Development of a Radiological Monitoring System and an Emergency Response System at Brunch No.2 of SevRAO in Gremikha

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As is well known, most of radiation-dangerous facilities and their supporting infrastructure involved into the decommissioning & dismantlement of Russian Nuclear Submarines (NS) are located in the Northwest region of Russia and, first and foremost, on the Kola Peninsula coast. An estimate of the integral radiation potential of such facilities is given in Table 1.

Table 1. Radiation Potential of Radiation-Dangerous Facilities Involved into the NS Dismantlement Process in the Murmansk Region

Facility	**Number**	**Radiation potential, SNF, Bq**	**Radiation potential RW, Bq**	**Total, Bq**
NS and Reactor Units (RU)	105	2,2E+17	2,5E+16	2,4E+17
Andreeva Bay	SNF storage facility - 4 SRW storage facility -11 LRW storage facility - 4	3,70E+17	2,2E+14	3,70E+17
Gremikha	SNF storage facility -2 SRW storage facility -2 LRW storage facility -2 LRW-storing floating tanks – 4	1,00E+17	3,7E+13	1,00E+17
Nuclear Maintenance Support Vessels (NMSV)	15	1,3E+16	2,50E+10	1,3E+16
Total over the region		**6,50E+17**	**2,4E+16**	**6,7E+17**

Among many NS dismantlement-supporting infrastructure entities former Land-Based Storage Facilities (LBSF) in Andreeva Bay and Gremikha settlement merit a special consideration (see Figure 1).

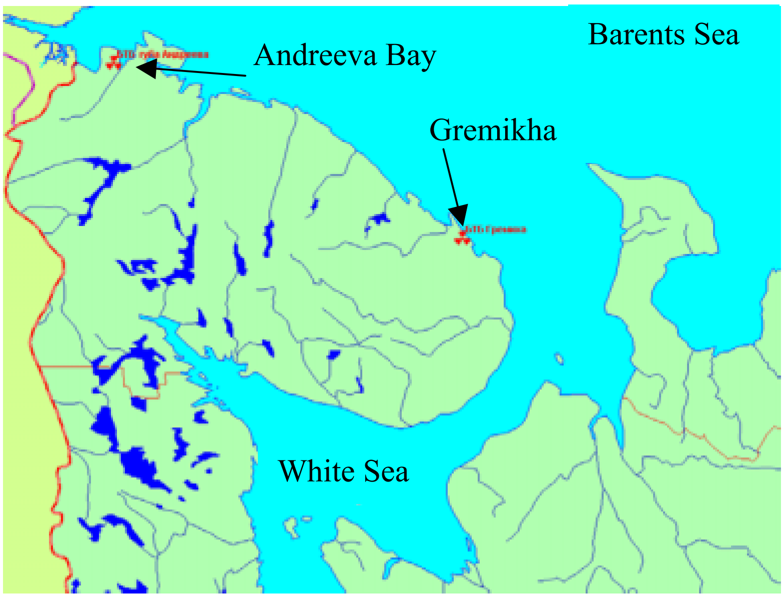


Figure 1 General map of the Kola Peninsula and its neighborhoods indicating the location of former LBSF in the Northwest region of Russia

These LBSF have the following principal peculiarities:

- huge amounts of Spent Nuclear Fuel (SNF) and Radioactive Wastes (RW) stored at their sites,
- worn-out condition of engineering support systems,
- lack of information on actual status of the radiation potential within individual storage facilities, some territories and water areas;
- vulnerability of RW storage sites as regards atmospheric precipitations, and radionuclide wash-out beyond the LBSF site boundaries,
- huge scope of work necessary to eliminate potential hazard issuing from these facilities for their personnel, the nearby population and the environment,
- remoteness from land-based transport communications (especially in Gremikha case).

Under actual conditions of work the activities on removing radiation-dangerous materials from LBSF and their subsequent environmental remediation would last for years, whereas the threat not only for LBSF personnel and other involved persons but also for the population of the nearby areas and the environment would permanently persist.

Because the present workshop focuses on the former Gremikha LBSF, our attention will be also concentrated on this facility presently known as the Branch n°2 of SevRAO Federal State Unitary Enterprise. A general map of Gremikha area and a scheme of the former LBSF layout are given in Figures 2 and 3.

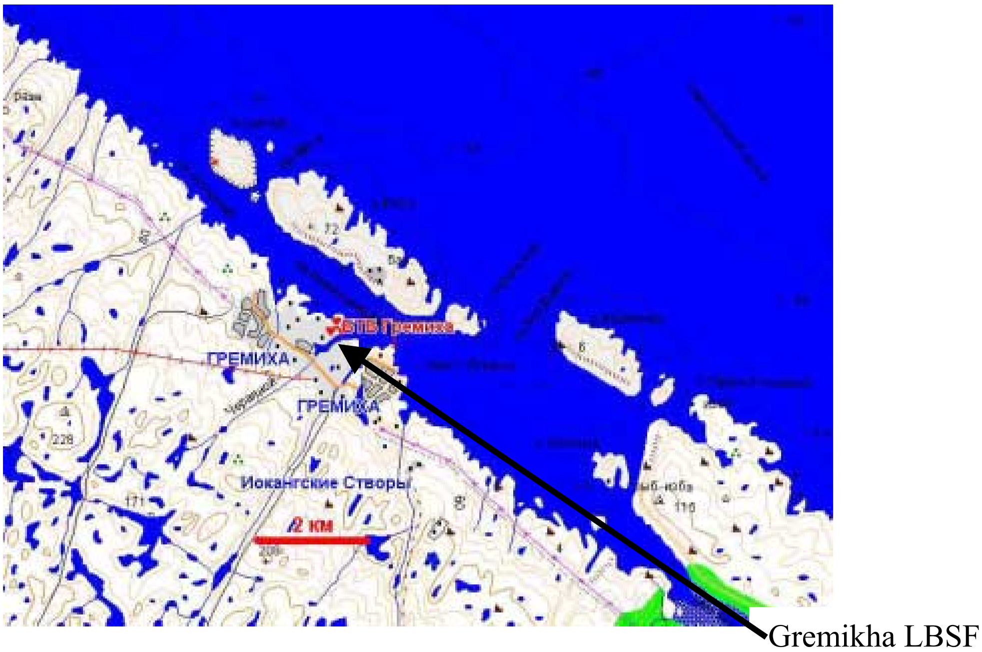
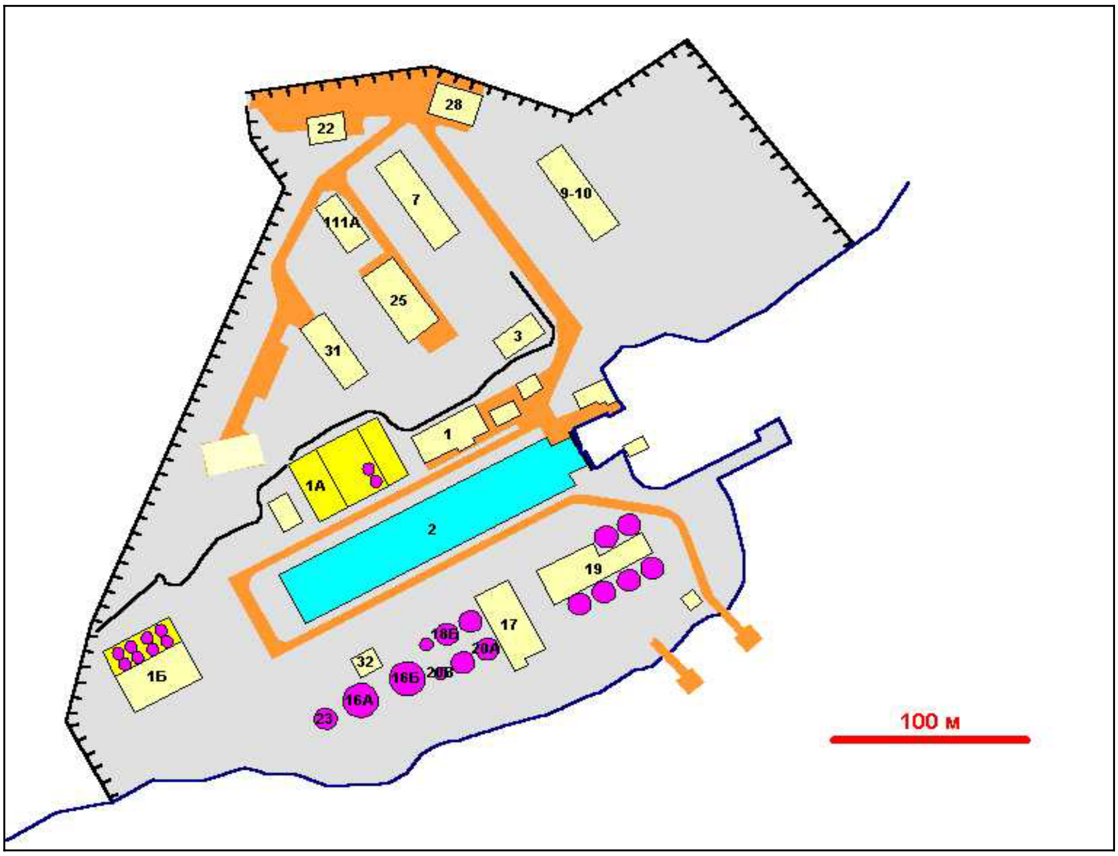


Figure 2 Neighborhoods of the former Gremikha LBSF



1 –SNF storage facility; 1A –core reloading building; 1Б – storage facility for spent reactor cores of liquid-metal coolant reactors; 17 – LRW decontamination & processing complex, 19 – LRW storage facility; 25 – special laundry

Figure 3 Gremikha LBSF layout

The "Gremikha" LBSF area of about 15 000 m^2 area houses a variety of buildings, storage facilities and storage areas:

- nuclear materials and RW are stored at the LBSF site under different conditions;
- in many cases safety regulations in force are non-observed;
- an appreciable part of the LBSF site is contaminated;
- to develop a remediation project for the LFSB site and its radiation-dangerous facility, detailed and trustworthy data describing their radiation situation are necessary;
- the available information is incomplete, an appreciable data amount being lost;
- to receive a real view on the actual situation at the LBSF site, a detailed radiation examination is necessary including:
  - gamma-beta survey followed by cartogram generation;
  - determining surface ground contamination and drawing the relevant diagrams;
  - identifying levels of the radioactive contamination on surfaces of the LBSF buildings & storage facilities;
  - taking samples of ground in most contaminated areas, measuring specific activity of the samples taken and determining their radionuclide composition;
  - radiation examination of Solid RW (SRW) stored within covered storage facilities and at temporary open-air sites;
  - radiation examination of all Liquid RW (LRW)-storing tanks, determining LRW specific activity and chemical composition.

Radiation potential of Gremikha LBSF

No precise data on the radiation potential of the former Gremikha LBSF site and facilities are actually available. Only approximate estimates can be obtained based on the results of sample survey performed 2 to 3 years ago.

Environmental threats issuing from LBSF are determined by:

- first, accumulated amounts of SNF, SRW & LRW and
- second, specific conditions of their storage and interactions with the environment.

To date at the former Gremikha LBSF are stored:

- 106 Spent Fuel Assemblies (SFA) - in SNF storage facility;
- 112 to 114 casks housing SFA packages – at SRW temporary-storage pad;
- 6 spent reactor cores – within liquid-metal reactor core storage facility.

The integral activity of SFA of NS water-cooled reactors is estimated at about $\sim 2.6 \cdot 10^{16}$ Bq ($7 \cdot 10^5$ Ci), whereas the SNF activity of the above 6 spent reactor cores at about $(3.7 \div 7.4) \cdot 10^{16}$ Bq ($\sim(1 \div 2) \cdot 10^6$ Ci).

SRW of Gremikha LBSF is stored at:

- open-air temporary storage pad;
- not established SRW storage;
- open-air pads within the LBSF site as the decommissioned bulky transport & processing equipment.
- SRW, being presently stored at the Gremikha site, comprise:
- individual assemblies of NS Power Reactor Installations (PRI) equipment in containers;
- filter-catchers with sorbents of activity of NS PRI primary and third circuits, in containers;
- elastron, rags, individual protectants and instruments, in containers.

The integral SRW volume makes up about 550 m^3, its integral activity being estimated at about $3.7 \cdot 10^{13}$ Bq (10^3 Ci).

LRW are stored in deepened tanks representing a component of the LRW-processing technological complex.

Altogether about 1930 m^3 of LRW are stored within the above tanks, their integral activity being estimated at about $1.5 \cdot 10^{11}$ Bq (4.2 Ci).

In addition to LRW stored in established storage tanks, the Gremikha LBSF has:

- about 60 m^3 LRW in former SFA storage facility which integral activity makes up 7.8·1010 Bq (2.1 Ci);
- about 31 m^3 LRW in floating tanks of 2.5·109 Bq (6.8·10-2 Ci) integral activity.

It is the open-air SRW storage pad that is most hazardous facility – even under normal operating conditions - of the former Gremikha LBSF due the presence of both SNF and filter-catchers with sorbents of the primary circuit activity.

This open-air pad determines the gamma dose rate value in an area up to 100-180-m radius decreasing from 7-10 μSv/h to 1-0.5 μSv/h. The ground contamination at the open-air site area is characterized by radionuclide migrations with water flows out of the pad due to atmospheric precipitations; the specific activity of ground samples beyond the concrete wall fencing the open-air site reaches $4.5 \cdot 10^7$ Bq/kg for ^{137}Cs and $5.7 \cdot 10^6$ Ci/kg for ^{90}Sr.

However principal threat from huge SNF&RW amounts stored at Gremikha site is due neither to routine operating conditions, nor to the present-day contamination of storage rooms and open-air pads, but to potential emergencies when handling the spent reactor cores of 705-design NS reactors, operations with other radiation-dangerous materials including potential unauthorized actions involving SNF&RW. LMC cores, which criticality can be reached upon 20%-filling with water, are of special concern because under their protracted storage such a risk must not be ruled out.

Recently, Nuclear Safety Institute (IBRAE) of the Russian Academy of Sciences has performed preliminary estimates of hypothetical accidents at different Gremikha LBSF storage facilities with an analysis of potential implications. More specifically, several scenarios of aircraft crash accompanied with explosion and fire have been considered. In keeping with the IBRAE's estimates, such emergencies would result in radionuclide spreading out of the Gremikha LBSF site and, thus, in contamination of the nearby territories. Few examples of a variant of such computations are given in Figures 4 and 5.

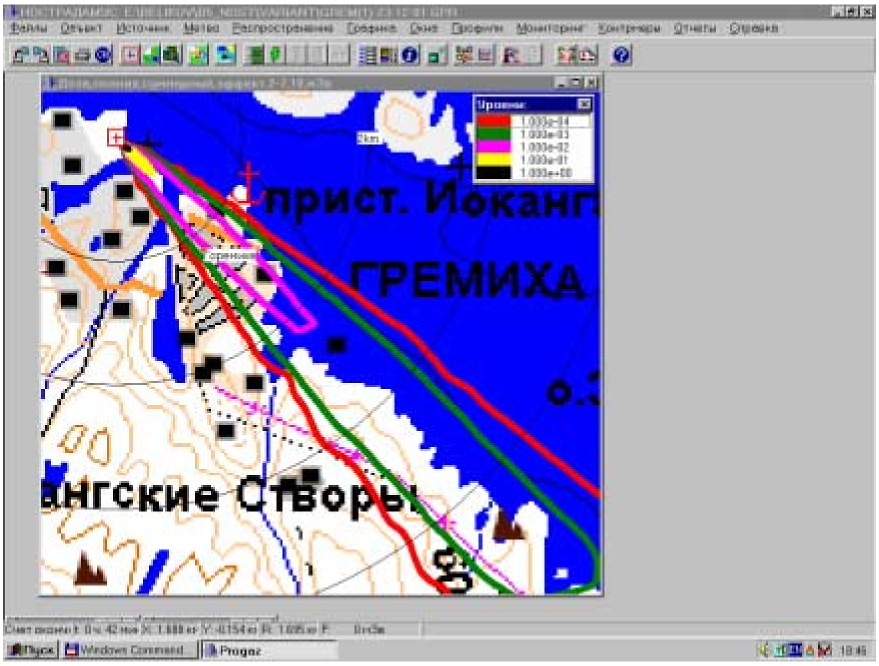


Figure 4 An example of displaying the results of modeling the consequences of a fire resulting from lightweight aircraft fall on SRW storage facility using the NOSTRADAMUS Computer Code

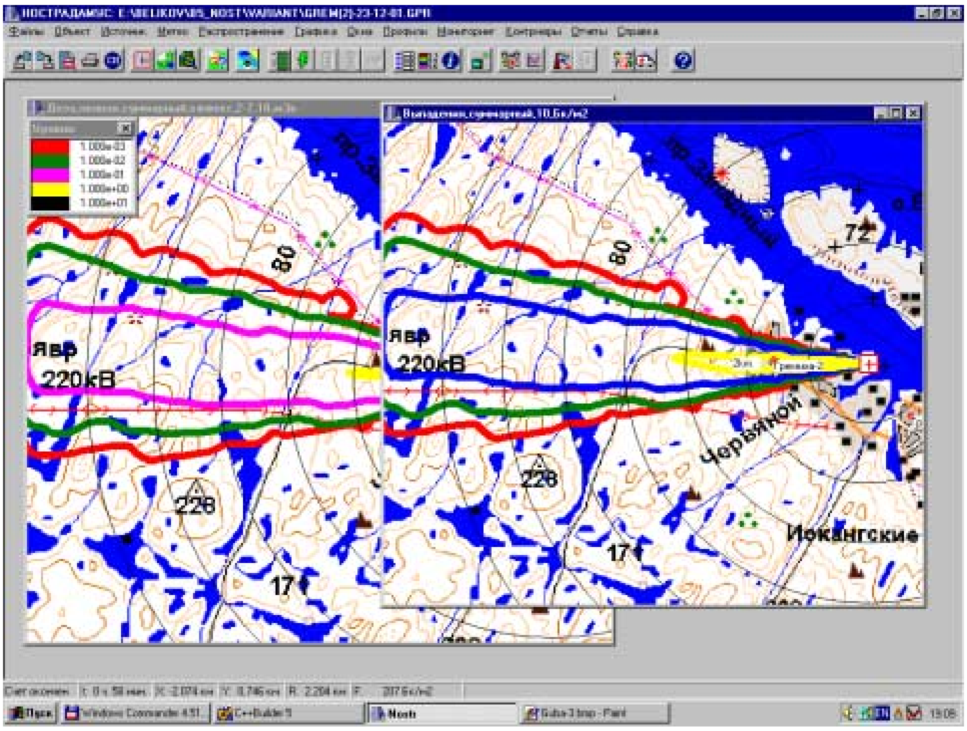


Figure 5 An example of displaying the results of modeling the consequences of a missile fall on SNF storage facility using the NOSTRADAMUS Computer Code

The following results have been obtained in computations (Table 2).

Table 2

Distance along the trace axis (km)	Integral surface contamination (Bq/m^2)	Integral annual dose (mSv)
1	$2*10^6$	7
2	$1.1*10^6$	5.5
3	$9*10^5$	5
5	$4.5*10^5$	2
10	$2.3*10^5$	1
15	$1.1*10^5$	0,5

Considering that the distance from the former Gremikha LBSF to Gremikha settlement makes up about 1.3 km to 2 km south-east and about 3 km west, the dose commitment to the local population is estimated at 5-7 mSv. Thus, the radiation-dangerous facilities of the former Gremikha LBSF are recommended to be considered as the first-rank potential hazard units, whereas Gremikha settlement itself to be included into the SevRAO Branch n°2 radiation-control area in keeping with the Russian Radiation Safety Regulations (1999) in force.

It should be pointed out that potential implications of even minor radiation accidents could exceed their analytical estimates due to inevitable indirect implications.

However so far, despite obvious topicality, the issue of considering indirect damages has not been studied yet - safe for general statements. Moreover no task for detailed investigation of this problem has been even set. Such a situation is partly due to baffling complexity of this challenge which solution necessitates consideration of a variety of different-nature factors, such as: economical, physical, social, environmental, psychological, medical, etc. Unfortunately, under the present-day level of our knowledge of the problem some indirect-damage components can be only estimated from qualitative standpoint.

Recently, an attempt has been made by IBRAE to perform structuring of indirect damages by most important factors (lines) analyzable to a greater or lesser extent from the quantitative standpoint. These are:

1. economic damages resulting from excessive measures on eliminating implications of an emergency situation;
2. damage due to public health deterioration resulting from psychological stress multiplied many times up by the mass media;
3. changes in the whole society attitude to atomic energy (general population, politics and managerial authorities);
4. damage due to a decrease in export potential of the country;
5. groundless reducing of economic activities (e. g., fishery) due to unjustified fear of the radionuclide contamination;
6. damage due to cutting down bi-lateral and multi-lateral international cooperation because of decreasing the country's credit in the international community’s opinion;
7. drastic stirring up of activities of the “Green’s” and other extremist’s movements - usually accompanying nuclear and radiation accidents & incidents – able to cause serious damage to public interests;
8. damage resulting from extra-costs needed to develop large-scale educational and elucidative work with the population, various political groups and chief managers.

Thus economic, social, political and other indirect-type damages can exceed many times direct damages. For this reason, one should not be carried away by minor values of the estimated radiation risk because they describe only the "iceberg" top.

The experience of realization of protective measures accumulated in the course of liquidating the consequences of major radiation accidents at the Southern Ural and Chernobyl NPP has shown that the efficiency of some large protective measures can be extremely low under certain circumstances. By now, a critical assessment of the protective measures, which were realized after the accidents, was made by specialists [Major radiation accidents]. Several examples can illustrate this idea. In accordance with the Russian safety standards, prevention of the collective dose of 1 Sv-person is accepted as equivalent to saving of one year of full-value human life. Today, the appropriate maximal expenses in Russia can be estimated as $20,000.

From this viewpoint, let's consider such measures, as sheltering, temporary evacuation of population, evacuation and resettlement (Table 3). Evaluations of expenses for preventing the dose of 1 Sv-person show that only the first decisions on relocation of population were economically efficient. In all other cases (Chernobyl - after 1986, Southern Ural - after 1957), the resettlement was not justified. The direct expenses were too large, the prevented dose was small, and the indirect costs were quite essential. The observed increase of the death rate among the evacuated population, which was not connected with radiation effect (Southern Ural, Buldakov's data) are among these costs. On the contrary, such highly efficient measures as sheltering were practically not used.

Table 3 Comparative efficiency of protective measures connected with restriction of radiation exposure

Protective measure	Experience (location, time)	Range of costs, US dollar per 1 Sv-person	Range of individual prevented doses, mSv
Urgent relocation	Ural, October 1957	300 – 600	13000 – 23000
	Chernobyl, April to May 1986	1000 – 15000	100 – 3000
Planned resettlement	Ural, November 1958	6000 – 100000	40 – 200
	Chernobyl, 1990 to 1991	130000 – 500000	50 – 100
Evacuation of children and pregnant women	Chernobyl, May to September 1986	4000 – 400000	< 1 – 40
Sheltering	Pripyat town, April 26 and 27, 1986	0.02 – 1	5 – 100

The works on settlement accomplishments played also a significant role. However, there was no radical decrease of exposure doses for the population due to realization of both mentioned measures (see Table 3).

In connection with the forthcoming realization of the rehabilitation programs, it is interesting to discuss the estimations of so-called water protection measures in the ChNPP zone directed to activity localization and prevention of its further distribution [Major radiation accidents] (Table 4). Apparently, the realization of so costly measures on prevention of 1 to

20 Ci activity distribution in conditions, when the soil contamination density was tens to hundreds Ci/km^2, was not justified.

Table 4 Estimations of the efficiency of water protection measures in the Chernobyl NPP zone and their consequences for the environment

Protective measure	Localized* activity, Ci	Specific cost, thous.$/Ci	Consequences for the environment
System of filtering dams	2 - 3 ^{137}Cs	1 500 – 2 300	Underflooding of forests in the area of 4,000 ha
Channel banks	12 - 20 ^{137}Cs	250 – 420	Interception of 4.5 billion cubic meters of sand, which could bury uliginous sediments in the Kyev reservoir
Isolation of cooling pond	< 1 Ci	> 10 000	Elevation of the level of subterranean waters within the ChNPP site

*"localized" means "which distribution was prevented".

Within the system of actions aimed at preventing the radiation incidents and minimizing their implications, including those performed at facilities dealing with the decommissioned NS, SNF& RW, both automatic and automated systems for radioecological monitoring and emergency response able to transfer information to local and/or basic information-analytical centers are of crucial importance. However so far no automated system to be used at the Russian Navy operation or/and decommissioning-related facilities has been finished.

It should be pointed out that to date the Murmansk region authorities – including Mr. Y. Evdokimov, the region governor, - show much interest in the development of a regional information-analytical center for radioecological safety and crisis situation management focused on solution of the following tasks:

- Accumulation and rapid submission to the user of information on radiation-dangerous facilities including their geographical situation, general description, current status and radiation potential;
- Receiving, processing and submittal of information on the radioecological situation at the nearby territories and water areas with a possibility of using the results of control & measuring systems of other agencies as well as of newly created systems;
- Simulating radioecological implications of potential radiation accidents at different facilities and ensuring information support of the making decision process on modes & ways of their minimization and mitigation;
- Supporting trainings and exercises involving personnel of the concerned facilities and the agency regional-level emergency units;
- Providing for a possibility of transferring radioceological monitoring data to the Situation Crisis Center (SCC) of the RF Ministry for Atomic Energy (Minatom) and the subsequent integration of the developed regional system into branch-, departmental- and national-level monitoring systems similar to the Unified Automated Radiation Monitoring System (UARMS) of Russia.

A schematic diagram of the regional structure for radioecological safety management is demonstrated in Figure 6.

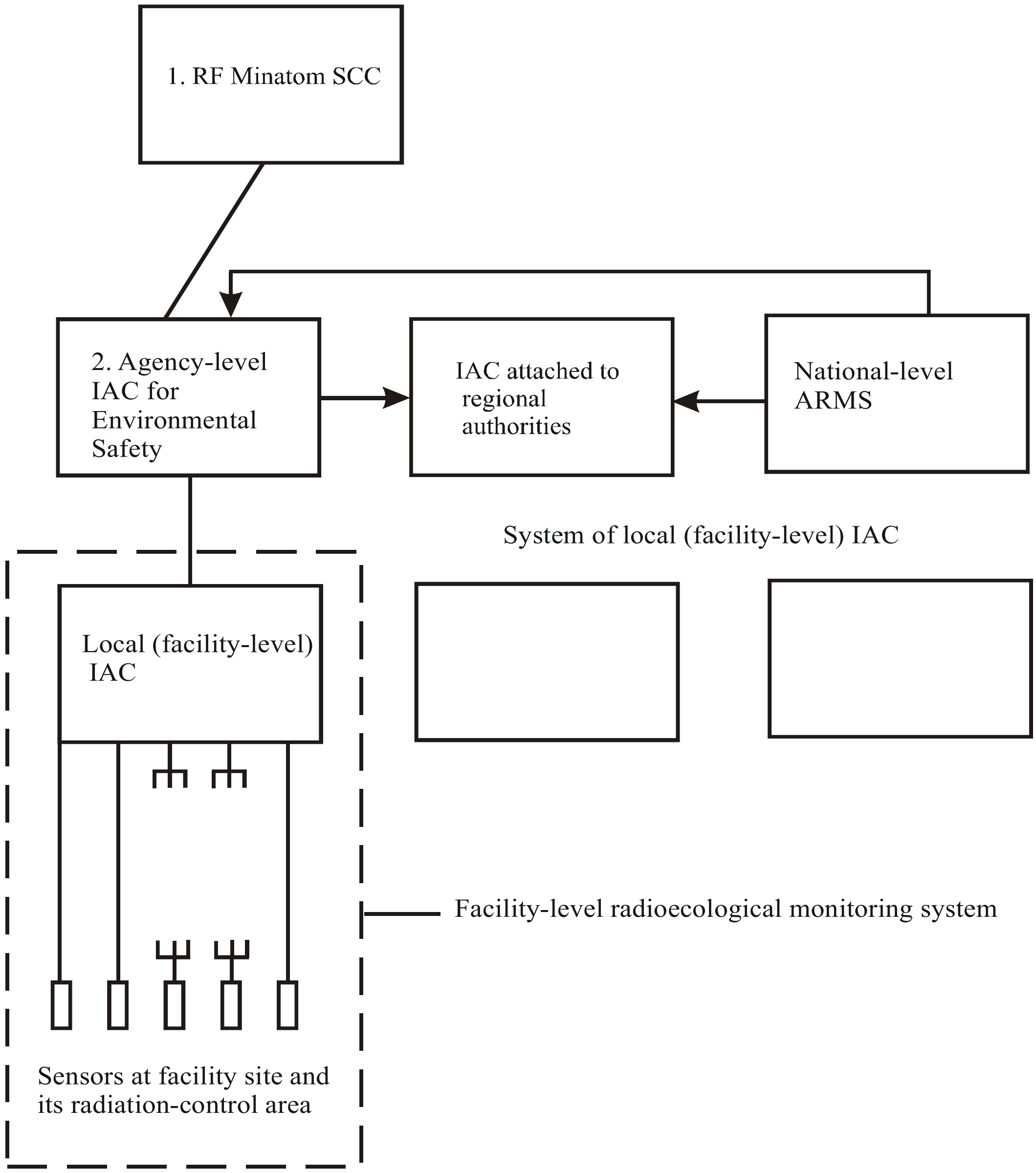


Figure 6 Block-diagram of the regional system for radioecological safety

Local subsystems of the radiation monitoring at radiation-dangerous facilities should constitute important elements of such information & analytical center. One of such local systems is recommended to be developed at the SevRAO Branch n°2 site.

Russia has already collected some profitable experience in the development of radiation monitoring systems. Thus, within the framework of the "Radiation Control at Facilities Involved into the Decommissioning and Dismantlement of Russian Strategic Ballistic Missile Nuclear Submarines (SSBN) – Application of the PICASSO System" international "Arctic Military Environment Cooperation" (AMEC) program, the designing and construction of radiation-monitoring systems at both Atomflot FSUE and Poliarnyi Shipyard n°10 (Poliarnyi town) have been carried out by the IBRAE RAS since 1999 (Figure 7). To implement the Project, the Norwegian side has put at Russia’s disposal a computer program for visualization of the radiation monitoring results - PICASSO-AMEC – developed on “PICASSO-3” basis, whereas the Russian side ensures support in measurement and communication and has provided software to process information and transfer the results into the “PICASSO-AMEC” system. The system under consideration has been just put into pilot operation at Atomflot FSUE; in 2004 similar system is to be completed at the Shipyard n°10 (Figure 8).

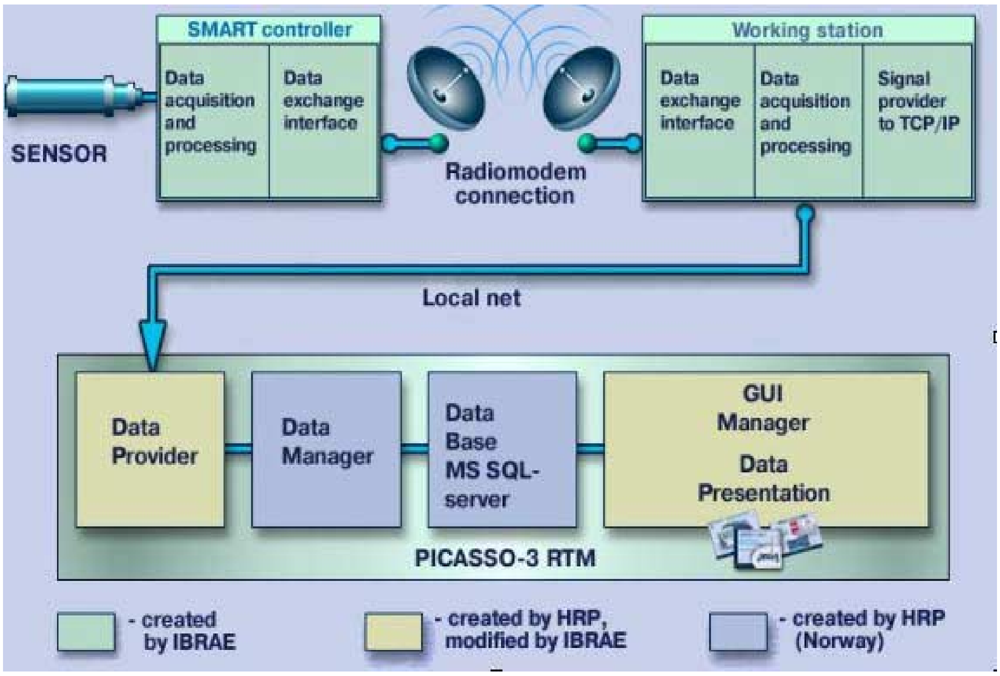


Figure 7 Structural scheme of the radiation monitoring system developed at IBRAE RAS within the AMEC international program (signals from sensors via a system of converters, wire or radio communication are transferred to facility-level Information & Analytical Center (IAC), accumulated and used for current analysis of the radiation situation)

In addition, the development of a regional information-analytical center for environmental safety has recently begun at DalRAO FSUE (Vladivostok-city).

This project is considered as a component of the Regional Environmental Safety System (RESS) open to further upgrading and build-up. The program–engineering complex under construction will make it possible to realize on-line access to information on the current technical status and the radiation situation at the facilities involved into NS-dismantlement process in Russian Primorie (the Far East region). With consideration for further upgrading, the Regional Information-Analytical Environmental Safety Centers (RIAESC) can be used for purposes of informing interested entities – including public funds – on radiation-dangerous facilities and the current status of the NS dismantlement process in the Far East region (Figure 9).

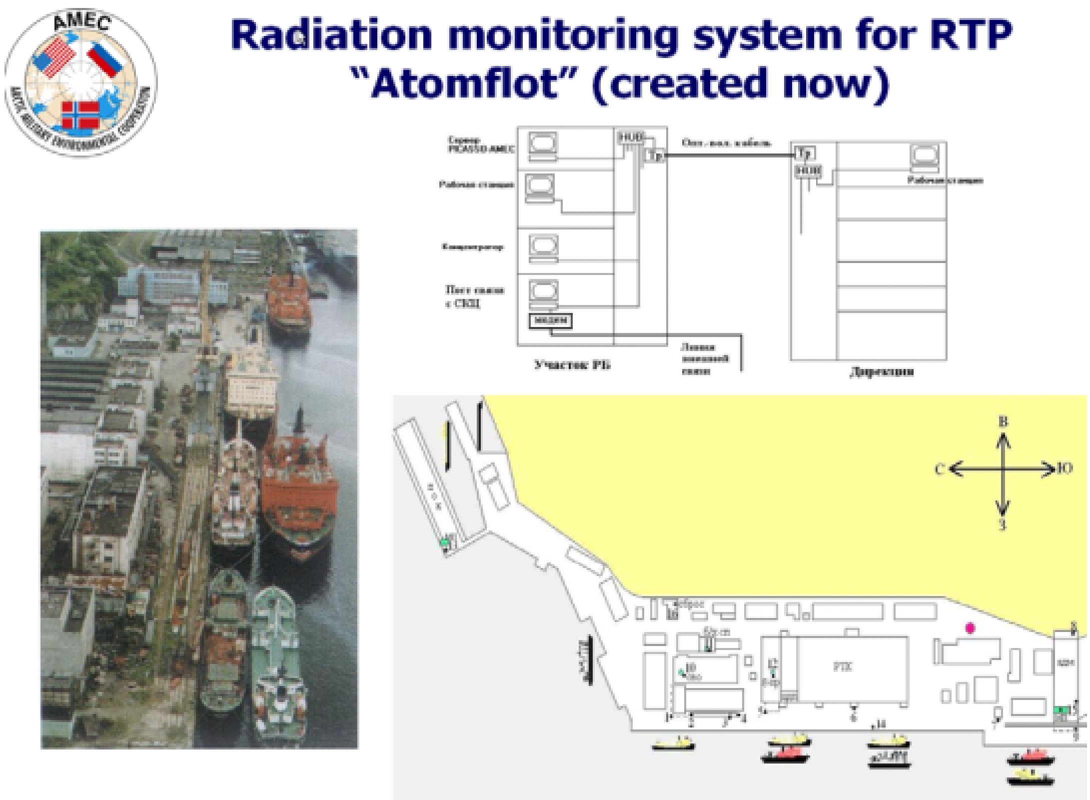


Figure 8 Atomflot FSUE radiation monitoring system includes 14 air & water radiation monitoring sensors and a weather station

Figure 9 Facilities covered by the radiation monitoring system of the Branch n°2 DalRAO FSUE (2003)

Similar-type system to be developed at the SevRAO Branch n°2 in Gremikha should include:

- Automated sensors of the control over the radiation situation at the former LBSF site and throughout the restricted-access area;
- Automated air & water monitoring devices;
- LBSF-level computer system for collection, transfer, storage and analysis of the radiation monitoring-related information;
- Computer programs for simulation of radioecological implications of potential radiation accidents to perform information support of the making decision process on their minimization and elimination;
- Ensuring a possibility of transferring the collected data to both the Murmansk region IAC and the RF Minatom SCC and the subsequent step-by-step integration of the local-level system under construction into branch- and agency-level systems and, finally, into unified national monitoring systems similar to the UARMS of Russia.

Such a system is to be developed at the SevRAO Branch n°2 in the coming 12 to 18 months, the integral cost (design, equipment acquisition and mounting) being estimated at about € 600 000.