

RISK AND SAFETY



THE FAR EAST



NUCLEAR TECHNOLOGIES
AND ENVIRONMENT

Risk and Safety

The Far East

Nuclear Technologies
and Environment

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This brochure addresses a wide range of experts in environmental or radiation safety; decision-makers in the field of environment or public protection in the case of radiological emergencies; public environmental organizations; students, and those who are interested in the issues of stable development of Russian Far East.

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The Russian Federation

FAR EASTERN FEDERAL DISTRICT





INTRODUCTION

Geographically, the Far East is Russia's most eastern part covering Primorsk/Khabarovsk Krai, Amur/Magadan/Sakhalin/Kamchatka Regions, Koryak/Chukotka Autonomous Districts and Jewish Autonomous Region. The Republic of Sakha (Yakutia) is usually considered as part of the Far Eastern Federal District (FEFD) too. The FEFD is particularly notable for its huge areas (almost 40% of Russia's territory) and its considerable remoteness from main industrial centers of the country.

The FEFD covers the area of 6.2 mln. sq. km and extends for more than 5 ths. km from north to south. In the south, Russia shares its land frontiers with Korean People's Democratic Republic, Mongolia, and China, as well as its sea frontiers with Japan, Korean People's Democratic Republic, USA, and Canada. Nearly 7 million people live in the Far East. Varied natural climatic conditions (from a polar and sharply continental climate in the north to a monsoon one in the south-east of the District) have stipulated for non-uniform settlement/development of the areas. In polar regions, the density of population is extremely low (0.1 man/km²), while this index reaches 14 man/km² in the south (Primorsky Krai or south of Khabarovsk Krai).

The District is rich in varied minerals, such as tin/tungsten/lead-zinc/iron ores and diamonds. The Far East is one of the most important gold fields of Russia. District's own energy resources comprise coal deposits, oil and gas fields. Its rivers have considerable hydro-energy resources and are rich in valuable fish species. The potential for using the World Ocean's resources is huge.

When developing the Far East, the Russian state has always aimed to preserve control over the most important strategic reserves of raw materials, as well as to enter the system of international labour division in the Asian-Pacific Region, thus, having provided itself military/political/economic influence in the Pacific basin.

Being purely military initially, the expansion of Russian Empire to the east gradually turned into industrial development of the region by the late 19th century. State support for railroad building served as a spur to the growth of business activity. Owing to the inflow of capital/resettlers/workers,

the sea/river navigation as well as the trade developed. Coal mining started and first hydro-electric power stations were built. Soon after the Civil war and intervention, the Soviet authorities began to recover destroyed economy of the Far East and started socialist reforms. In the 1930s, sizeable investments were funded to speed up industrialization. In 1932, the Far Eastern branch of the All-Union Academy of Sciences was created to fully involve natural resources of the District in the production process. The armed conflict with Japan on Lake Khasan in 1938 followed by the Great Patriotic war for long interrupted the process of industrial building. It recovered only in the 1950s-1970s, when large industrial metallurgical/oil-chemical/coal/woodworking enterprises emerged in the region. Cities and rural settlements enlarged considerably. Scientific potential started to reinforce and the network of research institutes began to develop.

Nuclear technologies spread in the Far East in the 1960s. A striking force of Soviet nuclear submarines was placed, as well as the bases of technological service and ship repair plants were established on the Pacific coast in the “Cold War” years. “The peaceful atom” was used as well. Radioisotope Thermoelectric Generators (RTGs) began to be installed along the coastline for the purpose of energy supply of the lighthouses located in areas difficult to access. In the early 1970s, the Bilibino Nuclear Power Plant (NPP) was built for energy supply of mining and gold-mining facilities in Bilibino settlement, Chukotka. The Komsomolsk (Far Eastern) and the Primorsk NPPs were planned to be built, however those plans never were actualised.

In 2006, the Government made a decision to speed up the development of Russia’s nuclear energy-industrial complex to provide for geopolitical interests and power safety of the country. New construction of nuclear power plants is not envisaged in the Far East until 2015, though in the Primorsk authorities declared for the construction of a new NPP. The prospects for using mobile floating nuclear plants are discussed in Kamchatka/Chukotka. It is no wonder, as durable operation of the Bilibino NPP in Chukotka and that of nuclear submarines in Kamchatka certify to reliability and environmental compatibility of nuclear technologies.



However, the majority of the Far East people do not believe that the peaceful atom can be safe, especially after the 1985 submarine accident in Chazhma Bay, Primorsky Krai and 1986 Chernobyl accident. The messages on radioactive contamination of the environment by the Pacific Navy sites still emerge in local mass media. Orphan RTGs remain the focus of public attention in Chukotka. To what extent are public concerns justified? To answer the question, it is necessary to analyze whether any risk exists for the public to be exposed during normal operation of nuclear sites; whether the potential for large radiological emergencies exists in the region; and if respective organizations/authorities are ready to implement effective actions on public protection in the case of radiological emergencies. All these questions are addressed in this brochure.

The first part of the brochure evaluates radiation effects during normal operation of nuclear sites and compares them to other industrial risk factors. The authors analyze the data of state surveillance and environment-protective services as well as the results of Russian and international expeditions whose teams studied radio environmental consequences of Russia's nuclear fleet activity. All the references are listed at the end. Official data on the radio environmental conditions caused by the nuclear fleet operation are given in CD "The White Book-2000" attached to the brochure.

As regards a large radiological emergency, such probability cannot be excluded theoretically. Therefore, the second part of the brochure is dedicated to the items of emergency forecast/prevention at nuclear- and radiation-hazard sites. And the last part describes the emergency response system and gives some idea of who is responsible for radiation protection of the public, how notification is performed, what emergency measures are and when they are required.

This brochure addresses a wide range of experts in environmental or radiation safety; decision-makers in the field of environmental or public protection in the case of radiological emergencies; public environmental organizations; students of higher education institutes, and those who are interested in the issues of stable development of Russian Far East.

NUCLEAR TECHNOLOGIES IN THE FAR EAST

Nuclear power installations have been used in the Far East for almost half a century. First, these are ship reactors of Nuclear Submarines (NS). In the former USSR, the NS bases existed in Primorye, Khabarovsk Krai and Kamchatka, while today they exist only in Kamchatka. The Bilibino NPP with four power reactors is located in Chukotka. More than a hundred of lighthouses and RTG sites exist along the coasts of Sakhalin, Kuril Islands, Chukotka and other places.

Nuclear reactors contain nuclear material, and, on certain conditions, the potential exists for the accidents caused by the development of an uncontrolled chain fission reaction (a nuclear hazard). Apart from it, certain radioactive chemical elements are generated during nuclear reactions (a radiation hazard). Therefore, the NS ship reactors and the NPP power reactors are of potential nuclear and radiational hazard. The RTGs are only of radiational hazard as they do not contain nuclear material.





Nuclear Fleet

Nuclear power implementation in the military shipbuilding started in this country in the middle of the last century. The first NS was launched in the White Sea in July 1958. The first commissioning of a submarine reactor took place in the Far East in 1960. Overall, an unprecedented number of nuclear submarines and surface vessels was built for the USSR's Navy. By the 1990s, their general number had amounted to nearly 250 units. In parallel, a comprehensive, ramified and specific infrastructure was established with basing points, coastal/floating technical bases, ship repair plants, and vessels designed for radioactive waste collection/storage/processing/transportation.

Upon the end of the arms race, the Soviet Union assumed the obligations to reduce its nuclear arsenal. Disarmament programs coincided with the end of the operation lifetime of 1-st and 2-nd generation submarines (30-40 years). The number of decommissioned NSs awaiting the dismantling increased rapidly, and the probability for severe emergencies, including those with radio-environmental effects, grew with time.

The scale, duration and technical complexity of the activities have placed the NS dismantling among priority national tasks. In 1995, the dismantling program was given the presidential status. However, a heavy economic situation of that time did not make it possible to secure required resources and proper arrangements. The situation started to change in 1998, when Minatom of Russia (The state corporation "Rosatom" at present) was assigned as a state customer-coordinator of the activities. After that number of dismantled NS started to increase gradually. The current dismantling activities are financed by both the federal budget and off-budget funds (involvement in the economic turnover of secondary resources/equipment obtained during dismantling), as well as under international cooperation programs.

Nuclear Technologies in the Far East





Location of Nuclear- and Radiation-hazard Fleet Sites

- ◆ NS is based in Krasheninnikov Bay in Kamchatka.

- ◆ Berthing-places for decommissioned submarines or surface nuclear ships/vessels of Atomic Technological Service (ATS) are located as given below:
 - Primorsky Krai — Razboyinik, Abrek, and Pavlovsky Bays, and
 - Kamchatka — Krashenninikov and Seldevaya Bays.

- ◆ Sites for dismantled NS are as follows:
 - Primorsky Krai — Razboyinik and Bolshoy Kamen' Bays, and
 - Kamchatka — Seldevaya Bay.

- ◆ Coastal infrastructure for NS dismantling is represented by:
 - Primorsky Krai — ship repair plant “Zvezda” in Bolshoy Kamen'town and “SRZ-30” plant of the Ministry of Defence's in Dunai settlement;
 - Kamchatka — North Eastern Center for Ministry of Defence's military equipment repair/dismantling.

- ◆ Sites for spent nuclear fuel/radioactive waste management are as follows:
 - Primorsky Krai — DalRAO facility (affiliate No.1) in Fokino town,
 - Kamchatka — DalRAO facility (affiliate No.2) in Viljuchinsk town.

Radiation Consequences of Nuclear Fleet's Activity

The NS have a multi-barrier radiation protection system to keep radio nuclide releases into the environment below safety standards. In practice, radio nuclide contents are tens and hundreds of times below the admissible levels in the immediate proximity to atomic ships. There was neither supernormative radiation exposure of the public during the overall normal operation of the NS in the Far East nor significant radio environmental consequences, except for the 1985 submarine accident in Chazhma Bay, Primorsky Krai (see below).

Apart from radiation hazard objects are the NS bases, coastal and floating sites of technological service, and ship repair plants. Some of them are located in the vicinity of residential areas. For 45 years, the radio environmental status has been of the background level (Table 1) in

■ No excess in public exposure dose limits has been observed for 45 years of NS operation/dismantling in the entire Far Eastern Region

practically all such residential areas in the Far Eastern Region. A contribution of human-induced radionuclides to the total radioactivity of atmospheric aerosols is registered by special methods. Sometimes sensitive devices register aerial radio nuclide activity of Co-60, Sr-90 or Cs-137 above natural background levels at the border of industrial territories. For instance, that happens at the “Zvezda” plant borders upon Bolshoy Kamen’ town due to the NS dismantling work.

The registered radio nuclide concentrations are hundreds or thousands of times below the Maximum Permissible Concentration (MPC) levels and tens of thousands of times less than natural radio nuclide concentrations in the surface air.

The many year submarine operation has not entailed deterioration of the radiation status in the technical areas of a major part of Fleet’s sites (80%) and their internal water areas. For instance, the radiation environment has remained of background level in Krasheninnikov Bay, Kamchatka, for 40 years of NS basing and for 20 years of NS berthing, when waiting subma-



rine dismantling. The same can be said for the situation in Razboynik Bay where the three-compartment reactor blocks have been stored since 1991.

Only in a few Fleet's sites (20%) there are local spots of radioactive contamination in their technical areas (in immediate proximity to the wreck submarines or nearby the containers with solid Radioactive Waste (RW), or at the berthing-places of special vessels). There, the levels of

TABLE 1.

Range of Gamma Exposure Dose Rate in Areas Adjoining Administrative Borders of Fleet's Sites [1].

| Settlement | Pacific Fleet's Sites | Exposure Dose Rate, Sv/h |
|------------------|-------------------------------|--------------------------|
| Vladivostok city | 30-40 km from sites of basing | 0.06-0.16 |
| Big Stone town | 0.5 km from the Star plant | 0.08-0.19 |
| Andreevo | 3 km from the Star plant | 0.09-0.15 |
| Tchaikino | 1 km from the Star plant | 0.07-0.15 |
| Temp | 1.5 km from the SRZ-30 plant | 0.08-0.15 |
| Razboynik | 1 km from the SRZ-30 plant | 0.08-0.18 |
| Dunai | 3 km from the SRZ-30 plant | 0.08-0.15 |
| Rakushka | NS berthing (until 1998) | 0.012-0.26 |
| Pavlovsky | NS berthing | 0.010-0.18 |
| Zavety Ilyicha | NS berthing (until 2007) | 0.05-0.17 |
| Viljuchinsk-3 | NS basing/berthing | 0.03-0.15 |
| Seldevoy | Ns repair/dismantling | 0.02-0.12 |
| Viljuchinsk town | 15-20 km from NS basing | 0.04-0.17 |

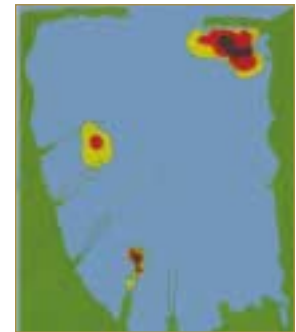
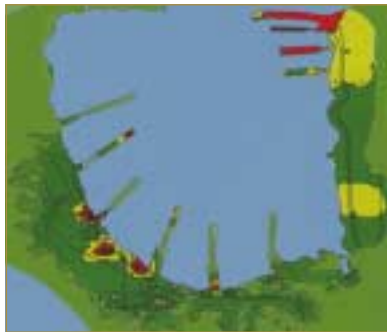
In the South of Primorsky Krai, the natural radiation background varies from 0.07 to 0.29 $\mu\text{Sv/h}$.

Nuclear Technologies in the Far East

specific radio nuclide activity in soil and sediments may exceed Navy's admissible standards by 10 times (references to the standards see in p. 20). As a rule, the linear size of these sites ranges from a few to tens of meters. They only reach hundreds of meters in 2 cases: at the ship repair plant in Chazhma Bay and in Pavlovsky Bay around the two wreck submarines located at the pier adjoining the Bay exit (see scheme below). Naturally, permanent radiation monitoring has been arranged in the zones and the time for personnel stay there is strictly limited. The emergency submarines are placed far from the localities and trespassers on the technical areas is prosecuted. So, the wreck submarines do not have a negative impact on the residents.

As for contaminated sediments in the internal water areas, human-induced radionuclides, as a rule, are bind to soil, while their concentrations do not exceed the MPCs in organisms, algae, fish, scallop, crabs or shrimps living on the bottom.

Pavlovsky Bay: gamma dose rate in technical area (on the left); two wreck nuclear submarines in the area of maximum exposure (central); and contamination of bay bottom (on the right). Color ranges: background level of 0.08-0.2 $\mu\text{Sv}/\text{h}$ as green; 0.2-0.6 $\mu\text{Sv}/\text{h}$ as yellow; 0.6-2.4 $\mu\text{Sv}/\text{h}$ as red; and above 2.4 $\mu\text{Sv}/\text{h}$ as brown.





Accident in Chazhma Bay, Primorsky Krai, 1985

The history of Soviet/Russian Navy's nuclear fleet has known several severe radiological emergencies related to submarine operation. However, practically all of them were of local nature and only the August 1985 accident on K-431 submarine in Chazhma Bay was accompanied by a considerable radio nuclide release into the environment.

The accident occurred due to violation of the working technology, when loading the reactor with fresh nuclear fuel. A spontaneous chain reaction took place. At that time, the reactor dome was not fastened and, the fuel assembly was thrown out from the reactor as a result of heat explosion. 10 people from the reloading brigade died immediately. A radioactive cloud formed. A fire that had occurred was suppressed four hours later.

The combustion products jointly with large radioactive particles fell out around the affected submarine within the radius of 50-100 m. Radioactive contamination impacted the vessels being in immediate proximity, as well as part of the shipyard's area and part of the Chazhma water area. The maximum gamma-rate was 10-20 thousands of times higher than the background in the vicinity of the affected submarine.

The initial size of the radioactive cloud was 20-30 m at the 50 m height. Afterwards, it started to enlarge and further spread, owing to the northwest wind, to the direction of Vladivostok city. The cloud crossed the Dunai Peninsula in the form of a narrow strip and reached the eastern coast of Ussuri Bay. When the cloud moved over the bay which width is about 30 km, the density of radioactive fall-outs decreased to the background level at the dis-

■ Main part of the radioactive releases fell onto the ship repair plant's territory, the Chazhma water area and onto a desert part of the Dunai Peninsula. The accident did not impact the radiation status either in Vladivostok or in other localities, including nearest to the plant villages Temp, Razboyinik, and Dunai

Radioactive Contamination by Cobalt-60 in Bottom Sediments and Soil after the NS Accident in Chazhma Bay in 1985 [1].





tance of 15-20 km from the coast, without impacting the radiation status in Vladivostok or its suburbs. Therefore, basic radioactive fall-outs deposited on the plant's territory, in the Chazhma water area and in a desert part of the Dunai Peninsula.

Some 30% of the ship repair plant's territory was exposed to heavy radioactive contamination. Nearly 2,000 people were involved in decontamination work. Half a year later, the plant operated as usual. The greatest doses were obtained by the military personnel who turned out to be in the place of accident and by those who suppressed the fire on the submarine. Acute radiation sickness developed in 7 people, and 39 people exhibited some of its symptoms.

The same year, the K-431 submarine with a concrete-poured reactor was transported to the berthing-place in Pavlovsky Bay, on the other side of Strelok Gulf. And a new 100-300 m radius area of contaminated bottom sediments was formed in the berthing-place.

As a result of the accident, mainly short-lived radionuclides of iodine and noble gases (their half-life period being minutes and hours), as well as Co-60 and Mn-54 (their half-life period being 5.3 years and 312 days respectively) entered the environment. The share of long-lived radionuclides of Sr-90 and Cs-137 (their half-life period being nearly 30 years) was quite small; therefore two months later, seawater radioactivity fell almost to the background level in the epicenter of the accident.

The bottom sediments radioactivity was stipulated mainly by Mn-54 and Co-60 radionuclides. Sea currents discharged them partly from the plant's water area into the open part of Chazhma Bay and, afterwards, into Strelok Gulf. By 1990, the boundaries of radio-contaminated bottom sediments were stabilized. In the south, this area is limited by the

■ Human-induced radio nuclide concentrations do not exceed 0.01 times the MPC at all environmental sites at the distance above 500 m from the accident place

central part of the Putyatın Island and by Abrek Bay in the north (see scheme). Afterwards, the contaminated area began to reduce. Decreased rate of radio nuclide discharges from Chazhma Bay, silting, and radioactive decay contributed to the reduction. Since 1997, behind the plant's administrative borders the dose rate was below 0.60 Sv/h.

Today, human-induced radionuclides are under the silt layer of the 3-40 cm depth in the epicenter of the accident; though, continue to remain on the surface in the sites of rock yield. The Co-60 content reaches 1,000-3,000 times the MPC in the most contaminated sites. Apart from it, small fragments of the destroyed core that were not taken from the bottom during the plant's decontamination and that generate quite intensive radiation are under the silt layer too. At the same time, Co-60 concentrations do not exceed 0.02 times the MPC in seawater, 0.1-0.6 times the MPC in algae, and are less than 0.01 times the MPC in fish and hydrocole (crabs/shrimps etc.).

In the area of coastal radioactive trace in the desert part of the Dunai Peninsula, radioactivity decreased 10 times or more for the first 8 days after the accident. The greatest density of contamination was revealed in the forest site of the 200-650 m width and the 3.5 km length. The trace dimensions reduced for the past years, owing to natural radioactive decay of Co-60 and its penetration into soil to 10-40 cm. In single spots, soil contamination reaches 2-5 times the MPC, though radio nuclide content in vegetation remains less than the admissible standards.

On the opposite side of the radioactive trace in Ussuri Bay, Co-60 concentrations in bottom sediments are significantly less than in the coastal trace. Immediately after the accident, the maximum level at the bottom reached nearly 4 times the MPC. Six years later, it was less than 1.5 times the MPC, and below 0.2 times the MPC at the distance of 700 m from the coast. Radio nuclide concentrations in seawater were tens or hundreds of times below the MPC from the moment of radioactive trace forming.



Radioactive Waste Disposal in Seas

For many years, RW disposal in the World Ocean was practiced by leading nuclear states, including the USSR. Overall within 1946-1982, 14 countries performed RW disposal in 47 areas of the Pacific/Atlantic Oceans. Apart from the Russian Navy, Japan/South Korea/New Zealand disposed of RW in the Pacific Region. In 1957, the International Atomic Energy Agency (IAEA) started to develop a methodology on RW safe disposal of RW in seas. In 1972, the London Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter was signed. The London Convention was followed by a number of regulatory recommendations issued by IAEA. Finally, in 1983, member-countries declared a voluntary moratorium on at-sea dumping of any radioactive waste. Russia joined the moratorium in 1994 [1].

In contrast to other nuclear states, this country buried in seas only RW resulting from the nuclear fleet's operation. Ten areas were chosen for disposal at the distance of tens or hundreds kilometers from the coastal line (see the maps). For instance, the areas of RW dis-



Areas where liquid RW was discharged (1-7, 9, 10) and solid RW is flooded (6, 8, 9, 10) [1]

posal in the Sea of Japan are separated from the shelf by the 3.5 km deep-water cavity, as well as by warm and cold streams.

High activity waste was not discharged into seawater. At standardized discharges, experts proceeded from the fact that a zone radius of contaminated seawater with radio nuclide concentrations above 1 MPC should not exceed 1 km. RW disposal to a particular area was performed in the 5-12 year interval.

The area of radio-contaminated seawater never reached the shelf zone or the coastal line during liquid waste discharges. Already several days after the discharge, human-induced radio

■ Human-induced radio nuclide concentrations in sea products fished out have never exceeded the MPC for the entire period of RW discharges into the sea of Japan

nuclide concentrations in seawater did not exceed admissible levels. Due to different dilution rates in varied areas of the sea, a triple reserve coefficient was introduced into the standards. For 40 years, this reserve justified itself only once, in early 1986, when the accident occurred on a submarine in Pavlovsky Bay and the activity of liquid radioactive waste was twice of the standards.

In the USSR, the Navy's activity on RW disposal into seas was strictly regulated practically from the very start-up. By a number of parameters, the procedures/requirements designed for the soviet fleet were stricter than, for example, those for the US Navy. From the standpoint of current radioecology, in the majority of cases the MPC values in seawater were significantly lower for the Navy than it is required for public and environmental safety provision now. In 1966, for instance, the Navy's regulatory documents (VSTZ-66) established the value of 3.7 Bq/l for the Cs-137 MPC in seawater. In 1990, the level decreased to 2.2 Bq/l (RKVS-90). At the same time, the current standards (RSS-99) have established the value of 11 Bq/l for Cs-137 MPC in drinking water.



Radio nuclide concentrations in sea products fished out have never exceeded the MPC for the entire period of liquid or solid waste discharges into the Sea of Japan. The environment and the public were even less impacted by RW disposal in open areas of Northwest part of the Pacific Ocean near the Kamchatka Peninsula, where the depths reach 4-5 km.

The first detailed information on RW sinking in Russia's seas was published in the 1993 Government Commission's report unofficially titled "The White Book-1993". The report concluded that the radio environmental status of the seas had deteriorated significantly, as a result of the domestic nuclear fleet activity. However, international marine expeditions and comprehensive research run by Japan, South Korea, Russia and the IAEA after 1993 have revealed no impacts on radiation environment in the Pacific Region due to the activity of Russian nuclear fleet or owing to the work of Japan and South Korean NPPs. This conclusion was confirmed by a group of eminent domestic experts under the lead of Yuri V. Sivintsev. They had collected and analyzed unpublished archive material and data on the domestic nuclear fleet, including NS dismantling. The research results are represented in the monograph "Technogenic Radionuclides in the Seas Surrounding Russia. The White Book-2000" (attached on the CD).

However, the experts' conclusion on insignificant radio environmental effects of RW sinking does not mean that it is necessary to revert to the above practice. Since 1994, Russia has been observing the moratorium on at-sea dumping. For future it is considered RW processing, long-term storage and final burial in isolated underground repositories.

- VSTZ-66 - The Temporary Sanitary Requirements for At-Sea Disposal of Radioactive Waste. The document was approved by Commander-in-Chief of the Navy and Deputy Health Minister of the USSR and enacted by the order of Commander-in-Chief of the Navy in 1966.
- RKVS-90 - The Guidelines for Monitoring Environmental Radioactivity at Mooring, Recharging and Repair Sites for the Ships with NPI. The document was approved by First Deputy Commander-in-Chief of the Navy in 1990.
- RSS-99 - The Radiation Safety Standards (SP 2.6.1.758-99). The document was approved by Senior State Sanitary Officer of the Russian Federation in 1999.

Bilibino Nuclear Power Plant

The Bilibino Nuclear Power Plant (BNPP) built in the mid 1970s provides for the life activity of mining and gold-mining enterprises in Chukotka and Bilibino settlement where nearly 7,000 people live. The BNPP generates electric/heat power and its total power makes up 48 MW.

Remotedness from the country's industrial areas, difficulties in and seasonality of cargo transportation have stipulated basic requirements for the BNPP design, such as high reliability, easy service and repair, the minimum volume of building activities and operation in the isolated power system. The plant has four same-type reactors placed in one reactor premise.





The nuclear heat and power plant is the sole source of heat power in the area, where the heating season lasts for 9 months a year. When the projected time for operation of the reactor blocks (30 years) expired, the NPP management fully supported by local administration and the public submitted a request to extend its operation term. Every unit was fundamentally repaired and enhanced so that the system and equipment characteristics might meet current safety requirements. Following the procedures of international environmental certification, the plant's management made a public announcement of its policy in the safety field. This announcement approves the primacy of nuclear and radiation safety over the requirements for generated power and profit earning (www.rosenergoatom.ru). In the summer of 2006 the sanitary and hygienic examination has confirmed that the BNPP's activity in the radiation safety field corresponds to current standards and procedures. Upon profound expertise run by surveillance authorities in 2004-2006, the operation term for all four reactors was extended for another 15 years.

Preparatory activities for plant's decommissioning are in process in compliance with the Federal target program "Development of Russia's Nuclear Energy Complex for the 2007-2010 Period and for a Prospect until 2015". The item of alternative sources of energy supply for the region after the BNPP is decommissioned remains open. On the one hand, decrease in the rate of Region's development has entailed the reduction of electricity requirements. The average

The service life extension for nuclear power units is widely used in the USA, Great Britain and other countries. In the USA, for instance, 20 power units have the lifetime extended from 40 to 60 years. France and Japan are in the process of arranging similar activities. In Russia, the 30-year operating life standard was defined in the 1950s-1960s, when there was a lack of actual data on NPP equipment wear. The experience gained since then made it possible to justify the opportunity to review this 30-year term. By late 2007, it was extended for 11 domestic power plant reactor units. The results are submitted to the IAEA

load on the BNPP for the past five years has been about 30% from the power established. On the other hand, already today gold-mining companies request 46 MW. In the prospect, also tin and copper-porphyrific deposits are planned for development. Apart from it, replacing powers will soon be required due to wear of the equipment at the Chaunsk heating plant and its decommissioning in the town of Pevek.

After the year 2015, varied options may be considered: among them is a transfer to coal energy, construction of the BNPP's second line or the two floating NPPs in Pevek and in Chersky settlement. The final decision will depend on the development program for Chukotka Autonomous District and the overall Far Eastern region.

Radiation Effects of Bilibino Nuclear Power Plant

In 5-km zone of observation around BNPP radiation monitoring is performed on a permanent basis. By Roshydromet's data, the plant works without exceeding admissible discharges/emissions.

■ Radiation dose rate ranges from 0.08 to 0.11 $\mu\text{Sv/h}$ within the 100-km BNNP area, that corresponding to natural background level throughout the Russian Federation's territory

It should be noted that introduction in 1999 of new sanitary procedures for design/operation of the NPPs has toughened the standards on total radiation impact of the NPP on the public and the environment. The admissible dose, stipulated by gaseous and aerosol releases or liquid discharges, was established as 0.02 mSv/y. Health risks from such dose are considered

negligibly low. Actual emissions/discharges from the BNPP are significantly lower than standard values.

In recent years, actual radio nuclide discharges into the open hydrographic network jointly with liquid effluent have not exceeded 1% from admissible levels. The average annual radio nu-

Radioisotope Thermoelectric Generators



clide concentrations of Co-60, Sr-90 and Cs-137 in the waters of industrial storm sewage containing uncleaned unbalance waters from the BNPP are 10-100 times below the intervention levels established by the radiation safety standards for drinking water. In the Bolshoyi Ponneurgen stream where industrial storm sewage is discharged without treatment, radioactive contamination of bottom sediments by long-lived radionuclides of Cs-137 and Sr-90 is significantly lower than the values minimally valuable from the standpoint of radiation safety. Human-induced radionuclide concentrations in the reservoir located at a distance of 3.2 km from the BNPP and being a source of water supply for Bilibino settlement are below the background level.

Radioisotope Thermoelectric Generators

Radioisotope Thermoelectric Generators (RTGs) are used for energy supply of not-attended weather stations, lighthouses or other equipment. The RTG's solid multi-layer steel body contains radioactive substances, such as Cs-137 or Sr-90. As a result of radioactive decay of long-lived radionuclides, a heat current can be supported for tens of years. Due to this heat, a thermoelectric battery functions and is able to generate power as high as tens of watt.

Being in a solid container, the radioactive source does not represent a risk; though, direct human contact with an unprotected source may lead to overexposure, including fatal outcome.



Sites where 2 emergency RITEGs dropped

Regardless of small dimensions (6 1.4 1.1 m), the RTG weight may reach three tons. Helicopters are used to transport such installation. For the entire period of RTG operation in the Far East, they fell twice into the sea during their transportation by helicopters. The first case occurred in 1987, when the helicopter transported the RTG by means of the bracket system to the area of Nizky Cape on the Eastern coast of Sakhalin. In 1997, ten years later, the situation recurred in the area of Mary Cape in Sakhalin (see the map). The seawater samples taken from the sites where both RTGs sank do not contain excess Sr-90 concentrations.

Search for sunken RTGs was performed several times by the forces of the Pacific Fleet and EMERCOM of Russia. Only once, in 2006, the divers found single plates of the protective radiator in the specified square in the Okhotsk Sea (area #2 in the map), though, the radiation source was not discovered. Search was accompanied by measurements of gamma-radiation in the plates, bottom sediments and algae. The radiation level did not exceed natural background. In September 2007 the radioactive source was found and lifted aboard. The solid container was not damaged. Gamma radiation dose rate in the place of the source finding was of the background level. The source was safely transported to the RTGs storage in Sysoev Bay, Primorsky Krai. Search for the sunken RTG in the area #1 (see the map) will continue.

As a rule, no inhabited localities exist in the vicinity of the sites of RTG installation; anyway, the sites must be protected. Though in recent years, this condition was far from being adhered to everywhere; therefore, there were cases when RTGs were lost or stolen. In July 1998, for instance, the customs officers from Primorye discovered a dismantled RTG in the scrap metal reception point in the Korsakov commercial port. They revealed that the RTG had been stolen by scrap collectors.

A damaged RTG was situated on Navarin Cape in Chukotka. A cross-country vehicle is supposed to have disrupted it in 1999. The prohibited area was established within 150 m radius from RTG where radioactive strontium-90 concentrations exceeded hundreds of times the

Comparison of Industrial Risks



admissible level. In 2007 the RTG was placed into a shipping cask and transported to the place of RTGs storage in Sysoev Bay.

The RTGs' operation life is about 11 years. As of today, more than 30% of previously installed generators have exhausted their resource. All exhausted installations are transported to the temporary storage point in Sysoev Bay where a special RTG repository has been built with American assistance in 2006. Rosatom plans to dismantle all Russian RTGs by 2012. Budget funding for a number of activities on RTG decommissioning is envisaged by the Federal target program "Nuclear and Radiation Safety Provision for the Year 2008 and for the Period until 2015".



Transportation of expired RITEGs to Sysoev Bay

Comparison of Industrial Risks

After presenting radioecological consequences of nuclear technologies usage, let us compare them with environmental effects of some traditional kinds of industrial activity.

Hazard from bad substances dispersed in the environment can be measured basing on sanitary and hygienic requirements, first, MPCs. If the content of a harmful substance in the environment below MPC it is considered safe for a human being. If concentrations exceed the MPC level, a health risk occurs. It is not always possible to define unambiguously the extent of the risk, as the value of potential damage much depends on the strictness of the require-

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Should a risky exposure dose be compared to the height of the Ostankino television tower, the dose limit for the public would correspond to one brick thickness

ments approved by the state with respect to the provision of public health protection from this particular kind of substance.

Let us illustrate it by comparing normative approaches to the effects caused by harmful chemical and radioactive substances. Compare, for instance, environmental contamination by lead, one of the most wide-spread and hazardous inorganic substances, with that caused by Cs-137 that may enter the environment in case of a radiological emergency.

Lead enters the environment jointly with emissions/discharges from the non-ferrous metallurgy enterprises, or as a result of corrosion of varied lead linings, including lead-acid batteries. However in cities, the most important way is entering with car exhaust, when using ethyl gasoline with tetraethyl lead additives. Lead hazard for human is stipulated by its high toxicity and its capability to accumulate in the body. Lead accumulation is accompanied by nervous system affection, mental deterioration, a decline in physical activity, or movement disorder. Lead anemia or endocrine system impairment may develop. Lead is especially hazardous for children.

Aerial average annual lead concentrations in the Far East's large cities, such as Komsomolsk-na-Amure and



Vladivostok, reach 0.4-0.5 g/m³, that being somewhat higher than the MPC (0.3 g/m³). Children's organisms have proved to accumulate metal at such levels. When aerial contamination by lead compounds is above 20 times the MPC, general intoxication in the adult body begins to develop. Therefore, lead standards do not practically have a "safety margin", as functional changes in human body can be observed even when the MPC level is exceeded insignificantly.

Cs-137 is beta- and gamma-radiating isotope of cesium. MPC for Cs-137 concentrations in drinking water make up 11 Bq/l. Russian Radiation Safety Standards (RSS-99) have established this value, proceeding from the following. If within a year an individual consumes daily two liters of drinking water containing such Cs-137 concentrations, the annual effective dose for him will be less than 10% of the 1 mSv/y value, the admissible limit for human-induced public exposure (i.e. the tenfold safety margin is envisaged by the MPC).

In its turn, the 1 mSv/y dose limit also has, at least, the tenfold safety margin. Theoretically, the potential for a damage of biological molecules exists at any whatever small exposure dose. Though, the risk that human organism could not cope with the damage and develop a disease is negligibly low at small doses. In practice until now, harmful health effects of radiation have not been observed at the exposure doses below 10 mSv/y and can hardly be revealed even theoretically.

Radiological science assumes an increase of risk for cancer development in the remote period after exposure within the range of 10 through 200 mSv (with a latency period of 5 to

■ Accident-free use of nuclear power does not have a negative impact on the public or the environment, while chemical contamination of the environment is quite an actual and even more severe risk to the residents of large cities or industrial settlements

30 years). When a dose exceeds 200 mSv, an increase in the frequency of remote cancers among exposed persons becomes statistically significant. General intoxication (acute radiation disease symptom) in adults begins at doses above 2,000 mSv obtained for a short time period (seconds, minutes or hours). Therefore, if the Cs-137 concentration in drinking water is below the MPC, the exposure dose is, at least, by 100 times less than a dose entailing potential remote effects or by 2,000 times less than a dose leading to acute disease symptoms.

The conclusion from the lead and Cs-137 comparison has more general nature. The MPCs for many harmful chemical substances have no “safety margin”, while the MPCs for human-induced radionuclides have 2-3 mathematical orders “in reserve”. So, when assessing the risk associated with the use of nuclear and other industrial technologies, it is necessary to bear in mind that the approach to regulation of the radiation factor is much stricter, as compared to the chemical factors.

Chemical Contamination

The major part of the Far East’s natural environment has not been yet affected by human activity. Though, severe anthropogenic contamination takes place in single areas, first, in large cities, such as Vladivostok, Khabarovsk, Komsomolsk-na-Amure, Petropavlovsk-Kamchatsky, Yuzhno-Sakhalinsk, etc. Environmental problems accompany such activities as mining or non-ferrous metal processing. Work at mines/queries leads to the extraction from land tenure of considerable number of agricultural and forest lands. The area of affected lands amounts to tens of thousands of hectares in the south zone where above 80% of minerals are extracted by the open-cut method. Also, significant human-induced transformation occurs with regard to chemical composition of plant/soil cover, atmosphere, or surface and underground waters.

Powerful source of anthropogenic contamination is represented by facilities pertaining to the fuel-energy complex. Low-coal lignite extracted mainly in South Yakutia is a traditional

Comparison of Industrial Risks



energy carrier in the Far Eastern Region. Small brown coal deposits exist in the Amur Region, Sakhalin, Kamchatka and Primorsky Krai. The cost of local coal is 1.5 times cheaper for consumers, as compared to imported coal, and, therefore, it is widely used for common needs of the public and the industry. At the same time, coal-fired plants and boiler-houses are poorly equipped with environment-friendly equipment; therefore, sizeable volumes of contaminants enter the atmosphere.



Coal pit development in Sakhalin

Water contamination. The Amur River and its tributary the Ussuri are the main rivers in the Far East. Both are chemically contaminated due to effluent discharges by Russian and Chinese industrial facilities. Accident discharges are especially hazardous. Communal effluent also enters river water. In accordance with the Ministry of economic and external relations of the Khabarovsk Government, China contributes most to it, as the Chinese population size in the Amur River basin outbalances the size of the Russian population by 15-20 times (<http://www.adm.khv.ru>).

Water quality in the Amur River deteriorates from the category “medium contaminated” (categorization by Roshydromet Agency) in the area of Blagoveshchensk to that of “contaminated” in Khabarovsk or “dirty” in the cities of Amursk, Komsomolsk-na-Amure, and Nikolaevsk-na Amure. Average annual concentrations of copper, lead, manganese or phenols available in river water in these cities exceed 20-50 times the MPC. The Chernaya and the

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Berezovaya Rivers in the Amur River basin, as well as the Dachnaya and the Podkhorienok Rivers in the Ussuri River basin relate to the category “extremely dirty” [3].

Severe focal contamination of small rivers is observed in Sikhote-Alinj Mountains and in Sakhalin where mining of minerals and/or their initial processing is under way in valleys. For instance, heavy metal concentrations in the Rudnaya River flowing along the Sikhote-Alinj eastern slope and falling into the Sea of Japan are of the level of 10-40 times the MPC and those of boron reach the level of 5 times the MPC, owing to contaminated effluent discharges



Zolotoi Rog Bay



by the facilities involved in mining/processing of tin and polymetallic ores. Though, the Okhinka River on which shores oil-producing enterprises are located has remained the most contaminated for decades. Oil products concentrations in the river reach 400- 500 times the MPC and correspond to the level of extremely high contamination, while maximum concentrations have reached 2,886 times the MPC. Water in the majority of other rivers in Sakhalin (above 60%) relates to the category “contaminated”.

Contamination has a negative impact on both the status of environmental systems and life quality of the public. River water is the basic source of household drinking water supply for 70% of the residents in Priamurye. Only 5% of water supply falls on underground sources in Khabarovsk and 13% does in Komsomolsk-na-Amure. At the same time, almost 40% of water pipes in the Far Eastern Region lack a full complex of sewage disposal plants, as well as 12% do not have any disinfection installations. In 2004 for instance, 25% of selected water samples were not appropriate to hygienic standards from the standpoint of sanitary chemical indices, while 10% did not correspond by microbiological ones. The use of low quality drinking water results in outbreaks of acute enteric infections and the spread of type A viral hepatitis.

Considerable volumes of contaminants enter the seas jointly with river water. Apart from it, plenty of industrial/communal/port facilities from seaside cities do not have essential treatment plants and discharge effluent directly into coastal waters.

The most human-induced load falls on Peter the Great Bay where a lot of settlements, railroads, the Vladivostok/Nakhodka seaports are located. Shipyards, the facilities pertaining to mining, fish-processing, power, building, food and light industries, and agriculture contribute to it too. Oil hydrocarbons or synthetic surface-active material as thin film cover large water areas. Plenty of organic compounds and heavy metals are available in water or bottom sediments as emulsified or thin balanced forms in the vicinity of a contaminated source.

Amur Bay, Zolotoi Rog Bay and Ussuri Gulf adjoining the city of Vladivostok represent the most contaminated part of the Peter the Great Bay. Zolotoi Rog Bay located in the center of Vladivostok is surrounded by multiple berths and is the most contaminated water area. Overall water surface happens to be covered by oil film. In summer time contamination by oil products exceeds 20 times the MPC. Multiple excess phenol/copper/iron/mercury concentrations are registered.

Air Contamination. According to the data provided by the state observing system, a high or a very high level of air pollution was registered in 2002-2006 in 15 cities of the Region where more than 2.7 million people reside (55% of urban population in the FEFD District). In 2005, the list of Russian most polluted cities covered Petropavlovsk-Kamchatsky, Magadan, Ussurijsk, Yuzhno-Sakhalinsk, Komsomolsk-na-Amure, Khabarovsk, and Blagoveshchensk.

Basic chemical pollutants in the urban atmosphere are suspended substances, formaldehyde, phenol, nitrogen dioxide, and benzpyrene. Energy enterprises and auto transport are the main sources of air pollution in the above cities.

Suspended substances in the air are particles of dust, ash, soot or other substances generated during burning of all types of fuel or during other processes. Long-term impact of suspended particles leads to respiratory or circulatory diseases.

Benzpyrene relates to 1-st class (the highest) hazard substances and is carcinogenic.

Nitric dioxide is 2-nd class hazard substance impacting the respiratory, immune or cardiovascular systems.

Phenol is 2-nd class hazard substance impacting the cardiovascular and the central nervous systems, kidneys, and liver.

Formaldehyde is 2-nd class hazard substance; has irritant, allergic, mutagenic or carcinogenic effects and increases carcinogenesis caused by other substances, in particular, benzpyrene

Comparison of Industrial Risks



Sizeable heat stations contribute most to air pollution, when emitting sulphur and nitric oxides. Though, small boiler-houses, main heat suppliers for dwelling houses, emit more carbonic oxides than the boilers of Dalenergo and the Primorsk hydroelectric power plant taken together. Small boiler-houses often not equipped for waste treatment are located directly in the residing area. Their low chimneys restrict the potential for a spread of harmful emissions in the atmosphere. Under conditions of dump climate and billowy relief, local air pollution turns out to be significant.



Auto transport ranks either first or second in the contribution to air pollution in cities. The unsatisfied technical status of auto transport, low quality car fuel, and bad roads are the main causes for that.

Adverse health effects of polluted atmospheric air or contaminated water and soils are maximal in large industrial cities/localities where gold-mining enterprises are located or polymetallic ores mining/dressing is performed. See below for the two examples.

Vladivostok (Primorsky Krai). Vladivostok, the largest city in the Far Eastern Region, is populated by more than 0.6 million residents. The air is heavily polluted in single districts of Vladivostok where benzpyrene or suspended particles concentrations are above 20 times the MPC and nitric dioxide concentrations are more than 30 times the MPC. Above half of the pol-

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lutants enter urban air from auto transport. The situation is complicated by the fact that traffic jams are frequent in Vladivostok's narrow streets.

A smoke plume emitted through the pipes of the coal-fired heat station # 2 can be traced as far as 8-10 km northeast and covers almost one third of the city. Also, 38 large and about 1,400 small boiler-houses provide heat for Vladivostok. In windless weather, aerial releases jointly with mist create heavy smog over single districts of the city. The heat station # 2 pollutes Vladivostok and the water area of Ussuri Bay by natural radioactive elements and heavy metals. The downtown sites have been revealed to contain soils intensively contaminated by lead/zinc/antimony or other elements which concentrations exceed tens times the MPC.

Rudnaya Pristanj Settlement (Primorsky Krai) is located in Dalnegorsky district on the shore of the Rudnaya River flowing into the Sea of Japan. 5,000 people reside in the settlement. The city-forming enterprise is represented by a lead-melting plant using lead concentrates. The plant's equipment was made within 1935-1973 and has become out of date at present. The entire area of the settlement, especially its central part within the 1 km radius from the plant, is extremely contaminated by heavy metal compounds, first, lead which concentrations in soil range between 30-120 times the MPC. Rudnaya Pristanj has been officially defined as the locality of hazardous contamination for human health.



Blanch transportation to the lead-melting plant in Rudnaya Pristanj settlement



Conclusions

Table 2 and 3 represent the results of the analysis we performed with respect to the factors of chemical and radiological risks in the Far East. Table 2 summarizing radiological data indicates that sanitary-hygienic or environmental standards have not been exceeded for half a century of using nuclear technologies.

Table 3 indicates that the levels of varied chemical pollutants in atmospheric air or river water exceed tens of times the MPC or that soil contamination in zones intended for building reaches 100 times the MPC or is even higher. It allows us to make a conclusion that chemical contamination of the environment is quite an actual and even more severe risk to the residents in large cities and industrial settlements.

■ Chemical contamination of the environment is quite an actual and rather severe risk to the residents in large cities and industrial settlements

If the reader was not familiar with the issues of radiation safety, this conclusion may surprise him as it contradicts to widespread notions. Actually, environmental friendliness of nuclear technologies is simply explained. In nuclear power, the products of nuclear fission, i.e. nuclear waste, remain within fuel without emitting into the environment, as it occurs in traditional power engineering based on organic fuel. It is a tremendous environmental advantage of nuclear reactors. Though, a highly potential radiation hazard is its reverse side, since a huge amount of radioactive substances is concentrated in reactor installations.

We shall narrate about the radiation safety provision at the sites of Nuclear Fleet and the Bilibino NPP in the Part II.

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TABLE 2.

Human-induced Radio nuclide Concentrations in Natural Environments outside Technical Areas of Nuclear- and Radiation-hazard Sites [1]

| Nuclear- and Radiation-hazard Sites | Environment | Times in Excess of MPC |
|--|---|---|
| Pacific Fleet's sites | Coastal or near coastal zones outside technical areas | < 0.01 (⁹⁰ Sr, ¹³⁷ Cs) |
| Areas of RW sinking | The Sea of Japan and Northwest of the Pacific Ocean | < 0.01 (⁹⁰ Sr, ¹³⁷ Cs) |
| Radioactive trace following the accident in Chazhma Bay (1985) | Water area outside administrative borders of the plant: <ul style="list-style-type: none"> • Bottom sediments, seawater, algae, fish and hydrocole; • Soils in the surveillance zone of the Dunai Peninsula | <0.01 (⁶⁰ Co, ⁹⁰ Sr, ¹³⁷ Cs) <0.01 (⁶⁰ Co, ⁹⁰ Sr, ¹³⁷ Cs) |
| Sites where RTGs sank in emergency | Seawater | < 0.01 (⁹⁰ Sr) |
| Emergency RTG on Navarin Cape | Soil outside the 150 m prohibitive zone | < 1 (⁹⁰ Sr) |
| Bilibino NPP | The 30 km surveillance zone | < 0.01 (⁶⁰ Co, ⁹⁰ Sr, ¹³⁷ Cs) |

Comparison of Industrial Risks



TABLE 3.

Times in Excess of MPC by Contaminant Concentrations in Environments of the Far Eastern Region in 2004-2006, [4-10].

| Environment | Location | Substances | Times in Excess of MPC |
|-----------------------|---|----------------------|------------------------|
| Amur River waters | Amursk city | Copper | 30-49 |
| | | Lead | 10-20 |
| | Komsomolsk-na-Amure | Copper | 20-30 |
| | | Manganese | 30-42 |
| | | Lead | 2-4 |
| | Nikolaevsk-na-Amure | Phenols | 30-40 |
| Rudnaya River waters | Krasnorechensky settlement | Copper | 5-10 |
| | | Zinc | 20-40 |
| | | Manganese | 10-30 |
| | Dalnegorsk city | Boron | 2-5 |
| Okhinka River waters | In sites of effluent discharges from oil fields | Oil products | 500-2886 |
| Near coastal seawater | Golden Horn Bay in summer time | Oil products | 10-20 |
| | | Phenol | 2-10 |
| | | Copper | 2-30 |
| | | Iron | 2-20 |
| | | Mercury | 2-4 |
| | Nakhodka Bay | Copper | 2-6 |
| | | Iron | 2-50 |
| | | Zinc | 2-3 |
| | | Lead | 2-10 |
| | | | |
| Air | Vladivostok | Benzpyrene | >20 |
| | | Suspended Substances | >20 |
| | | Nitric Dioxide | >30 |
| | Yuzhno-Sakhalinsk (2004) | Nitric Dioxide | 5-15 |
| | | Soot | 10-30 |
| Soil | Vladivostok | Lead, arsenic, zinc | 4-15 |
| | Rudnaya Pristan | Lead | 30-120 |

RADIATION SAFETY PROVISION

Radiation safety for nuclear reactors is provided by creation of subsequent protective barriers on the way of potential radio nuclide spread in the environment. For instance, the NS physical barriers retaining radioactive substances in assigned volumes or boundaries comprise a fuel matrix, fuel containment, a reactor vessel, a reactor enclosure, a reactor compartment, and a solid submarine hull. Apart from it, a buffer area exists to protect the public from radiation-hazard sites. The objective to preserve the integrity/efficiency of physical barriers is provided, owing to obligatory performance of organizational and technical measures. Selection, training, retraining, and attestation of specialists with regard to their knowledge of technological processes and safety requirements protect personnel from potential errors. Should physical barriers be destroyed, personnel/public/environmental safety is provided by available emergency actions or plans, as well as by staff training for their operative implementation.

When designing nuclear power installations, all scenarios and potential ways of accident occurrence are reviewed and analyzed. If an accident takes place due to events unconsidered by the design, it is called a beyond-the-design-basis accident. Its worst option is a spontaneous chain reaction involving the destruction of protective barriers, as well as radioactive release into the environment. The scale of emergency consequences at nuclear installations is referred by the International Nuclear Event Scale (INES). The INES scale has levels from 1 to 7 (see Table 4). The Chernobyl accident has been assigned Level 7, the highest. The 1985 Chazhma accident on the K-431 submarine relates to Level 5.

Let us see how radiation safety is provided at the sites of NS dismantling and what emergencies are potential there.



Complex Dismantling of Nuclear Submarines

Generally, sequence of the NS dismantling activities is as follows. After a nuclear submarine is decommissioned from the Navy, it remains at the berthing-place for a certain period of time to be further transported to the plant for dismantling. The initial operation of the dismantling process is unloading of Spent Nuclear Fuel (SNF) from the NS reactor. It is a complicated and potentially hazardous operation; therefore, the unloading technology is agreed every time with regulating and surveillance authorities. Fuel assemblies are extracted from the core and placed into special protective casings inside shipping casks. To reduce radioactivity the latter remain in the repository for some time before they are transported for processing.

After the SNF is unloaded, workers cut off the reactor block. Most often, it consists of three compartments (the reactor and the two adjacent sections), or sometimes it comprises four to six ones. The work is performed at a building berth or on a floating dock. Thanks to that no inadmissible radioactive pollution of the air or contamination of the areas/water areas at the shipyards occurs. The reactor block is launched into water and transported to the site of temporary storage in the water area. Afterwards, a one-compartment block is made out of the three-compartment one for the purpose of its long-term storage on the coast.

Equipment dismantling and melting of single parts of the reactor block may take place in 70-100 years with the aim to reuse metal. The reactor blocks available on a special site under control do not represent a threat to either the public or the environment. Therefore, the item of their further dismantling deals with economic expediency (the ratio between the storage term and the prices for metal, etc.).

■ After the SNF is unloaded the submarine is no longer a nuclear-hazardous object

NS Dismantling in the Far East

61 of 78 nuclear submarines decommissioned from the Navy have been dismantled recently. As of early 2008, 5 submarines are in the process of dismantling and another 12 are awaiting their turn, 14 of them containing the unloaded SNF.

Workers withdraw fuel assemblies from the core through the coastal complex or the floating repository and place them into special casks. In Primorye, the casks are stored on the territory of the Star plant. In Kamchatka, the SNF casks are loaded into the repository of a floating technical base that delivers fuel to Primorsky Krai, either to the coastal base in Sysoev Bay or to the railroad terminal at Dunai village. There, workers reload the casks into special railcars to be further transported to the Mayak facility in Chelyabinsk Region for processing.



Storage of three-compartment reactor blocks afloat in Razboyinik Bay

Transportation of nuclear submarines that have lost their floating properties represents quite a complicated task. Several such submarines are available in Pavlovsky Bay in Primorsky Krai, and in Krashennnikov Bay in Kamchatka. Case specific tugging projects are developed every time. The need to increase an organizational-technical level of preparatory activities has become evident after the “K-159” submarine sank during its transportation in the Barents Sea in August 2003.

Complex Dismantling of Nuclear Submarines



After cutting the nuclear submarine in Primorye, workers tug its three-compartment blocks from the “Zvezda” plant to Razboyinik Bay. The construction of a cutting line to create one-compartment blocks is under way at present in the vicinity of the site designed for storage of three-compartment blocks afloat. One-compartment blocks will be stored at a special coastal site which is presently under construction in Ustrichny Cape. In Kamchatka, three-compartment blocks still remain in the water area of the shipyard to be further transported to Razboyinik Bay for the purpose of creating one-compartment blocks.

A plan exists for Ustrichny Cape to establish also a single site for long-term storage of the 3 wreck submarines that have remained afloat in Pavlovsky Bay for more than 20 years. Prior to that, the submarines will undergo special plant treatment.

If the current dismantling rate remains, all decommissioned NSs must be cut off by 2010 in compliance with Rosatom’s plans. Afterwards, the reactor blocks will be placed in Razboinik Bay for temporary or long-term storage (www.minatom.ru).

Dismantling of Surface Vessels and Ships of Atomic Technological Service

As of early 2008, two nuclear surface vessels of the Pacific Fleet were decommissioned but one still contains the SNF. The nuclear- and radiation safety provisions for such vessels are similar to those solved during submarine dismantling.

Four vessels of Atomic Technological Service (ATS) await dismantling. The ATS vessels provide for the loading of nuclear submarines and surface vessels with fresh fuel and also are used to take and transport the SNF/RW. The ATS vessels will be dismantled by individual projects/technologies approved by state authorities jointly with safety regulators. Besides, dismantling will cover two contaminated repair ships where defect nuclear fuel was stored before 2002, namely: one in Primorsky Krai and one in Kamchatka. Their dismantling is planned for the coming years.

TABLE 4.
International Nuclear Event Scale (INES) for Nuclear Power Plants

| Scale Level | Effects outside NPP Site | Effects on NPP Site |
|---|--|---|
| 7 Major accident | Major release: widespread health and environmental effects (Chernobyl, Ukraine, 1986) | Radiological barrier destruction |
| 6 Serious accident | Significant release: likely to require full implementation of planned countermeasures (Mayak Facility, Russia, 1957) | Radiological barrier destruction |
| 5 Accident with off-site risk | Limited release: likely to require partial implementation of planned countermeasures | Severe damage to reactor core/radiological barriers |
| 4 Accident without significant off-site risk | Minor release: public exposure of the order of prescribed limits | Significant damage to reactor core/radiological barriers/fatal exposure of a worker |
| 3 Hazardous incident | Very small release: public exposure at a fraction of prescribed limits | Severe spread of contamination/acute health effects to a worker |
| 2 Incident | No release: no overexposure to the public | Significant spread of contamination/overexposure of a worker |
| 1 Anomaly | No release: no overexposure to the public | Anomaly beyond the authorized operating regime |
| 0 Deviation | No safety significance | |



Potential Emergencies

The most probable emergency situation resulting from NS dismantling operations is the loss of control over a radioactive source. For example, radioactive materials may be accidentally introduced into scrap metal generated from the dismantling operation. There then exists the possibility that human exposure may occur during transportation activities before the contamination is discovered.

Accidents entailing significant radioactive contamination outside the industrial site are much less probable. The fact is that the number of gaseous radioactive substances able to spread quickly onto large areas is quite insignificant at the sites of dismantling, while solid or liquid waste represents the overwhelming majority of radioactivity in the region. Solid waste is localized and, in principle, cannot spread rapidly in the environment. If liquid waste penetrates into the water area, pure waters will dilute it for several hours, that significantly decreasing its hazard.

The maximum “design-basis” accident at shipyards is a fire occurrence in the reactor compartment during the submarine dismantling at an open berthing site (owing to technology violation or due to personnel errors). The effects may reach Level 4 by the INES scale, that signifying “an envisaged accident”, i.e. in the shipyard’s area.

In the case of the maximum beyond-the-design-basis accident, its consequences may be hazardous to the environment (but no higher than level 5 by the 7-grade INES Scale). This may happen during the SNF management procedures that are the most potentially hazardous out of all kinds of the NS dismantling activities.

What may happen during an accident entailing the sinking of nuclear submarines, NPI-based vessels, or floating technical bases with RW/SNF aboard? Theoretically, it is possible that all protective barriers may open simultaneously. Supersensitive devices can reveal human-induced radionuclides at a distance of tens or hundreds of kilometers from sunken objects, though, radioactive concentrations will be much lower than the MPC. Macroalgae or bottom

organisms may be subject to quite a severe radioactive threat within the radius of several tens of meters from sunken objects. The changes in such volumes associated with radiation effects are not able to cause a reproductive shift in the natural balance of marine biocenosis. In practice, there was no salvo discharge of radionuclides into the sea water when the “K-159” submarine sank in the Barents Sea in 2003. Radiation monitoring data reflected natural background level.

Special submersible barges (See the photo) have been recently used to prevent sinking of the NS containing unloaded nuclear fuel and devoid of floating properties. In the Northwest, the three submarines have been successfully transported in that way to the shipyard in Severodvinsk. Starting from 2008, such experience will be used in the Far East.



Emergency submarine is transported by submersible barge, 2007

Spent Nuclear Fuel/Radioactive Waste Management

Long neglected, the issue of SNF/RW management had led to the situation when the repositories/reservoirs of Navy's coastal bases were overfilled, the infrastructure fell into decay, and storage conditions did not meet safety requirements. After the year 2000, Minatom of Russia (Rosatom at present) started to take active efforts to solve these issues within the scope of NS dismantling activities.



To remediate the sites for coastal storage of RW/SNF in the Far East, a special facility DalRAO was created with a leading office in Vladivostok and the affiliates in the towns of Fokino (Primorsky Krai) and Viljuchinsk (Kamchatka). After nuclear- and radiation-hazard sites of the Pacific Fleet in Sysoev Bay (Primorsky Krai) and in Gorbushachja Bay (Kamchatka) were transferred to DalRAO, intensive activities started to recover the systems of physical, nuclear, and radiation protection and to reduce environmental risks at the sites.

In Primorsky Krai, under international assistance programs the plant “Zvezda” was equipped with solid waste compacting line, floating complex for liquid waste processing “Lily-of-the-Valley”, costal complex for SNF unloading. Apart from that new metal-concrete containers were developed for SNF storage, and a special site for their temporary storage at the plant area.

Now the total amount of accumulated LRW is constantly reducing, however progress is not so evident in the field of solid waste. As of today, single large waste has been fragmented, removed from open sites, packed and placed in the repositories. The item of creating the melting installation for solid metal waste has not been solved yet for the coastal base in Sysoev Bay. To transfer low- or intermediate-level solid waste into a safe state, it is necessary to create a regional center for processing and long-term storage. It is also necessary to transport solid waste from Kamchatka to Primorsky Krai.

Reconstruction of the railroad site from the plant to Smolyaninovo station and from Sysoev Bay to the same station will allow accelerating the rate of SNF delivery to the “Mayak” facility and increase its transportation safety. The decision on these items was made within the framework of the Federal target program “Nuclear and Radiation Safety Provision for the year 2008 and for the period until 2015”.

International Assistance Programs

Russia is actively involved in the international system of agreements/treaties/conventions on general items of nuclear, radiation and environmental safety provision, when using nuclear power. Cooperation in the field of dismantling/remediation of radiation-hazard sites decommissioned from the Navy and the Nuclear Civil Fleet started in 1991 and has passed several milestones.

In the first years, the international programs were mainly aimed to assist Russia in liquidation of nuclear weapons. In the 1990s, Russia obtained financial assistance from the USA for the program of strategic submarine disarmament/dismantling within the scope of the American-Russian non-proliferation program. In particular, the equipment delivered by American side to the Far Eastern plant “Zvezda” amounted to 6 million USD.



“Lily-of-the-Valley” floating complex for LRW processing (“Zvezda” plant)

In 1993, to assist Russia in liquidation of nuclear weapons, Japan secured 70 million USD for these purposes; however afterwards, the amount increased to 208 million USD.

With time, the priorities of international cooperation started to shift to the field of radiation safety provision during disarmament activities. To prevent liquid radioactive discharges from entering the Sea of Japan the above mentioned floating complex “Lily-of-the Valley” was constructed for the plant “Zvezda”. In the Program “Global Partnership against Proliferation



of Weapons/Material of Mass Destruction” started in 2002 special measures on radiation safety provision during NS dismantling and SNF/RW management were included as well. The sum of \$20 billion from the Global Partnership Program covers the 10-year period. No less than \$2 billion out of this sum will be spent on NS dismantling and remediation of the fleet’s radiation-hazard sites.

Under the Global Partnership Program the American side financially supported dismantling of 11 nuclear submarines and the SNF land-based repository construction at the “Zvezda” plant. The repository is equipped with all state-of-the-art safety systems, including the Automated Radiation Monitoring System (ARMS), video surveillance, reliable communications, and the fire alarm system. In 2006, the RTG repository began operation in Sysoev Bay thanks to the financial assistance provided by American side too.

Japan also joined the Global Partnership Program. In 2004, the Victor class submarine was dismantled within the scope of the “Russian-Japanese Activities Plan” in the Far East. In 2005, an agreement was signed to dismantle another five multi-target submarines; the first one was already dismantled. Australia and Canada also expressed their wish to participate in complex dismantling of Russian nuclear submarines in the Far East. The Australian government has decided to join Japanese activities, while Canada will fund the reconstruction of the railroad from the plant “Zvezda” to Smolyaninovo station, as well as the dismantling of three submarines at the “Zvezda” plant when the Russian side transports them from Kamchatka.

Involvement of the increasing number of the states in these international programs has put on the agenda the item to develop a strategic Master Plan defining a general outline of the activities, as well as precise plans for every specific trend. The development of this plan for the Northwest Region started in 2004 within the framework of the International Program “Northern Dimension Environmental Partnership”. The strategic Master Plan plays a positive role in arranging the activities in the Northwest. Rosatom plans to use this approach in the Far East too.

Bilibino Nuclear Power Plant

The main objective of radiation safety at the NPP is personnel/public/environment protection from radiation impacts. With this aim, the following actions are performed:

- ◆ Permanent control over radiological indices reflecting the status of NPP equipment or the plant's premises belonging to the reactor sector;
- ◆ Localization of RW or other radioactive sources within the established boundaries of the plant's constructions, as well as in all operation modes;
- ◆ Automated radiation monitoring of the environmental status around the NPP.

We will briefly narrate the radiation safety provision at the BNPP.

Radiation Monitoring at the BNPP

Radioactivity levels in the NPP premises during normal operation of the reactor are significantly lower than admissible values, though they may increase in the period of repair or overload activities. Therefore, permanent control over the content of radioactive gases/aerosols is performed and the dose rate is measured, as well as the levels of surface contamination of the premises/equipment/working clothes/personnel. The objective faced by the service of internal dosimetry is to perform radiation monitoring at the plant and carry out the measures on radiation protection of personnel.

Control of the premises is performed via stationary systems that measure the levels of ion-



Operator's working place in internal dosimeter service at Bilibino NPP



izing radiation or radionuclide concentrations. These systems automatically send signals that warn about a radiological threat to the plant's personnel. Individual dosimeters register the exposure doses obtained by personnel.

In the recent years, exposure doses for the BNPP employees have been gradually decreasing. The average annual dose was 11.5 mSv in 1996 (when the sanitary standard was 50 mSv/y for personnel), and decreased to 3.6 mSv by 2005 (new standard is 20 mSv/y).

The radiation safety status of the NPP is estimated not only by the level of personnel exposure but also by radioactive releases/discharges into the environment. Let us repeat once more that actual amount of radionuclides entering the environment around NPP is much less than admissible levels (see page 24).

SNF/RW Management

Accumulated SNF/RW available at the NPP represents a potential risk of radioactive contamination of the environment. Strict control/accounting of the SNF/RW amount is performed, the annual balance is made up with regard to its volume/activity, and its transfer/accumulation in special repositories is registered.

At the BNPP, workers unload from the reactors the fuel assemblies with irradiated fuel and place them into special containers to be stored in the three "wet" repositories in the reactor hall. At present, the last third repository is loaded. In 2008, the new fourth one is to be commissioned.

At the industrial site, RW is placed into special repositories that provide for its reliable safe isolation from the environment. Questions regarding the safety of long-term storage and ultimate disposal of accumulated SNF/RW, today, are associated with the prospects of creating the state system of SNF/RW management under the operating federal targeted program on nuclear and radiation safety.

Radiation Monitoring

The BNPP external dosimetry group performs monitoring of potential environmental effects of the NPP within the 5-km zone. The group is equipped with a mobile laboratory. Control points exist around the NPP in the vicinity of important municipal sites, evacuation ways, etc., to take atmospheric/soil/water/snow samples.

Apart from that permanent automated radiation monitoring is performed around the BNPP via the ARMS system. Ten radiation sensors (see the map) are located on the territory of the plant, the buffer area and the surveillance area. Sensor readings are transmitted by radionetwork to the central computer that processes and analyses the data. The specialized BNPP sensors and its communication system can work at very low temperatures (reaching minus 70 C) and at considerable changes in power supply voltage. Information from the sensors also is delivered to Moscow to Rosenergoatom's Crisis Center and Rosatom's Situation-Crisis Center. Operative data from the BNPP ARMS systems is transmitted to state authorities in Chukotka, which are the Civil Defense and Emergency Department (CDE), the State Sanitary and Epidemiological Surveillance Center, and the Nature Management/Environmental Protection Committee.

Potential Emergencies

The worst scenario of a beyond-the-design-basis accident considered by the BNPP emergency plan is Level 4 accident by the INES scale without a significant off-site risk. In such a case the potential for radioactive release into the environment is low, and exposure doses obtained by the residents in Bilibino settlement do not exceed the intervention levels. Therefore, urgent protective measures are not be required.

Bilibino Nuclear Power Plant



Radiation sensors indicate the radiation dose rate delivered per unit time (more often for an hour). If sensor data are:

up to $0.3 \mu\text{Sv/h}$ — the situation is normal;

between $0.3\text{-}1.2 \mu\text{Sv/h}$ — it is required to make inquiries; and

above $1.20 \mu\text{Sv/h}$ — there is the potential for an accident.

($1 \mu\text{Sv/h} = 100 \mu\text{R/h}$)



Mobile laboratory of Bilibino NPP's external dosimetry group

Non-radiological effects may be much heavier. If the accident takes place during severe winter weather and the plant ceases to generate electricity, the residents will have to be evacuated. In this case, the emergency plan envisages public transportation by auto transport to Kiperveem airport followed by further delivery by air to the regions of resettlement.

The accident resulting in more severe radiological effects (up to Level 7 by the INES scale) is only probable when extraordinary “external” factors such as a heavy transport airplane crash or a purposefully planned terrorist attack occur. Theoretically, natural catastrophes, for instance earthquakes, may also become “external” reasons for a severe accident. Though, potentially risky phenomena, such as squally wind, heavy rain, floods, dust storms, or tornados have never been observed in the BNPP area. The plant is located between the two large seismic zones, which are Kuril-Kamchatka area and Chersky zone, and happens to be in the so called “white spot” where almost no seismic events have been registered. The nearest centers of heavy earthquakes occurring on Eastern Chukchi Peninsula are in the distance of 700-800 km from the BNPP.

Therefore, probability of a radiological emergency with serious off-site effects and need of protective measures is extremely low, though, is not excluded in principal. Minimization of its consequences is the basic objective of the emergency response system.

TABLE 5.

Criteria for Declaring "Emergency Preparedness" or "Emergency Situation" status at NPP;
Exposure Dose Rate (Sv/h) as Controlled Parameter

| Site under Control | Emergency Preparedness Status | Emergency Situation Status |
|--|-------------------------------|----------------------------|
| Premises for Permanent Stay of Personnel in High Security Zone | > 10 | > 600 |
| Industrial Site/Buffer Area | > 2.5 | > 200 |
| Surveillance Zone | > 0.1 above background | > 20 |



Emergency response plan

The emergency plan envisages a strict procedure for personnel to follow during varied violations of the NPP activity, including excess of the limits of controlled radiation parameters in the plant's premises, at the industrial site, in the buffer area, and in the surveillance zone. Controlled parameters include a dose rate and airborne iodine-131 activity concentrations. When dose rate exceeds the established criteria in a point of control, either the status "Emergency Preparedness" or "Emergency Situation" is declared (see table 5).

According to the procedure, upon receipt of a message on potential occurrence of a radiation-hazard situation or an accident, the superior of the shift immediately reports to director and chief engineer of the NPP, dispatcher on duty from Rosenergoatom and Rosatom's Situation-Crisis Center, and chief of the State municipal technical surveillance inspection at the BNPP. As soon as the plant's director obtains the initial information on the event and its assessments/forecast, he makes a decision. If, for instance, the Emergency Preparedness status is declared, director immediately brings it to the notice of the superior of the shift, and the CDE headquarters chief, as well as informs the Rosenergoatom management and chairman of the Branch Emergency Commission. Afterwards, top managers define a procedure for localizing and mitigating the accident. The CDE headquarters chief notifies Rosatom, chief of Medical and Sanitary Unit, operative officer on duty per Chukotka District, head of administration, the Bilibino CDE headquarters chief, and officer on duty from the Bilibino Department of Internal Affairs.

Electric sirens that give a signal "Attention, everybody!" are activated to alert NPP personnel and residents of Bilibino settlement. The local broadcasting system transmits emergency message for five minutes. The message is duplicated through mobile loudspeaker devices and is transmitted by telephone to the heads of the facilities.

Radiation Safety Provision

Having been notified by the NPP director, administration of the Rosenergoatom comprising the BNPP declares an immediate meeting in its Crisis center in Moscow for the expert group that renders operative assistance to the NPPs (the OANPP group). The OANPP group obtains on-line basic radiological parameters of all NPP sensors, by which the safety status of any power unit can be assessed. The experts at any time can run a teleconference with the Bilibino plant's emergency center to discuss the situation or elaborate the countermeasures.

As soon as Rosatom is notified, the Branch System of Emergency Response gets involved in performing urgent measures.

The ARMS branch systems deliver comprehensive information to Rosatom's Situation-Crisis Center (SCC). This Center has communications, including satellite, with all branch sites and obtains data on all ordinary/extraordinary/emergency situations 24 hours a day.



Trainings at Bilibino NPP. NPP's director is in protected management point during videoconference with rosenergoatom crisis center

Should an emergency occur, the SCC operative dispatcher service will notify the Rosatom management and its appropriate services and provide them with operative information for the decision-making. The Branch Emergency Commission headed by Rosatom's Director is entrusted with the function to manage accidents.

If the OANPP group decides to involve one of Rosatom's regional special emergency and technical centers, all special equipment available (robots, special engineering or protective facilities, etc.) immediately deploys to the emergency site. Personnel of such center are ready to work right after arrival. In the case of an alert, the Defense



Ministry engineering troops or radiation and chemical protection departments located in the region may be used. If necessary, the OANPP group visits the emergency site and assumes operative management of all forces and departments.

In the Far East elimination of the consequences of severe radiological emergencies may involve forces and means of the branch system for prevention/elimination of emergencies (BSE), first, certified rescuers, special facilities or equipment of the DalRAO extraordinary emergency-rescue group based in the Fokino town.

If necessary, professional rescuers will be urgently summoned from the Chita Region where a single militarized mine rescue detachment of the Argun Mining and Chemical Association is deployed in Krasnokamensk city. The Argun detachment is part of the BSE permanent readiness units. Apart from it, the BSE comprises four other regional emergency technical centers equipped with the latest achievements in science and technology and staffed by professional rescuers.

Preparedness of personnel from nuclear- and radiation-hazard sites is achieved through systematic training. Emergency rescue specialists are trained monthly. Complex training for structural units of nuclear and radiation-hazard organizations takes place once a quarter. Staff training for the BSE local management occurs annually with involvement of authorities managing optimum emergency rescue units of permanent readiness. At the BNPP the large emergency drill took place in February 2005. In August 2002 command table top exercise attracted international observers from US-DOE and representatives from Alaska administration.

Proceeding from the training results, experts assess the emergency plans with respect to their completeness and actuality; specify the officers' liabilities/functions; develop the interaction between the BSE local management, authorities, and varied emergency units; as well as examine the BSE rigging and its readiness to perform actions under emergency conditions.

STATE SYSTEM FOR PREVENTION AND ELIMINATION OF EMERGENCIES

In emergency the main objective for personnel from nuclear or radiation-hazard sites is to prevent, manage and eliminate accidents through involvement of the BSE forces/means. Arrangements for radiation protection of the public and territory outside the buffer zone are the prerogative of the authorities of a territorial subsystem of Russia's unified state system for prevention and elimination of emergencies (RSE).

The RSE was established in 1994 to unite efforts, forces, and means of the authorities of different levels and facilities charged to protect the public and environment. The Ministry for Civil Defense, Emergencies and Elimination of Consequences of Natural Disasters (EMERCOM of Russia) manages the RSE activity.

The RSE structure comprises two subsystems: functional and territorial. The federal bodies of executive power create the RSE functional subsystems of two levels: federal and objective in the corresponding ministries/agencies. Rosatom's BSE is the RSE functional subsystem.

The territorial subsystem maintains five levels: federal, interregional, regional, municipal, and objective. Each level has its coordination bodies, standing authorities, daily management bodies, forces/means, financial and material reserves, as well as the systems of communications/notification/information provision.

In 2008, the National Center for crisis situation management has begun its operation within the EMERCOM structure. The Center was created to speed up and optimize the actions of all RSE elements during emergencies in any region, even the most remote from Moscow. Special equipment installed in the Center's building allows for experts or representatives from varied federal bodies to observe permanently the emergency development, have direct contacts with authorized persons of any level, and obtain an operative access to overall essential information, including departmental/corporate databases (for instance, the NPP ARMS data).



Territorial Subsystem in Far East

EMERCOM of Russia's Far Eastern Regional Center (FERC) coordinates activities of the RSE territorial subsystem. It manages subordinated search and rescue units, military units assigned to civil defense, and state fire service units, as well as coordinates activities of EMERCOM of Russia's Central Administrative Boards (ERCAB) on the territory of ten subjects of the FEFD.

In daily activity, the FERC keeps in touch with the organizations that perform emergency monitoring/forecasts, including the Moscow Research Institute of Civil Defense/Emergencies and its space monitoring laboratories in Krasnoyarsk and Vladivostok, the All-Russian Monitoring and Forecast Center, and the Regional Hydrometeoservice Department. In 2003, the FERC's own monitoring/forecast center was created. It gathers and analyzes data on potential sources of emergencies and their grounds in the FEFD area and in contiguous countries, as well as forecasts emergencies and their consequences in detail with regard to a municipal unit, a city or a district.

In 2005, power was divided between federal and regional authorities, including in the field of civil defense, fire safety, and public and environmental protection from emergencies (Federal Law No. 122 of 22.08.04). Primorsky Krai exemplifies the work of the RSE territorial subsystem.



EMERCOM of Russia's Far Eastern Regional Center, Khabarovsk

RSE Regional Subsystem in Primorsky Krai

The Primorsky Krai governor is head of Krai's civil defense and chairman of the regional emergency commission. The Chief Directorate of EMERCOM for the Primorsky Krai carries out federal functions of the RSE regional subsystem. Its main tasks are to implement state policy, carry out surveillance and inspection functions, make arrangements for and manage civil defense, and urgently response to emergencies. The EMERCOM Chief Directorate structure in Primorsky Krai has its own territorial center for emergency monitoring/forecast. The center, apart from operative data collection/analysis, arranges laboratory control aimed to reveal radioactive contamination of environmental sites, foodstuffs, drinking water, and food or forage raw material.

The regional authorities are responsible for emergency prevention/elimination, fire suppression, and human rescue at water sites. To perform the above, the Primorsky Krai administration has set up a special governing body, which is the Primorsky Krai state enterprise for fire safety, civil defense, and public and environmental protection from emergencies. Regional authorities organize and keep ready essential forces/means, run public training in the modes of protection in emergencies, create and support material/technical/food/medical reserves and individual protection facilities, as well as provide for their timely delivery to the public. If necessary, the CDE state enterprise makes arrangements for radiological, chemical or other kinds of reconnaissance. Its staff includes qualified experts in radiation safety.

The CDE state enterprise jointly with the EMERCOM Chief Directorate plans and performs preparatory activities on evacuation to safe areas, deploys medical or other essential enterprises in the case of intermunicipal or regional emergencies, keeps the public notified and informed, makes arrangements for and performs emergency-rescue or other required activities, and supports public order during such work.



Where can one apply to in the case of emergency?

| Authorities | Dispatcher on-duty (Tel.) | Press Service (Tel., E-mail) |
|---|--|---|
| EMERCOM of Russia www.mchs.gov.ru | (495) 626-39-01 operman@dvrc.kht.ru | Information/Public Relations Department (495) 668-05-36 (495) 449-99-99 (Hotline) |
| EMERCOM of Russia's Far Eastern Regional Center | (4212) 32-48-99 | (4212) 32-56-91 press_dv@rbcmil.ru |
| EMERCOM of Russia's Chief Directorate for Primorsky Krai | (4232) 43-28-27 | (4232) 43-23-74 gugochs2004@mail.ru |
| EMERCOM of Russia's Chief Directorate for Khabarovsk Krai | (4112) 42-49-97 | (4112) 42-38-26 uprgo@uprgo.kht.ru |
| EMERCOM of Russia's Chief Directorate for Chukchi Peninsula | (42722) 2-43-74 | (42722) 2-84-44 |
| Rosatom www.minatom.ru | (495) 933-60-44; (495) 239-23-11 | (495) 949-22-63 npokrovskaja@skc.ru |

State System for Prevention and Elimination of Emergencies

The CDE state enterprise in cities also comprise the unified on-duty dispatcher services “01” that coordinate actions of on-duty dispatcher services in the city and at facilities/organizations/enterprises, regardless of their property forms, agency assignment, surveillance and control forces, or permanent readiness units. The “01” service obtains information on the accident from citizens (by the “01” telephone number allocated), dispatcher services of the facilities, and from executive bodies interacting with each other.

Action Coordination in Emergencies

Upon receipt of the emergency message, the “01” service operative shift shall identify the situation, immediately report to chairman of the regional emergency commission and chief of the CDE office, and notify authorities. If the emergency represents a threat to human life or health, the on-duty person via his notification facilities shall inform the public about the modes of protection. When the regional administration officers arrive at the emergency place, they will assume management. Starting from this moment, the “01” service will provide information support for administration and its interaction with the services involved to eliminate the emergency.

The “01” service in the cities of Nakhodka/Ussurijsk/Artem/Vladivostok are equipped with special hardware and



Operator from common dispatcher-on-duty service "01"



software complexes to monitor the status of hazardous sites. This system has the same action principle as the BNPP ARMS. Facility sites are equipped with varied sensors to define concentrations of harmful chlorine or ammonia vapors, those of combustible vapors of oil products, propane, etc. A mobile and navigation terminal is installed in the mobile facility transporting hazardous cargo. Continuous data from the facilities under control is delivered by radiochannel to the “01” service center.

Control of Hazardous Production Sites

Control of potentially hazardous sites is performed, when declaring industrial safety. Production sites where hazardous substances are created, used, processed, generated, stored, transported or disposed can obtain a license to be further operated only after they have passed obligatory procedures for declaring industrial safety. Hazardous are combustible, oxidizing, burning, explosive, and toxic substances, as well as those representing a threat to the environment.

The industrial safety declaration for an operated site is a volume document comprising the following lists:

- ◆ List of the most hazardous parts and/or production areas of the declared site, including the emergency risk indices;
- ◆ List of the most valuable factors impacting the risk indices;
- ◆ List of primary actions aimed to reduce the emergency risk.

The lists are based on a detailed analysis performed with regard to the conditions of accident occurrence/development; risk evaluation of personnel and public injury; or property and environmental damage. The declaration also contains data on professional and emergency training of personnel, indicating examination regularity; situation plans analyzing the action

State System for Prevention and Elimination of Emergencies

zones of impacting factors; emergency scenarios; analysis of the allocation of potential territorial risk of human death from accidents in the site area and adjoining territory.

The declaration is submitted to surveillance and executive authorities at regional and municipal levels to inform them of the work performed. Heads of administrations from regional cities/districts review systematically the process of safety declaring for the sites introduced to the list at the emergency commission meetings and take required decisions to enhance the activity and to strictly observe the term for development of safety declarations.

■ Nuclear- and radiation-hazard sites are designed, taking into account the wind pattern, and built mainly at the leeward side with respect to residential area, medical preventive and child institutions, recreation centers and sports facilities

According to data provided by Rostekhnadzor, more than 4,000 hazardous production sites are registered in Primorsky Krai. 79 of them contain hazardous chemical substances. Among hazardous productions are not only large chemical and mining enterprises, such as the Bor Mining and Chemical Industrial Complex in

Dalnorsk or the Dalpolymetal facility in Vladivostok but also industrial refrigerating complexes using ammonia and water and sewage sites using chlorine, etc.

Nuclear- and radiation-hazard sites in Primorsky Krai cover the plant “Zvezda” in the city Big Stone, the shipyard in Dunai settlement, and the DalRAO facilities. In a severe accident, health effects of radiation are possible at these plants and protective measures may be required. All enumerated facilities adhere obligatorily to the procedure of declaring industrial safety and have respective licenses. It means that the management performs regular comprehensive risk evaluation with regard to emergencies and associated threats, as well as analyzes the sufficiency of actions taken to prevent emergencies. Also, measures are developed to reduce the scale of emergency consequences.



Role of Local Authorities

The objectives for local authorities are likely to be the most difficult, as they are these who make decisions based on protective measures proposed by experts.

The experts forecast the development of radiation environment, estimate public doses and elaborate recommendations on protective measures. Local authorities make decisions taking into account not only expert recommendations but also a variety of attendant circumstances, including the interests of local people. For local authorities, the public risk perception is more important than the risk itself. Therefore, local decisions do not always correspond to scientific expert recommendations.

Scientific recommendations are based on predictable dose prevented by a protective action and contamination levels. The intervention levels are defined by the RSS-99 so as to prevent any clinically defined exposure effects. Thus, no cases of acute radiation sickness among the public have occurred in any emergencies at nuclear facilities, including Chernobyl.

Evacuation is used when predictable doses are within the range of 50-500 mSv for the first 10 days. If doses are above 500 mSv, evacuation is obligatory; should doses be less, experts make a forecast for a more remote period: a month or a year. If doses exceed 30 mSv during the first month, a temporary resettlement is involved. To terminate it, the level of 10 mSv per month is established.

Sheltering is used for the term of no more than 1-2 days in immediate proximity to the emergency location, if the dose predictable for the first 10 days ranges from 5 to 50 mSv. Use of protective properties of buildings/constructions within the period of greatest exposure inten-

■ Actions taken soon after the accident make the maximum preventive effect. Timely public sheltering and running iodine preventive measures allow prevention of high collective doses at much lower cost.

State System for Prevention and Elimination of Emergencies

sity (during the first hours after the accident when a radioactive cloud appears over the locality) multiply decreases the probability that residents will develop a radiogenic cancer.

Iodine Prophylaxis is used if a great amount of radioactive iodine-131 entered into the air. Getting into the human body via unprotected respiratory apparatus or with food, it

■ Radioactive iodine is hazardous, if an accident occurs at the operating nuclear reactor. "Iodine hazard" decreases significantly when the reactor is in out-service state

accumulates in the thyroid gland and negatively impacts its function. The most effective protection is the intake of stable iodine, namely: potassium iodine in tablets or powders (iodine prophylaxis). The maximum protective effect is achieved at preliminary reception of stable iodine or simultaneously with radioactive iodine. Iodine preventive measures decrease the doses to thyroid gland by several times, thus mitigating the risk of developing pathology.

In the first days following the emergency, radioactivity levels in the environment decrease quite quickly, mainly, due to decay of short-life radioisotopes. Accordingly, basic public exposure falls on the first days; therefore, decisions to take protective actions should be made quickly and implemented effectively. Any delay with respect to sheltering, evacuation or iodine preventive measures in the early period gives rise to future problems, including social issues.

It is obvious that radiation preventive measures result in the disruption of normal lifestyles, changing the habitual course, economic and social functions. The intervention entails not only economic damage but also psychological stress that may negatively affect public health. The main principle of radiation protection is that damage decrease as a result of dose reduction should be sufficient to justify harm and cost of the intervention, including social cost.

Role of Local Authorities



In what cases is the harm from intervention greater than the benefit of protective actions? Such conditions are clearly defined by the RSS-99. Two types of the intervention levels (level A and level B) are defined for a large-scale radiological emergency. Protective actions are justified at doses above level B, while they will bring more harm than benefit at doses below level A.

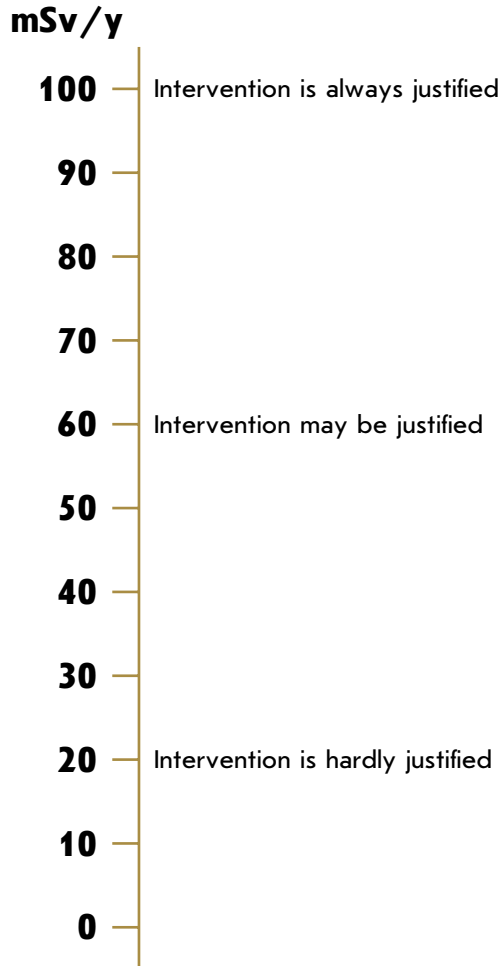
When estimated doses are between levels A and B, decisions about protective measures should be made per specific situation and local conditions such that pure benefit of dose reduction would exceed, as much as possible, the disruption from intervention. For instance, estimated doses are a little higher than Level A for evacuation, while weather conditions are extremely adverse (a hard frost). A decision maker should compare forecasted radiological risks with the damage predicted from evacuation, including the number of people who might caught cold or pneumonia, etc. It is most likely that the right decision in this situation

■ Protective Methods in Case of Radiological Emergency:

- ◆ Evacuation from contaminated areas;
- ◆ Sheltering in protective constructions or buildings along with immediate sealing off the windows, doors, air holes, etc.
- ◆ Use of individual protective facilities (respirators, gas masks, protective clothes/footwear, etc.);
- ◆ Use of antirad preparations; such as KI pills
- ◆ Exclusion of contaminated food/water from consumption;
- ◆ Contaminated area access restrictions;
- ◆ Individual cleansing and decontamination of clothes, equipment, etc.

State System for Prevention and Elimination of Emergencies

Intervention criteria under conditions of long-term radiological impacts depending on annual dose



will be strict adherence to a sheltering regime until weather conditions become acceptable for evacuation.

As emergency exercises show, local authorities are inclined to make unjustified decisions from the radiological point of view in the cases when predicted doses range between Levels A and B. Resettlement of people from minimally contaminated areas a long time after the emergency may exemplify the fact. In such cases, great resources are spent to reduce an insignificant risk. Actions taken soon after the accident make the maximum preventive effect. Timely public sheltering and running iodine preventive measures allow prevention of high collective doses at much lower cost.

Local authorities' competencies in these items increase considerably through emergency exercises and trainings. When organizing emergency exercises at Rosatom's facilities, local authorities co-manage the events and are enabled to

Role of Local Authorities



use to maximum state-secured resources for developing their territorial radiation safety systems.

Therefore, interest shown by local authorities in emergency exercises and drills at Rosatom facilities is one of the vital conditions for realizing state-established citizens' rights to life/health/personal property protection in the case of severe radiological accident.


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ACRONYMS

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| ARMS — Automated Radiation Monitoring System | MPC — Maximum Permissible Concentration |
| ATS — Atomic Technological Service | NPP — Nuclear Power Plant |
| BNPP — Bilibino Nuclear Power Plant | NS — Nuclear Submarine |
| BSE — Branch System for Prevention/Elimination of Emergencies | OANPP — Expert group that renders operative assistance to the NPPs |
| CDE — Civil Defense and Emergency Department | RF — Russian Federation |
| EMERCOM — Russian Federation's Ministry for Civil Defense, Emergencies and Elimination of Consequences of Natural Disasters | Rosatom — The State Corporation "Rosatom" |
| FEFD — Far Eastern Federal District | RSE — Russia's Unified State System for Prevention/Elimination of Emergencies |
| FERC — Far Eastern Regional Center | RTG — Radioisotope Thermoelectric Generator |
| IAEA — International Atomic Energy Agency | RW — Radioactive Waste |
| INES — International Nuclear Event Scale | SCC — Rosatom's Situation-Crisis Center |
| LRW — Liquid Radioactive Waste | SNF — Spent Nuclear Fuel |
| | US-DOE — US Department of Energy |

The background features a stylized landscape with a light green sky, a yellowish ground, and a blue body of water at the bottom. A simple brown fence with two vertical posts and a horizontal line runs across the middle. A single, detailed drawing of a tree stands between the fence posts. To the right, there are faint, sketchy outlines of trees.

The brochure from the Risk and Safety Issue narrates the impact of nuclear- and radiation-hazard sites on the environment of the Far Eastern Region and describes the radiation safety status, potential emergencies and their consequences, as well as preparedness of appropriate organizations and local authorities for effective actions on public protection in the case of radiological emergencies.

This brochure addresses a wide range of experts in environmental or radiation safety; decision-makers in the field of environmental or public protection in the case of radiological emergencies; public environmental organizations; students of higher education institutes, and those who are interested in the issues of stable development of Russian Far East.

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