing and manufacturing of nuclear charge Δ-phase of plutonium, these values will be equal to 17 and 20 kg, respectively [63].

The most striking example of nuclear power contribution to nuclear proliferation is Canadian-Indian cooperation. In 1974, in the Thar Desert, India tested a nuclear explosive device using plutonium produced in the Canadian CANDU reactor.

3. Implementation of the MOX program requires mass transportations of plutonium and plutonium-containing materials that increase the risk of theft and terrorist acts on the railway, as nuclear facilities involved in Russia's plutonium program, are located in thousands of kilometers away from each other.

4. These indicated rates of "utilization" of plutonium through the production and use of MOX-fuel (up to 3.5 tons of metallic plutonium per year from each side, summing up to a maximum of

7 tons) does not even cover the rate of production of reactor-grade plutonium consisting in spent nuclear fuel. Annually 70 tons of reactor-grade plutonium consisting in spent fuel as shown above, is feasible for use in nuclear weapons are produced at nuclear power plants worldwide. World stocks of weapons-grade plutonium recovered from warheads by the year 2000 was 160 tons. Thus, use of weapons-grade plutonium in production of nuclear fuel and its subsequent exposure at nuclear power plants cannot be a solution to the problem of surplus weapons-grade fissile materials.

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