DOD USA
With participation of TMC
(Technology Management
Company)

ATRP-R
(Advanced Technology Research Foundation)
With participation of
Ministry of Defense
Ministry of Nuclear Energy
Russian Academy of Sciences

FINAL REPORT

ATRP-R project

"Environmental Security Implications of Decommissioned Russian Nuclear Submarines, Including Dismantlement: Feasibility Study"

____________ A A Sarkisov

ATRP-R Expert Council Chairman

Moscow, 2000

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The Ministry of the Nuclear Energy of Russia has considered the Final Report of the ATRP-R project: "Environmental Security Implications of Decommissioned Russian Nuclear Submarines, Including Dismantlement Feasibility Study". We are of the opinion that all the aspects of the possible environmental security implications of decommissioned Russian nuclear submarines have been discussed in this Final Report

We agree that the main danger at dismantled nuclear submarines handling roots from nuclear-radiation consequences of the possible accidents In the report in question the potential scenarios of the emergency situations which may occur at different stages of dismantlement are treated

In the course of the analysis of the current state of works on the Russian nuclear submarines dismantlement the normative-legal basis of the dismantlement is given as well as the data on the number of submarines dismantled by the year of 2000 and data on dismantlement infrastructure of the North-West and Far Eastern regions All the stages of the nuclear submarines dismantlement technologies are discussed and the Russian concept of the complex dismantlement till the year of 2010 is given The conclusion about the necessity of the systematization of the normative-legal acts of Federal and regional levels which form the requirements and norms for decommissioned Russian nuclear submarines handling

All these and other materials of the Final Report are considered valuable initial data for the conduction of future researches (including the researches in the network of international programs and agreements) on environmental security implications of decommissioned nuclear submarines

The materials of the given Final Report will be used by the specialists of the Ministry of the Nuclear Energy of Russia in their work

(Deputy Minister of Nuclear Energy of Russia) V Lebedev

The Russian Academy of Science has studied the Final Report of the ATRP-R project. “Environmental Security Implications of Decommissioned Russian Nuclear Submarines, Including Dismantlement Feasibility Study” and considers it to be a step towards the research of the ecological security of the regions participating in the process of nuclear submarines dismantlement

Taking into account a large number of the nuclear submarines to be dismantled, their poor technical condition and radiation potential as well as the condition of the maintenance facilities , nuclear submarines dismantlement can be named amongst the most important ecological problems which draw attention of many states and international organizations

It is very important that at this stage of works the formation of meta-database has began on different aspects of nuclear submarines handling after their decommissioning and on environmental security implications of decommissioned nuclear submarines

The obtained results may lay good basis for the start of new international programs and projects on ecological problems including the continuation of the researches on ATRP-R project

(Vice –President of the Russian Academy of Science) N Laverov

The Department of the Head of the Ecological Security of the Russian Defense Ministry has viewed the Final Report of the ATRP-R project "Environmental Security Implications of Decommissioned Russian Nuclear Submarines, Including Dismantlement Feasibility Study" We are of the opinion that the main goal of the first stage of the works has been achieved- proved is the technical feasibility of the further researches in the field of the environmental security implications of decommissioned nuclear submarines

Much attention in this report is paid to the contamination sources and potential threats rooting from the process of nuclear submarines dismantlement The priority range of the works on the ecological security increase during nuclear submarines dismantlement and storage has been defined in accordance with risk degrees for the environment and population The analysis of the risk evaluation, their methodological and normative-legal aspects is given in the report in question

The analysis of the monitoring methods and principles of the integrated monitoring system formation in the regions participating in the dismantlement process are of great importance

The proposals for the future works given in this report may be a basis for the development and realization of the future projects and programs

The obtained results of the given Final Report will be used by the specialists of the Defense Ministry of the Russian Federation in their work in the field of ecological security

The following works must be done

- the development of the norms of the allowable concentrations of radionuclids in the sea water, sea sediments and the places of nuclear submarines utilization and storage Coordination of these norms at international level,
- data systematization on the environmental problems in the regions participating in handling of the decommissioned nuclear submarines,
- data systematization and analysis of the variants of radioactive and non-radioactive pollutants in the regions participating in handling of the decommissioned nuclear submarines Pollutants ranging according to their hazard degree,
- methods and technologies of ecological consequences liquidation of the possible accidents during the storage of the nuclear submarines, unloading of the spent nuclear fuel, radioactive wastes handling and dismantlement of the nuclear submarines and service vessels of the atomic fleet

(Head of Ecological Security Department of the Ministry of Defense of Russia) B Alexeev

THE LIST OF ABBREVIATIONS:

AB	- accumulator battery
ADT	-ammunition and defense technology
AF RF	-armed forces of the Russian Federation
ARA	-admissible residue amount
ASPP	-atomic steam producing plant
ASV	- atomic surface vessel
ATRP-R	- Advanced Technology Research Foundation
CG	-compensating group
CTB	-coastal technical base
EHF	-Ecologically Hazardous Factors
FP	-fission products
FTB	-floating technical base
GHP	-gas of high pressure
ICRP	-International Commission on Radiation Protection
IOH	-international organization on the health protection
ISM	-integrated monitoring system
LMHC	-liquid metal heat carrier
LRW	-liquid radioactive wastes
MAC	-Maximum Admissible Concentration
MD RF	-Ministry of Defense of the Russian Federation
MES RF	- Ministry of Emergency Situations of the Russian Federation
MNE RF	-Ministry of Nuclear Energy of the Russian Federation
NR	-Nuclear Reactor
NS	- nuclear submarine
NS	- nuclear submarine
PLS	-Place of Long-term Storage
PLS	-point of long-term storage
PTS	-Place of Temporary Storage
RAS	-Russian Academy of Science
RB	-Reactor Block
RC	-Reactor Compartment
RB	-Reactor Block

RED	-rate of the equivalent dose
Rosgidromet	-Federal Service on environment monitoring
RS	-Radioactive Substances
RW	-Radioactive Wastes
SCEP	-State Committee on ecological problems
SCR	-Spontaneous Chain Reaction
SES	-Sanitary Epidemic Service
SG	-Steam Generator
SH	-Solid Hull
SHPP	-Spent Heat Producing Plant
SIR	-sources of ionizing radiation
SNF	-spent nuclear fuel
SPU "Typhoon"	-Scientific Production Union "Typhoon"
SPZ	-Sanitary Protection Zone
SRS	-sharp radiation sickness
SRW	-Solid Radioactive Wastes
SUE "ZVEZDA"	- State Unitary Plant
SUE "ZVEZDOCHKA"	- State Unitary Plant
USASEC	- Unified State Automated System of Ecological Control
USSEM	- Unified State System of Ecological Monitoring
APS	-atomic power station
AZ	-active zone
OAC	-oriented admissible concentration
OSLA	-oriented safe level of affection
"n"year^{-1}	- number of events per year

THE PROLOGUE

In the final report of the first stage of ATRP-R program we have considered the possible impact of Russian submarines decommissioning and dismantlement on the ecological safety of the North-Western and Far-Eastern regions There exists enough open information, calculation-analytical models, experimental possibilities as well as organizational structures for the execution of such work

At the next stage we propose to form databases from the sources of information systematized at the 1st stage, to make a summarization and procession of the material, to perfect the methodology and execute risk assessment for the whole period (70-100 years) of handling the submarines and their elements after their dismantlement

The integral part of the future work is creation of the basis for the integrated monitoring system and development and implementation of the measures for risk reduction from submarines dismantlement

As it is shown in the report for the year 2000 183 nuclear submarines were decommissioned on the Northern and Pacific fleets all in all, nuclear reactor fuel was unloaded from 70 of them, dismantlement or the formation of reactor blocks has begun on 45 of them The dismantlement process on none of the utilized submarines has reached the stage of reactor compartment storage

The afloat period of the nuclear submarines and reactor blocks may amount to 30 and more years Because of the long afloat period the accident factor due to the construction aging, personnel errors, natural calamities or terrorism becomes dominant

One of the main tasks of the first stage was to gather the information (meta database) on different aspects connected with the process of submarine handling after decommissioning and possible ecological impact of this process on nature and population The plan for the database

(as a list of most important blocks of the information field with the corresponding sources) is placed in Appendix 2 It is shown there that the information field of the studied problem can comprise 13 blocks with each of the blocks combining the information on similar subjects For example, the information on "Technical conditions of the nuclear submarines", "Storage place of the wastes of the nuclear fuel" and so on In the list of information sources will you find the titles of the articles from periodicals, monographs, expert short letters, reports at seminars and conferences, scientific papers For each source we have indicated its storage place In the sections of the given report we have begun the process of gathering information for the database which at the present stage gives a quantitative notion on the utilization of the nuclear submarines in Russia, on the infrastructure of its execution, on the sources of pollution and potential hazards and scenarios of the

report we have begun the process of gathering information for the database which at the present

possible accidents As a matter of preliminary discussion we have touched on the questions of the assessment risk methodology and building of the integrated system of dismantlement monitoring

The major part of the materials prepared by the experts (ref Appendix 1) was handed over to The Russian Academy of Science IBRAE for processing, systematization, reference and editing. These materials were approved by the public authorities of the Russian Federation

The executors of the report are more than 40 leading specialists of the Ministry of the Defense, The Russian Navy, Ministry of Nuclear Energy, Russian Agency on Vessel Building, Russian Academy of Science as well other Ministries and Departments

1. INTRODUCTION

In this section the structure and history of a non-governmental organization ATRP-R is described The data on the content, scale and gravity of the ecological aspects of the nuclear submarine utilization is also discussed in this section.

1.1. Brief history of ATRP-R creation, its structure and main tasks

During the past two decades of the XX century especially after the Chernobyl accident the concern of the international community over radioactive waste handling problems has grown perpetually As a consequence of this anxiety there has been masterminded the idea of setting up the Nuclear Waste Advanced Technology Research Program Foundation Officially this concept was put forth by the Joint Declaration of Chairman of the House Subcommittee for Military Research and Development ,Mr Curt Weldon, and Chairman of the Russian State Duma Committee on the Russian North Mr Vladimir Gomon, and signed in February, 1997 in Washington D C

The initiative suggested in this Declaration was later supported in the Decree of the Russian State Duma № 1462 on June 4, 1997 and the US Senate Resolution № 224 of May 6, 1998

From September 1997 to March 1998 numerous meetings and consultations were held with the Representatives of the Parliaments of Sweden, Norway , The U S A, Denmark and many others. As a result of these meetings the initiative on ATRP-R creation was approved

The information on the given project was successfully presented at the **ACOPS** Session (Stockholm, January 1998) and at Intergovernmental Group on radioactive wastes problems in Russia (Brussels, February 1998)

The primary guidelines and objectives of this Program have been agreed by the Russian Ministry of Defense, Ministry for Nuclear Energy of the Russian Federation and a number of the Russian State Duma Committees IBRAE Research Institute has been identified as the primary scientific agency to be responsible for the Program from the Russian side

Weldon-Gomon's initiative has gained wide support and is defined by the utmost importance of the problems to be investigated These problems have global nature and can be decided via international cooperation

The main tasks of ATRP-R are

- Assessment and certification of technologies as related to the dismantlement of the nuclear submarines as well as evaluation of such technologies from the environmental security standpoint
- Creation of the international market and Internet database on nuclear wastes handling technologies

- Creation of the international market and Internet database on nuclear wastes handling technologies

- Obtaining support of the governmental bodies of the Russian Federation The USA and other countries for the Program implementation .

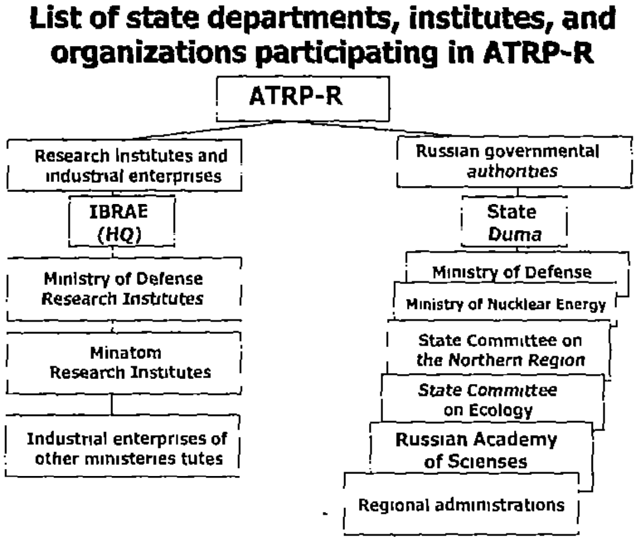

List of state departments, institutes, and organizations participating in ATRP-R

Fig. 1.1.

In order to implement the program in the Russian Federation there has been set up a non-governmental institution (foundation) of Advanced Technology Research Foundation for nuclear waste, i e ATRP-R The similar task from the US side has been authorized to TMC (Technology Management Company, Albuquerque, New Mexico)

The list of the state bodies, institutions and organizations of RF which take part in the ATRP-R program can be seen in fig 1 1.

In fig 1 2 you can see the organizational structure of the works on ATRP-R program

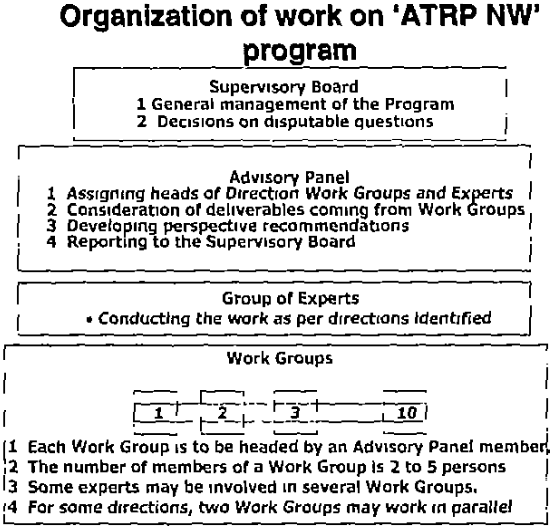

Organization of work on 'ATRP NW' program

Fig. 1.2.

Fig. 1.2.

As of this moment specifically for this Program there has been established the Supervisory Board which represents the ATRP-R supreme authority and the Expert Council, both comprising the representatives of the Russian Ministry of Defense, Navy, Ministry of Nuclear Energy, Russian Academy of Science and various other institutions of the Russian Federation. The list of experts who participated in this research is represented in Appendix 1

1.2. The content of the research of the 1st stage

In the year 2000, after a number of Russian-American meetings, there was reached the decision that at the first stage of the project the primary emphasis should be made on the issue of environmental security of the decommissioned Russian nuclear submarines As the first step of the study of the ES implications, a feasibility study was planned for this endeavor, outlined as an independent study.

Taking into account a large number of nuclear submarines to be utilized as well as their poor technical condition and their radiation hazard potential , the nuclear submarine dismantlement may be considered one of the most important ecological problems

The problem of the nuclear submarine dismantlement becomes even more difficult as most of the decommissioned submarines are located in the Far Eastern regions where nature is especially sensitive to the harmful anthropological interference

The following figures speak of the large scale of the nuclear submarine utilization problem

- the total activity of the spent nuclear fuel of the submarines amounts to more than 600 million Ci (2,2 10^{19} Bq), just to compare the total activity of the radioactive accumulated as a result of the activity of the atomic industry plants of USSR and Russia amounts to about 4 billion Ci (1,48 10^{20} Bq) [2]
- the total weight of the radioactive construction materials of the nuclear submarines to be utilized is over 150 000 tons,
- the total weight of the metal to be cut is 1 5 million tons [2]

The gravity of the problem of the nuclear submarine dismantlement is aggravated by the following factors

- Rapid increase of the number of the decommissioned nuclear submarines and the inadequacy of the spent fuel handling facilities in the North West and Far East regions of Russia,
- Inevitability of the lengthy on-water floating storage of the decommissioned nuclear submarines with spent fuel on board,
- Great amount of the liquid and solid radioactive waste accumulated during the past years of submarine operation, as well as spent fuel resulting from regular reloading of the active zones, practically exhausting the floating and surface nuclear fleet technological maintenance bases capacities (for spent fuel, liquid and solid wastes),
- Poor technical condition of a number of coastal and floating radioactive waste storage facilities,

practically exhausting the floating and surface nuclear fleet technological maintenance bases capacities (for spent fuel, liquid and solid wastes).

- Current practice of lengthy storage of the spent fuel in containers in the open areas within the direct vicinity of the actual nuclear submarine unloading operations,
- High total activity value of the spent nuclear fuel and radioactive waste

1.3. Current state of the works on the nuclear submarines dismantlement in the Russian Federation

There are many reasons why the nuclear submarines dismantlement process faces so many problems in Russia Below will you find 3 main ones

1 Decommissioning of a great number of nuclear submarines over a very short period of time

2 Decommissioning of many submarines fell on the years of economic crisis in Russia In these years the Russian Federation could hardly provide even the minimal financing for this project

3 There has been no realistic plan for the dismantlement of the nuclear submarines in Russia. The concept of complex dismantlement developed in 80-s was oriented for the long-term storage of the submarines in artificial caves which were built for submarine hiding This concept presupposed a costly re-equipment of the caves as well as development of a complex and very expensive transportation system For this and many other reasons this concept was turned down

The quantitative data on nuclear submarine decommissioning in Pacific and Northern Fleets is shown in fig 1 3 Fig 1 4 reflects the dynamics of the unloading of the spent fuel of the decommissioned nuclear submarine reactors The nuclear fuel remains onboard on more than half of the nuclear submarines to be decommissioned

Up to this moment not a single decommissioned submarine has been completely dismantled Because of the unavailability of the corresponding infrastructure for the long-term nuclear submarine storage, the dismantlement is conducted on a temporary scheme consisting of cutting out of the reactor block which consists of reactor compartment with 2 or more adjacent compartments which keep them afloat

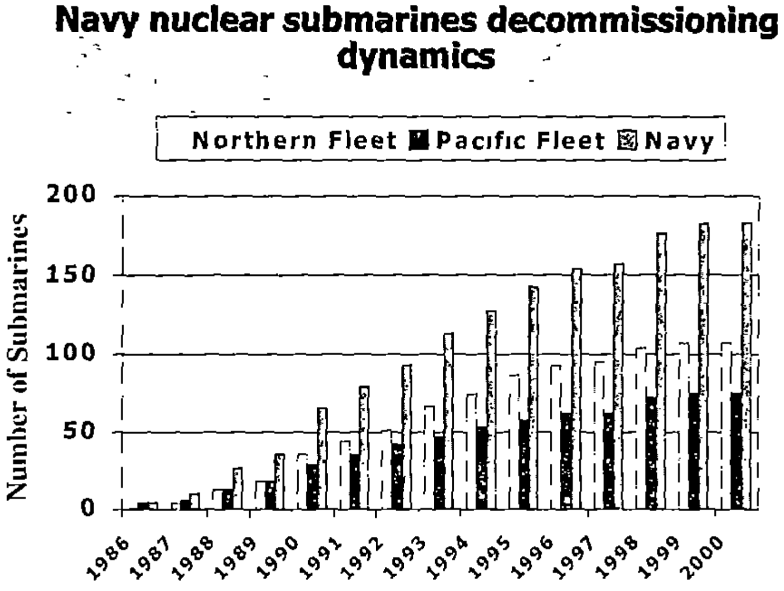

Navy nuclear submarines decommissioning dynamics
Northern Fleet
Pacific Fleet
Navy
Number of Submarines
200
150
100
50
0
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000

Fig. 1.3.

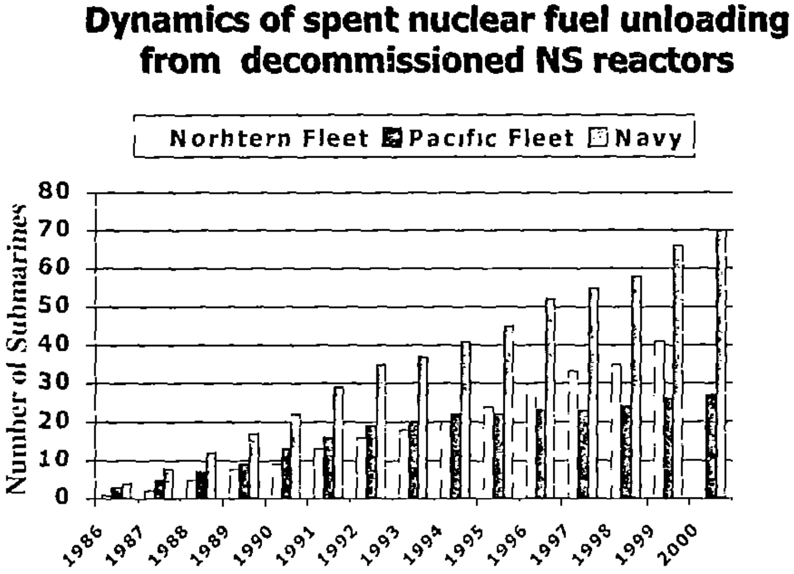

Dynamics of spent nuclear fuel unloading from decommissioned NS reactors
Norhtern Fleet
Pacific Fleet
Navy
Number of Submarines
80
70
60
50
40
30
20
10
0
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000

Fig 1.4

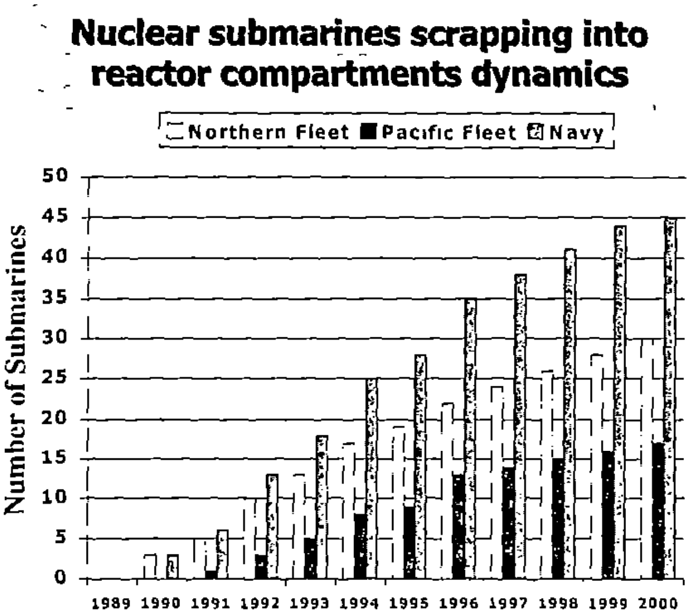


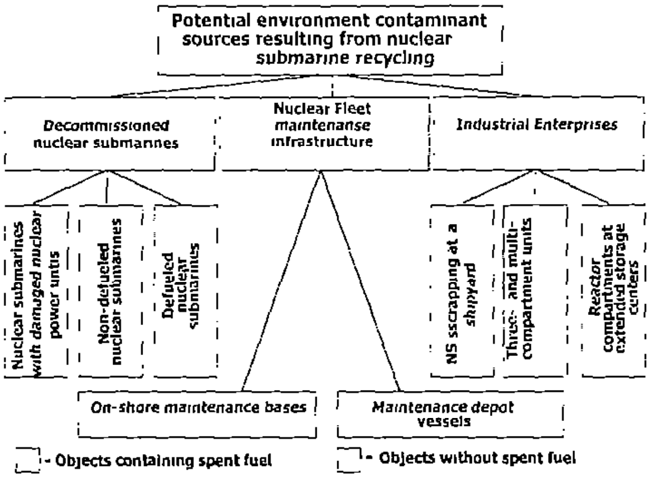
Fig 1.5

The created 3 or multi-compartments blocks stay afloat until works begins on cutting and formation of the reactor compartment with its further transportation to the place of a long-term storage

The dynamics of the nuclear submarine utilization on the temporary scheme is shown in fig 1 5

1.4. Risk factors and potential environment contaminants connected with nuclear submarines dismantlement

The main pollution sources connected with the process of nuclear submarine dismantlement are shown in fig 1 6



vessels
- Objects containing spent fuel
- Objects without spent fuel

Fig. 1.6.

1.4.1. Decommissioned nuclear submarines

Most of the potential ecological risk is connected with the decommissioned nuclear submarines and with those submarines which are located at long-term storage places

The hazard is defined by the nuclear fuel remaining on the submarines and by the poor technical condition of those nuclear submarines The decommissioned nuclear submarines are located in the places unprepared for a long-term safe storage Material part and measures on the capsulation of the solid (inner) hull and on preparation of the submarines for a long-term afloat storage Everyday operation of the vessel has been practically stopped, there is only 20 % of the crew aboard the vessel.[1,2]

Especially grave situation is with the nuclear submarines of the 1st and 2nd generations , the dismantlement of which is conducted very slowly due to the necessity of meeting international agreements on the reduction of the strategic nuclear submarines Most of the mechanisms and equipment are outdated The corrosion of the light (outer) hull has reached hazardous levels and there are leakages in the capsulation of the main ballast Mainly for the above-mentioned reasons the transportation of the submarines of the 1st generation from the storage and waiting places to the place of the dismantlement will be impossible in some years without the usage of the transportation docks [8]

All the above-mentioned facts put in danger safe afloat storage of a nuclear submarine and require the development and realization of the storage safety measures for the decommissioned nuclear submarines

Status of nuclear submarines decommission and recycling

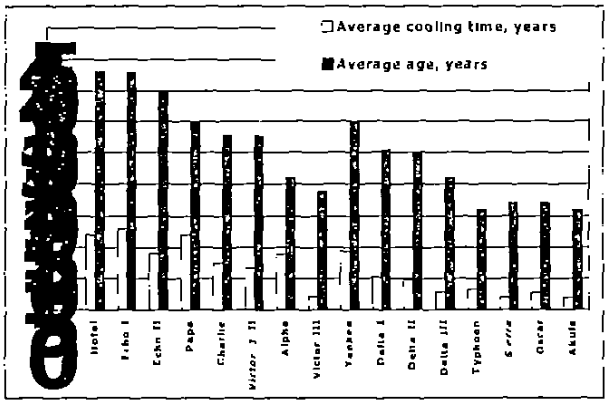


Fig 1.7.

These measures should include the provision of the absolute capsulation, floodability, nuclear, radiation and ecological safety and constant presence of the number of the crew aboard the vessel which is sufficient for the provision of the safe long-term afloat storage

In fig 1 7 will you find the average data on the age and storage period for the decommissioned nuclear submarines of different projects.

The general idea of the technical condition of the decommissioned nuclear submarines is given in tab 1 1

Status of Some 45 Nuclear Submarines (Decommissioned, Afloat)

№	Technical conditions	Amount of vessels examined	Percentage of vessels examined vs. total (45)	Comments
1	Hull leakages	14	31	Primarily North Fleet vessels, 5 of which with first frame leakages
2	Driving ballast leakages	34	76	14 submarines have their high air pressure devices down high sinking risk
3	First frame (nuclear power unit) leakages	9	20	
4	Potential PB emissions into atmosphere	44	97	

Tab. 1.1.

The most important problem of the decommissioned nuclear submarine storage is the unloaded nuclear fuel on 60% of them At present the number of the decommissioned nuclear submarines which are kept afloat totals 120, more than 110 of which have unloaded nuclear fuel The total radiation potential of the reactors nuclear fuel of these submarines amounts to 200-300 million. Ci In case of a hypothetical nuclear accident there may arise such consequences which will correspond to the 5^{th}-6^{th} levels of nuclear event scale (IANS-International Association on Nuclear Energy Control)

If we take into consideration that the accident in Chazhma Bay (in 1985) took place on the "fresh" fuel (the new active zone has just been loaded), then the consequences of the accident on the active zone will be more grave The overshoot of the long-lived nucluds in this case will be 3-4 times higher than during the accident on the "fresh" fuel [2] (More detailed description of the accident in Chazma Bay can be found in Section 4 of this Report)

The unloading of the active zones at present is restricted by many reasons That is why the period of nuclear fuel presence in the reactor active zones is expected to be a very long one

period of nuclear fuel presence in the reactor active zones is expected to be a very long one

At the current speed of active-zone unloading the questions of the spent nuclear fuel storage in the reactors become more serious.

A special attention should be paid to the nuclear submarines with damaged atomic steam-producing plants which are kept afloat on a long-term basis. Aboard these nuclear submarines there is nuclear fuel, the unloading of which is impossible due to the large dose exposure required for fulfillment of these works and lack of efficient safe technologies for handling the nuclear fuel of the damaged nuclear submarines Besides, each of these submarines requires the development of the special technology which should take into account the peculiarities of the submarine construction, its reactor as well as the character of the damage [3]

The list of nuclear submarines with damaged steam-generated units is shown in tab 1.2

Nuclear submarines with damaged steam-generating units

№/№	Class	Location	Accident kind	Notes
		Northern Fleet		
1	Alpha	Saida Bay *One reactor compartment*	Circuit pipe-lines leakage	Core is "frozen" by regular coolant Compartment *prepared for extended* waterborne storage
2	Alpha	Saida Bay *One reactor compartment*	Release of coolant to *the compartment*	Core is "frozen" by regular coolant Compartment *prepared for extended* waterborne storage
3	Echo-II	10 Navy shipyards	Reactor's core damage	Defueled
		Pacific Fleet		
1	Echo-II	Pavlovskogo Bay	Starboard nuclear reactor's thermal explosion	'Fresh' nuclear fuel at the larboard reactor Nuclear submarine is carried by 4 pontoons
2	Victor-I	Pavlovskogo Bay	Reactor's core damage	Spent fuel is onboard Nuclear submarine is carried by 4 pontoons
3	Echo-II	Pavlovskogo Bay	Reactor's core damage	Spent fuel onboard Nuclear submarine's bow lies on the soil

Tab. 1.2.

In this table will you also find some data on the character of the accident and on the technical condition of the reactor [7]

technical condition of the reactor [7]

At the places of such submarines storage the deviations from the ecological norms are observed Fig 1 8 gives a good illustration of this· levels of gamma-irradiation in the sea-floor precipitations of the Pavlovskiy Bay where the submarines with damaged reactor are located [4]

Dimensional and topographic image of the sediments gamma-radiation at Pavlovskogo Bay

1.- NS reactor accident location ,
2.- two nuclear submarines with damaged cores location ,
3 - special ships location

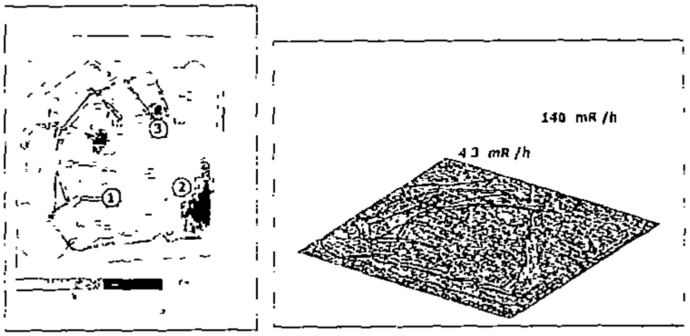


Fig. 1.8.

The problem of the damaged compartments handling requires the development of the new methods and technologies of active zone unloading with minimal dose exposures for the personnel The localization and temporary safe storage of the compartments with the damaged active zones should be undertaken to allow time for such technologies development

1.4.2. The vessels for the atomic fleet maintenance

The following vessels providing the atomic fleet maintenance are considered to be hazardous objects and potential sources of pollution

- floating technical bases for reactor recharging,
- special technical tankers

Floating depot ships for reactor refueling

№/№	Project	Construction, year	Service, years	Damaged spent fuel assemblies	LRW,m³ Ci	Technical condition
Northern Fleet						
1	326M	1960	40	No	140 18.32	After renewal can be used for refueling

| 1 | 326M | 1960 | 40 | No | 140
18.32 | After renewal can be used for refueling |

№/№	Project	Construction, year	Service, years	Damaged spent fuel assemblies	LRW,m³ Ci	Technical condition
4	326M	1962	38	No	67 34.7	After renewal can be used for refueling
3	326M	1963	37	No	93 9.6	After renewal can be used for refueling
4	326M	1964	36	No	126 118	Cannot be used for refueling
Pacific Fleet						
5	326M	1960	40	No	195 9	Cannot be used for refueling Used as a technical tanker – LRW and SRW management
6	326M	1962	38	No	68 49.284	Cannot be used for nuclear submarine reactor reloading Used as a technical tanker – LRW and SRW management
7	326	1964	36	>100	136 151	Decommissioned
8	326	1966	34	>100	47 5556.6	Decommissioned

Total amount of spent nuclear fuel stored being at on-shore depots· Northern Fleet about 20000 spent nuclear fuel assemblies, Pacific Fleet more than 10000 spent nuclear fuel assemblies.

Tab. 1.3.

Up to this moment 8 floating bases with the total of 32 000 ton displacement for reactor recharging have completed the servicing period (30 years) and with the volume of the spent nuclear fuel 5000 assemblages and liquid radioactive wastes about 9000 m³ (tab 1 3)

Also, 11 technological tankers with the total of 36 000 ton displacement have completed the servicing period (30 years) and with the volume of liquid radioactive wastes about 8230 m³ (tab.1 4) [1,2]

Technical tankers (collection, storage, transportation and distribution of LRW and SRW)

№/№	Project	Year of construction	Service, year	LRW, m³	Activity of LRW, Ci	Technical condition
Northern Fleet						
1	"Vala"	1960	40	-	-	Decommissioned Cannot be used as a tanker

| 1 | "Vala" | 1960 | 40 | - | - | Decommissioned Cannot be used as a tanker |

№/№	Project	Year of construction	Service, year	LRW, m^3	Activity of LRW, Ci	Technical condition
2	"Vala"	1965	35	5.6	0.074	Operation with maintenance
3	"Vala"	1962	38	749	8 81	Operation with maintenance
4	"Vala"	1968	32	850	17.84	Cannot be used as a tanker Used as a barge
5	"Vala"	1963	37	727	3.36	Operation with maintenance
Pacific Fleet						
6	"Vala"	1960	40	-	-	Decommissioned in 1992 Cannot be used as a tanker
7	"Vala"	1963	37	678 66	37 51	Cannot be used as a tanker Used as a barge
8	"Vala"	1969	31	859	0 894	Cannot be used as a tanker Used as a barge
9	"Vala"	1963	37	-	-	Cannot be used as a tanker Used as a barge
10	326M	1962	38	68	49 284	Used as technical tanker for LRW and SRW storage
11	326M	1960	40	194 5	9 02	Used as technical tanker for LRW and SRW storage

Tab. 1.4.

The repairing works on the vessels are restricted due to the high levels of radiation and radioactive pollution The problem of the dismantlement of these vessels is a separate specific task.

1.4.3. The facilities of coastal infrastructure

The facilities of coastal infrastructure are considered to be hazardous from the point of radiation and pollution The technical state of the storages of the spent fuel, solid and liquid radioactive wastes represents a special radio-ecological hazard

The coastal technical bases were constructed in 1962-65 with outdated equipment and devices for physical and radiation control Most of the bases are in emergency condition Due to this factor , radiation contamination has occured For example, the latest researches at the Pacific Fleet have shown that the whole technical territory of the coastal technical base (part of the Sysoev Bay and Bay Strelok) is polluted with the artificial nuclids (mainly with Ceasium-137 and Cobalt-60) The bases of the Pacific and Northern have similar radio-ecological problems

The data on the quantity and the total activity of the accumulated radioactive wastes at coastal storages is shown in tab 1 5 [5]

The data on the quantity and the total activity of the accumulated radioactive wastes at

Radioactive wastes amount and total activity

Region	Liquid wastes		Solid Wastes	
	Volume, m^3	Total activity, Ci	Volume, m^3	Total activity, Ci
North:				
region of Murmansk	4451 1	69,15	6901 9	1497,6
region of Severodvinsk	3639 4	263.15	2091,61	1103,64
Total:	**8090,6**	**332,3**	**8993,5**	**2601,24**
Far East:				
Primor e	6339 2	258 85	15060.05	259679,36
Kamtchatka	928.16	5595 0	863 2	1605.15
Sum:	***7267,36***	***5853,85***	***15923,25***	***261284,51***
Total:	***15357,96***	***6186,15***	***24916,75***	***263885,75***

Total activity of solid and liquid wastes amounts to ~ 27000 Ci.

Tab. 1.5.

1.4.4. 3-compartment blocks with reactor compartment

As it was mentioned earlier, due to the absence of the places for reactor compartment long-term storage and corresponding infrastructure at the fleets, at present the principle of the temporary storage of the cut-out afloat reactor compartments (in the form of 3 or multi-compartment block) is realized

Up to the present 45 nuclear submarines have been dismantled to some extent (at the Northern fleet-30 and at the Pacific-15) according to this scheme 8 blocks are at different stages of formation

Up to this moment The Navy has been responsible for three-compartment blocks but in accordance with the decision of the Russian Federation Government from 28 05 98 N518 the blocks are being handed over under the jurisdiction of the industry

Taking into account the significant amount of the accumulated modules and current works in this direction, there arises the necessity of scientific-technical evaluation of the possible ecological consequences of the temporary afloat storage of the reactor compartments.

Admissible afloat period of the 3-compartment is limited to the corrosion wear of its end partitions and evaluated by the experts as equal to 10-12 years

The continuation of the submarine cutting and afloat block storage require additional measures to increase the durability of end partitions and corrosion resistance of the "container" material (solid hull+ end partitions)

material (solid hull+ end partitions)

1.4.5. Spent nuclear fuel

The magnitude of the potential nuclear and radiation danger are defined by the spent nuclear fuel, in which more than 90% of all utilization components activity is concentrated At present more than 300 reactor cores and 80 000 heat-producing partitions are concentrated at the Navy facilities In the reactors of decommissioned nuclear submarines there remain onboard 200 reactor cores

The majority of the coastal and afloat storages are in poor technical conditions and their capacities are exhausted The problem of the long-term storage of the defective spent nuclear fuel of the transportation reactors is becoming more acute

The existing equipment and resources as well as the lack scheme of spent nuclear treatment do not allow for the required speed of reactor cores unloading from the reactors of the nuclear submarines to be dismantled

Means of the spent nuclear fuel transportation as well as the production facilities of the PU "Mayak" do not allow for the transportation of more than 20 active zones for the processing per year (around 5000 of spent heat producing assemblages) The most important problem, though, is connected with the spent fuel of the reactors using liquid metal as a heat carrier. On two submarines of this project active zones are "frozen" and there is no infrastructure for the removal of the spent parts from the reactor frame

In fig 1 9 the technological chain of nuclear submarine handling in the Russian Federation is shown

As applied to the submarines to be dismantled this scheme should be corrected upon taking into account the unloading of the spent fuel into metal-concrete containers and temporary storage of these containers at specially designed facilities in the Northern and Far Eastern regions

In the further studies there must be researched all the ecological risks connected with all the stages of the given chain

Technological chain for handling spent nuclear fuel from decommissioned nuclear submarines, and required infrastructure

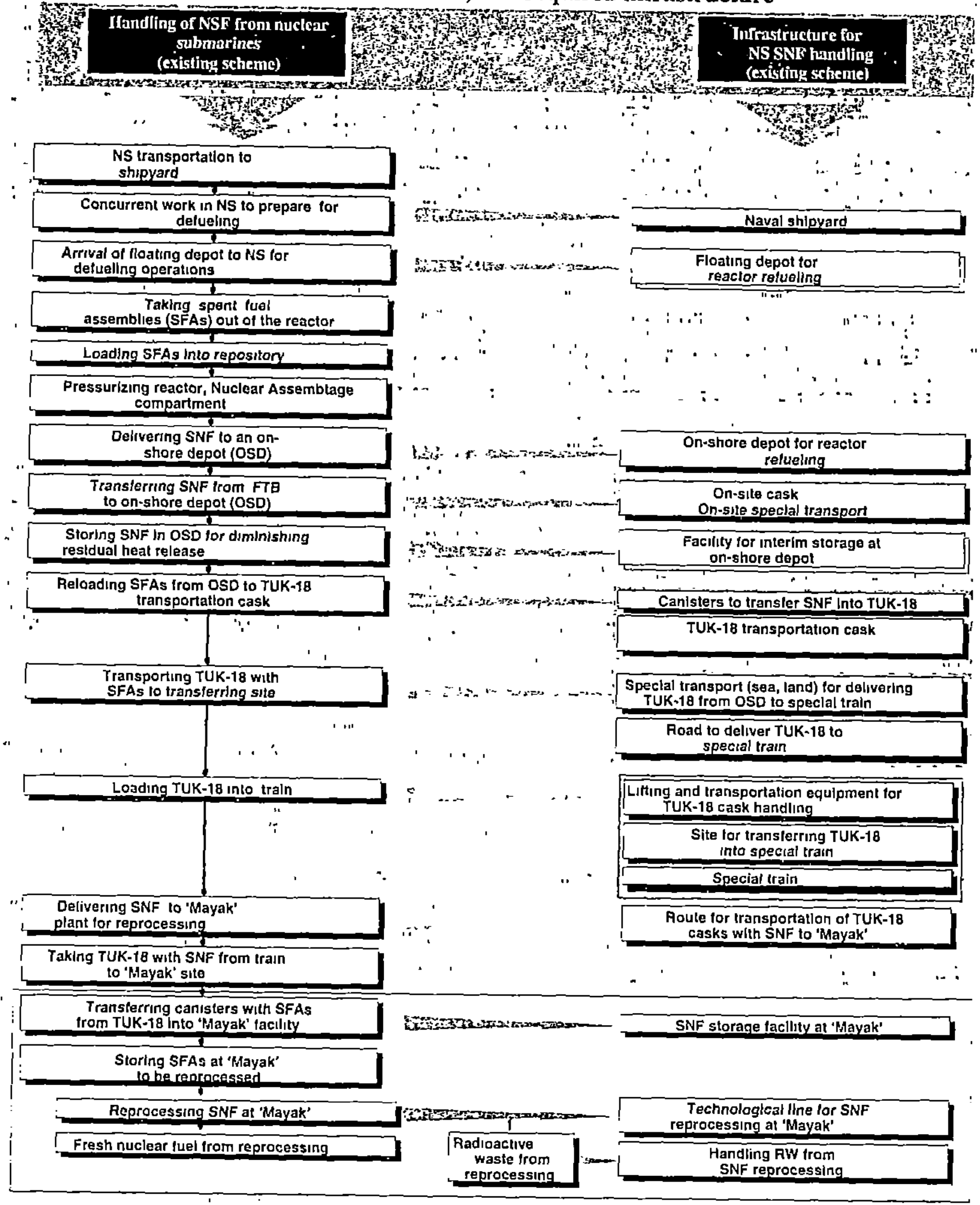


Fig 1 9.

1.4.6. Environment pollution during the process of nuclear submarine dismantlement

Traditional methods of gas and plasma cutting of the vessel constructions and equipment polluted with radioactive oxides and deposits of the isolation and paintwork materials lead to the pollution of the working areas and environment by a mixture of radioactive substances and high-toxic combustion products The dismantlement of only one nuclear submarine is accompanied by the dumping into environment up to 11,5 kg of chrome oxides, 22,5 kg of manganese oxides, 500 kg of carbon oxide and up to 650 kg of nitrogen oxide [6]

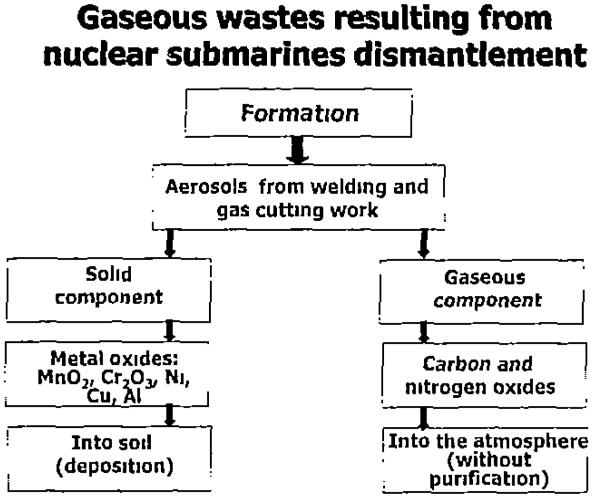


Fig 1.10.

The main hazardous gasiform combustion products evolving as a result of thermal impact on the metal and non-metal surfaces are represented in fig 1 10 Among those products are high-toxic substances of 1st and 2nd hazard class- oxides of chrome, manganese and substances with a pencil-beam activity mechanism- oxides of carbon and nitrogen In fig 1.11 the list of liquid and solid non-radioactive wastes, which are formed during the dismantlement of nuclear submarines and have a negative impact on environment and human's health, is shown [6]

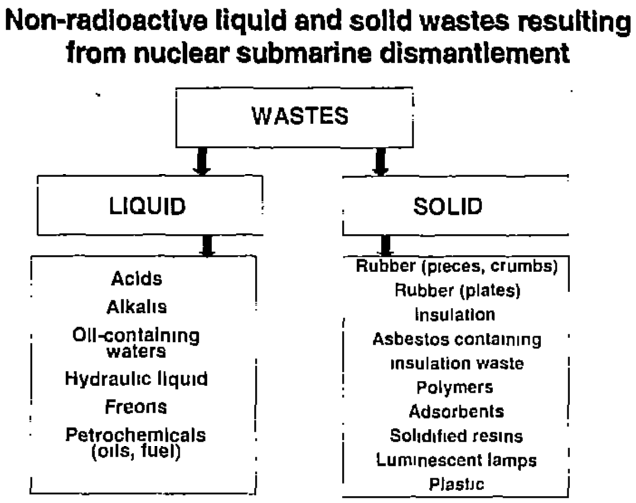


Fig. 1.11.

The qualitative parameters which characterize the wastes formed during dismantlement process depend on the nuclear submarine type and technological processes used

1.5. The place of ATRP program in the complex of existing programs and projects oriented on the research of the pollution problems of the Arctic Basin.

The protection of the Arctic Basin from the harmful anthropological influence is a very important international problem The given problem is connected with ecological safety at both regional and global levels The scholars of many countries suppose that the decision of this problem can be accelerated via cooperation of different countries not only in scientific sphere but in economic one as well

There are several international programs and projects aimed at deciding the aspects of this problem

1. AMEC Program (Arctic Military Environmental Cooperation)- this large-scale program aimed at assisting the Russian Federation in creation the infrastructure which would provide for the ecological safety of the region It presupposes the creation of the containers for the spent nuclear fuel as well as the construction of the facilities for the temporary storage of the spent nuclear fuel A special mention should be made to the fact that this program presupposes the creation of the systems of radiation ecological control at the military objects
2. AMAP Program (Arctic Monitoring Assessment Program) The given program deals with the analysis of the ecological consequences connected with the radioactive wastes and is oriented on the research of the real pollution levels The problems of the nuclear submarines dismantlement are not analyzed in this program
3. ANWAP Program (Arctic Nuclear Waste Assessment) has many different projects oriented on the evaluation of the nuclear wastes amount of the Arctic

3. ANWAP Program (Arctic Nuclear Waste Assessment) has many different projects oriented

4. MNTS-101-96B Project · Analysis of the nuclear wastes burial on the sea-floor of the Barents Sea and the Sea of Japan" One of the main tasks of the given project was the creation of the database on the nuclear submarines to be dismantled The reports of this program contains very useful information but on the whole the program was aimed at gathering and generalization of the data not at its analysis This program is not scientific in nature and the problems of evaluation, prognosis were not dealt with
5. INTAS Program (International Association for the Promotion with Scientists from Independent States of the former Soviet Union) There is only one project in this program which has its main task of researching the radio-ecological problems connected with the activity of the Russian Navy in the North One of the main tasks of the given project is evaluation of the possibility of transboundary transportation of the radionuclids after accidents at nuclear submarines Dismantlement of the nuclear submarines as uniform scheme is not analyzed, only separate accidents are researched There is no technological data and reference to the region of study
6. IASAP (International Arctic Seas Assessment Program)

As you can gather from the above-mentioned programs and projects, none of them deals specifically with the research of the ecological consequences connected with the process of the nuclear submarines dismantlement. Thus , the project proposed by ATRP-R is the first attempt of the systematic research of this scientific problem

Here are the unique features of the given project

- a complex character of the research The research of the negative impact of all harmful substances formed at different stages of nuclear submarine dismantlement on environment and human's health
- the research will cover two regions Northern and Far Eastern.
- The project will have a scientific research character and presupposes a wide use of mathematical modeling processes
- The priority aim of the further studies is not only the determination of the risks connected with handling of the submarines to be dismantled but cost-benefit analysis of the steps towards these risks monitoring and reduction

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2. DISMANTLEMENT OPERATIONS: PROCESS OVERVIEW

In this section the retrospective and legal basis for the utilization of the Russian nuclear submarines are discussed This section also deals with the analysis of the number and technical conditions of the nuclear submarines decommissioned by 2000 The stages and technology of the utilization are also shown The Concept of the Russian complex dismantlement till 2010 is treated in the given section

2.1. Brief history

Dismantlement process of the nuclear submarines in Russia began in 1985 when 3 submarines from the Northern Fleet and 2 –from the Pacific Fleet were decommissioned By that time the submarines had operated for about 25 years and their technical condition was considered unsatisfactory The dynamics of the submarine dismantlement , unloading of the spent nuclear fuel and formation of the reactor blocks can be seen from figures 1 3, 1 4 and 1.5 in the Introduction section of this report

To secure the nuclear and radiation safety-the first step in the technological chain of the nuclear submarine dismantlement should be the unloading of the spent nuclear fuel from the reactor. Then the reactor compartment is packed and cut and is transported to the place of long-term storage which provide for the safety of the personnel, population and environment.

Following the dismantlement technology as practiced in the USA, UK and France after the submarine has been decommissioned from the active service its nuclear reactor is defueled In the next step the reactor compartment is cut out and taken to an on-shore facility for lengthy storage, such a facility sufficiently distanced from the human settlements to protect the personnel, civilian population and human habitat [1-3]

Similar approach was also planned in Russia, yet the decommissioning of a large quantity of submarines in a short period of time exceeded the capacities of the technical and maintenance facilities providing for the appropriate dismantlement operations As a result the nuclear submarines were to be put in the transitional storage state awaiting for their spent nuclear fuel to be unloaded, their fore and aft parts to be cut away and the resulting three-compartment units being kept floating at the dislocation sites (two adjoining compartments, one on each sided of the reactor compartment, provide for the floating ability of the entire unit)

70 nuclear submarines are retired and defueled 43 reactor blocks have been formed, 9 are on the afloat storage, 18 at different stages of reactor block formation are at scrapping enterprises The general situation with dismantlement, unloading of the spent nuclear fuel is shown in fig 2.1

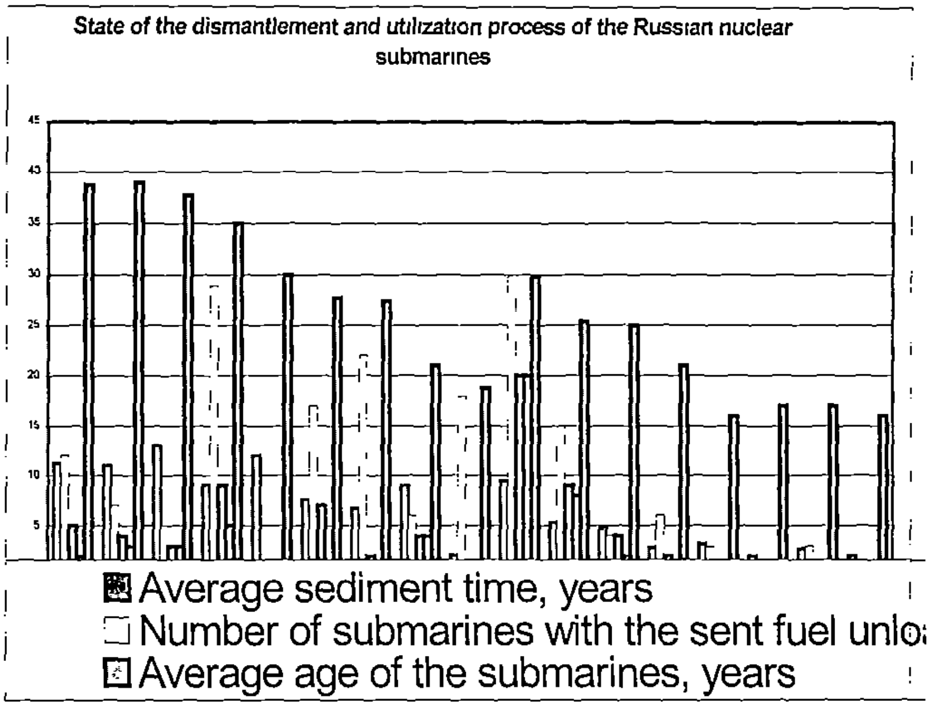

Fig 2 1.

Such a difference to the foreign dismantlement procedure has provided grounds for concern of various international agencies over the potential nuclear accidents with the resulting trans-border migrations of the radioactive substances, which called for appropriate research and anlysis of this problem.

Having evaluated the situation with the decommissioned Russian nuclear submarines the NATO Committee on the Challenges of Modern Society has appreciated the Russian dismantling procedures, however making note of the incompleteness of the dismantling technological cycle It was also determined that the Russian specific deviations from the commonly practiced international procedure do not bear a critical impact on the general dismantlement concept and the trans-border migrations of the radioactive substances risk was quite moderate, however in certain cases yet allowing for potential distributing of the radioactive substances through air, with the subsequent formation of the polluted radioactive environmental zones

This side of the issue was carefully reviewed during several seminars in the framework of the IBRAE/NATO cooperation in the years of 1995/1999, with a particular emphasis placed on the environmental security implications and radiation protection during all stages of the nuclear submarine dismantlement operations [2,3]

Currently there are being drafted the Federal Dismantlement System for the general supervision of the decommissioned Russian nuclear submarine dismantling operations and the

Currently there are being drafted the Federal Dismantlement System for the general

environmental rehabilitation of the radioactive hazards of the Russian Navy (to be completed before the year 2005), as well as the Nuclear Submarine and Surface Vessels Dismantling System Concept Both bills are linked to the transfer of the control over this issue from the Ministry of Defense of the Russian Federation (Navy) to Minatom (Russian Ministry for Nuclear Energy), which may facilitate the most appropriate investment channeling, given the actual financial and economic environment of Russia today, which could in its turn at the end of the day effectively increase the pace of the Russian submarine dismantling operations and provide for the environmental rehabilitation of the Russian Navy sites and territories (both coastal and the off-shore facilities).

The Minatom strategy shall provide for a faster unloading of the spent nuclear fuel from the nuclear submarine reactors and emergency offshore and coastal storage facilities, as well as provide for the safe handling of these materials As such, the long-term model work plan shall provide for the following results

- Provision of the safe afloat storage of the nuclear submarines with the fuel still on board up to the moment of their dismantlement.
- By the end of the year 2000 the spent nuclear fuel is to be unloaded from the nuclear submarine reactors in the amount of 20 unloadings per year, simultaneously providing for the temporary storage of such wastes,
- By the years 2005-2006 all of the spent fuel is to be unloaded from the reactors of all utilized nuclear submarines, as well as coastal and off-shore storage facilities, effectively lifting the threat of the radiation exposure as a result of emergency occurrences

Decrease the environmental risk at the radiation hazardous sites of the Russian Navy and provide rehabilitation operations for such territories

Following the aforementioned Concept such a faster pace of the spent nuclear fuel unloading operations from the floating reactor compartments (in the laid-up points of the Russian decommissioned nuclear submarines) shall be provided as a result of the following steps

- Setting up spent nuclear fuel reloading coastal facilities at the Russian Shipbuilding Agency shipyards,
- Development of the less complicated specialized nuclear fuel reloading equipment,
- Development of secure temporary spent nuclear fuel storage procedures at the shipyard facilities with the regular transportation routes and schedules established for the spent fuel shipments to the processing points

Both the spent nuclear fuel and radioactive waste handling facilities will be used for the continuous industrial servicing of the active nuclear vessels of the Russian Navy, spent nuclear fuel unloading from the coastal and off-shore storages, as well as for the air-conditioning and burial of the radioactive wastes

the radioactive wastes

However to make such an approach effective and practical it is crucial to first of all resolve a number of issues, most pressing of which are as shown below:

- Developing of the general criteria and prioritization of the radiation and environmental issues of the Russian Federation;
- Review and redrafting of the legal framework pertaining the governmental control over the security implications in the nuclear energy related industries

Resolution of all of the above-described objectives shall increase the efficiency and quality of the nuclear submarine dismantlement process

For the provision of the further works on the analysis of the implications of the dismantlement process on the ecological safety , the systematization of the big volume of information on dismantlement technologies at ship-building plants and technical bases of different regions of the country is absolutely essential

2.2. Technical condition of the dismantled nuclear submarines and problems of their safe afloat storage

To date, as a result of an increasing number of the decommissioned nuclear submarines the issues of the radiation and environmental protection have become even more critical Such a large scale decommissioning in the light of the drastic lack of funding and appropriate industrial facilities have preconditioned the emergency condition of the Russian Navy in the field of the spent nuclear fuel and radioactive waste storage, as well as the decommissioned nuclear submarines scrapping operations

In order to appreciate the scale of the problem it is enough to say that as of August 2000 there were over 200 retired and decommissioned nuclear submarines parked in various naval dislocation points of Russia, bays, lay-up bases, on-shore facilities in the vicinity of human habitats

All of this poses a serious threat of large nuclear and radioactive accidents, which could strike vast regions of Russia and seriously damage its civilian population

The real danger is characterized by the radiation risk taking into account the particulars of the event development connected with air ,seawater and floor sediments pollution as well as the pollution of the flora and fauna

Under existing circumstances it is very difficult to consider all the aspects of the ecological side of the problem and forecast the development of the events connected with radio ecological consequences of dismantlement However, some patterns can be seen from the analysis of the long operation and 10-year long period of dismantlement of the nuclear submarines

The decommissioned nuclear submarines and cut out and formed reactor compartments containing 1, 3 ,4 or more compartment blocks at present are located at the nuclear submarine

The decommissioned nuclear submarines and cut out and formed reactor compartments

basing places, at the places of temporary storage and at the ship-building plants of the Russian ship-building Agency.

The decommissioned nuclear submarines are based at the following points·

The Northern Fleet

Belomorsk military-naval base (Severodvinsk)
Ostrovnoy (p. Gremikha)
Bay Olenie
Town Skalistiy, bay Yagelnaya
Vidyaevo (Bay Ara)
Bay Saida (place of temporary afloat storage of the reactor blocks)
Town Zaozersk (Bay Bolshay Lopatka)
Town Zaozersk (Bay Nerpichiy)

The Pacific Fleet

Town Petropavlovsk-Kamtchatsk (Bay Krasheninnikov)
Zavety Ilitcha (Bay Postovaya)
Bay Pavlovskogo , Bay Strelok
Bay Razboinik. Bay Strelok (place of temporary afloat storage of the reactor blocks)

At present 88 nuclear submarines out of the above-mentioned submarines retaining spent fuel are located at the places of basing and storage 2 reactor blocks containing spent fuel (damaged submarines) are at the place of temporary storage in Saida Bay The rest of the nuclear submarines are located on the territory of the enterprises which execute the dismantlement. These nuclear submarines are at different stages of the preparation for the unloading or at the different stages of spent nuclear fuel unloading

The possibility of the active zone unloading is limited due to several reasons and the time of nuclear fuel presence in the submarine reactors may be very considerable

The presence of the nuclear submarines in the sediment with spent nuclear fuel still on board poses a potential radiation and radio ecological hazard The decommissioned vessels are located at piers being technically unprepared for the long-term afloat storage

In the laid-up mode the nuclear submarine with its spent nuclear fuel still on board presents a major potential nuclear, radiation and environmental hazard, which is constantly increasing due to the current continuing extension of the active service of the Russian nuclear submarines, which can sometimes reach over 25-30 years of service, and poor technical condition of particular submarines In tab 1 1 of the Introduction section selected 45 nuclear submarines in sediment are shown with the data on their technical condition

In tab 1 1 of the Introduction section selected 45 nuclear submarines in sediment are shown with the

To date the worst condition is characteristic of the Generation I submarine vessels, with the corrosion of their light hull having already reached the critical threshold values and in certain cases there have also been discovered primary ballasts leaks For a lengthy time interval over 40% of the nuclear submarines had no repairs and due maintenance There are many other preconditions for potential accidents, with the most probable being mistakes of the workers and personnel, high flooding and fire probability [4]

Fig 2.2 shows the principal scheme of the reactor compartment of the nuclear submarine which is kept on the water

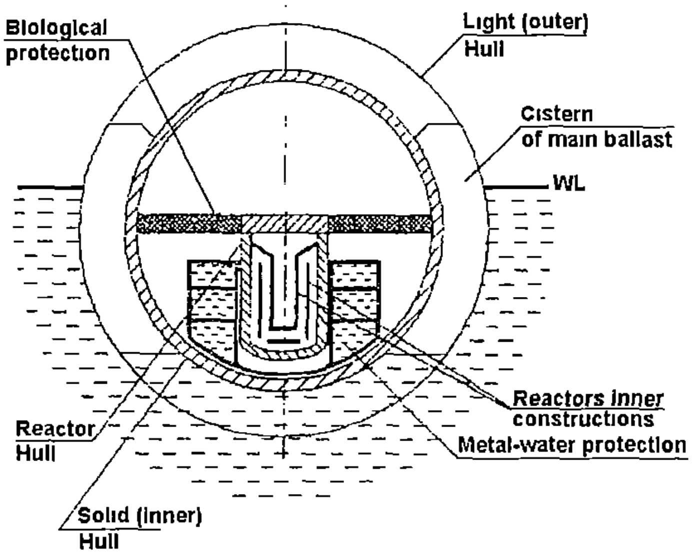

Fig. 2 2

In the unfortunate time of accidents on board of the nuclear submarines, the public is usually concerned with the resulting radiation and environmental implications Usually a special danger level system is practiced to evaluate such implications, i e the actual danger, administrative peril and social and psychological jeopardy The actual danger covers the potential radiation exposure with the resulting contamination of the air, seawater, seafloors, flora and fauna

At some places of basing the maintenance of the nuclear submarines with still-on-board spent nuclear fuel is restricted It is connected with the problem of maintaining the positive temperature in the reactor compartments at winter period (due to a poor energy provision of the region) This leads to the violation of the temperature condition and causes a problem of active zone unloading

The real afloat storage conditions of the nuclear submarines with the spent nuclear fuel on board do not guarantee their safety because of non-observance of the main requirements of the maintenance and regulations including

board do not guarantee their safety because of non-observance of the main requirements of the

- dock check ups and repairs are not conducted due to the deficit of the dock facilities of the ship-building plants and lack of financing of the above-mentioned works
- bottom-outboard fittings in case of maintenance measures absence (dismantlement, repair, solidity trials) increase the risk of outboard water penetration into the solid hull. This can lead (under definite circumstances) to the nuclear submarine sinking at the pier or during its transportation to the place of dismantlement,

The sinking of such submarines with unloaded active zones may lead to the local radioactive pollution of the water

- the service personnel is reduced by 75 %. The still working people mainly execute guarding functions and thus cannot guarantee the safety of afloat storage of the nuclear submarines
- At some places of the basing the maintenance of nuclear submarines is restricted (Gremikha Settlement) This is mainly connected with the problem of maintaining positive temperatures inside the reactor compartments during winter periods due to the problems of energy provision Similar situation may lead to the break of the temperature condition of systems and mechanisms of Reactor compartments in the winter period [5]

The time of active zones presence in the reactors of some nuclear submarines amount to 25-30 years which exceeds the existing technical conditions The break of the temperature condition may lead to the destruction of the heat producing elements, may create the problem of active zone unloading as well.

In tab.2 1 one can see the data on potential risk carriers of the nuclear submarine The absence or presence of these carriers aboard the submarine create a general picture of the potential hazard of the particular vessel

The evaluation of the presence of the potential risk carriers which influence humans and environment

№	Potential risk carrier	Northern Fleet		Pacific Fleet		Navy	
		Quantity	Share, %	Quantity	Share, %	Quantity	Share, %
1	Solid Hull(Inner)	10	15	3	6	13	11
2	Battery	53	78	2	3	55	45
3	Turbine oil	54	79	16	30	70	57
4	Diesel Fuel	33	49	1	2	34	28
5	Diesel Oil	32	47	3	6	35	29
6	Active zone	68	100	44	81	112	92
7	Heat carrier contour	13	19	6	11	19	16
8	Activity filter	65	96	49	91	114	93
9	High pressure gas	21	31	50	93	71	58
10	Vacuumation system	21	31	1	2	22	18
11	Absorber system	42	62	47	87	89	73

Tab. 2.1.

| 11 | Absorber system | 42 | 62 | 47 | 87 | 89 | 73 |

Taking into account the technical condition of the decommissioned submarines , conditions of their storage , the problem of provision of safe long-term afloat storage (15-20 years) becomes a very important one

The first measure to take is to unload the spent nuclear fuel as the forced long-term afloat storage of the first contour in the active zone is connected with the probable change in the configurations of the technological channels

A special attention should be paid to the safety of the long-term storage of the nuclear submarines with damaged heat producing plants

A long-term storage of such vessels poses a certain danger and presupposes a special responsibility of the personnel for the localization of the radiation background within the damaged compartment and the vessel on the whole.

The decision of the problem of treatment the compartments with damaged active zones requires the development of brand new methods and technologies of unloading of the damaged active zones from the reactor hulls These technologies are expected to require minimal radiation exposure of the personnel. Before such technologies are developed it is more reasonable to take decisions on localization temporary safe storage of the compartments with damaged active zones.

At present the strategy of handling reactor compartments with damaged active zones is limited to the provision of the reliable isolation from environment the cut-out damaged compartments in "sarcophagi"- reactor compartments of big diameter of the Russian nuclear submarines which are being decommissioned in accordance with the Agreement on strategic offensive arms reduction [6]

The most serious consequences on environment were caused by the accident of the nuclear submarine class "Echo-2" in 1985 (tab 1 2) Since 1985 this submarine has a depressurized (as a result of an explosion) reactor compartment and contains a "fresh" active zone which is still not unloaded and is located in the Pavloskiy Bay

The loss of floatation of the solid hull of the nuclear submarine and pontoons may lead to the sinking of the nuclear submarine and to further radioactive pollution of the Pavloskiy Bay, Gulf of Strelok and Peter the Great

Project-technical works on the preparation for the temporary afloat storage of the above mentioned submarines have shown the principal possibility of such works conduction at "Zvezdotchka", "Zvezda" of the Russian Ship Building Agency, at Poliaminskoy and Chazminskiy ship building plants of the Russian Navy. In the project works the conditions for sarcophagi formation have been defined as well as the measures which will provide their safe afloat storage.

formation have been defined as well as the measures which will provide their safe afloat storage.

The constructive measures providing impermeability of sarcophagi's frames have been also defined. The additional measures on corrosion prevention have been determined as well

The evaluation of the sarcophagus (with damaged reactor compartment) influence on environment as applied to the place of storage

The proposed method allows

- to safely isolate the damaged reactor compartments from the environment for a period of 25 years
- to exclude the expenditures on the service men and maintenance of the nuclear submarines
- to exclude at this stage financial and radiation losses connected with active zones unloading from the reactors
- for scientific and project organizations to develop brand new and reliable methods and technologies for active zones unloading from the reactor hulls which would not require great dose exposures of the personnel

The technical condition of the nuclear submarines with damaged steam producing plants requires quick measures on their dismantlement The dismantlement of these objects cannot be conducted on the general scheme due to the complex character of the consequences of heat composition damage and nuclear submarine constructions The risk evaluation during and after dismantlement process is required The risk evaluation is also required at the definition of the dismantlement model

2.3. Industrial dismantlement base

The reason for a non-traditional approach towards the nuclear submarine dismantlement in Russia stems from lack of technical capacities of the appropriate Russian industry, which effectively necessitated a transitional scheme This forced measure does not provide for the long-term solution of the problem, yet there appears to be no avoiding of this condition for at least another decade.

The complex dismantlement of the nuclear submarines presupposes the execution of a big volume of scientific-technical, organizational, production-technological and legal measures The dismantlement requires not only advanced technologies , big production facilities of the Russian ship-building Agency but the development of the dismantlement infrastructure as well

The dismantlement of the nuclear submarines is carried out at the following ship building plants and Navy facilities

North-Western Region:

"Severnoe Machine Building Plant" (Severodvinsk)

"Zvezdotchka" (Severodvinsk)

"Nerpa" (Snezhnogorsk, Murmansk Region)

"Severnoe Machine Building Plant" (Severodvinsk)
"Zvezdotchka" (Severodvinsk)

Poliarninskiy Ship Repairing Plant (Town of Poliarniy, Murmansk Region)

Murmansk Naval Plant "Sevmorput" (Town of Murmansk)

The Eastern Region:

Far Eastern Plant "Zvezda" (Town of Bolshoi Kamen)

Chazhminskiy Naval Plant (Bay Chazhma, Gulf of Strelok)

Kamtchatskiy Naval Plant (Town of Viloutchinsk, Kamchatka)

The enterprises of the ship-building industry have mastered the technology of the dismantlement of all classes of the nuclear submarines including the dismantlement of the submarines with titan hulls

In Northern and Far-Eastern Regions the places for temporary afloat storage of the reactor compartments have been created (because of the unavailability of the facilities for the long-term storage of reactor compartments)

In 1995-1998 at the ship-building plants ("Nerpa", "Zvezdotchka", "Zvezda") a new scrapping equipment was put into operation This equipment was delivered by the U S A in accordance with intergovernmental agreement on reduction of the offensive armament (mechanical scissors, guillotine stationary scissors-cutting complexes for hull constructions, technological line for cable pounding ("Zvezdotchka")

At "Zvezdotcka" the unique stationary complex on procession of the liquid and solid radioactive wastes will soon be built and the existing complex of liquid radioactive wastes will be modernized At "Zvezda" the trials of new floating complex on procession of the liquid radioactive wastes are coming to an end At present ship-building plants have the equipment for the utilization of 8-10 vessels per year Upon the completion of the utilization complex at "Nerpa" and creation of the specialized ship-scrapping production unions at ship-building plants of the Navy the production facilities will be capable of utilizing 18-20 nuclear submarines per year

In Northern and Far-Eastern Regions- at plants "Zvezdotchka" and "Zvezda" the works on stationary bases construction are being carried out These bases are intended for the unloading of the spent nuclear fuel are wholly financed by the U S A The estimated time of construction completion is 2001

2.4. Evaluation of the technical facilities for spent nuclear fuel unloading and its transportation. The current state of works and perspectives

Solving the problem of spent nuclear fuel treating wholly depends on the creation of the infrastructure for its unloading, temporary storage, processing and/or burial

Solving the problem of spent nuclear fuel treating wholly depends on the creation of the

The unloading of spent nuclear fuel from the reactors of the submarines is conducted according to the everyday operation scheme with the usage of Navy resources at the moorages of the ship-repairing plants Upon completion of the stationary bases at "Zvezdotcka" and "Zvezda", the unloading of the spent nuclear fuel will be executed by these plants as well as with the help of the floating technical bases.

At present the dismantlement of the nuclear submarines is carried out with the use of the transport-technological scheme of spent nuclear fuel treatment which was developed in the former Soviet Union and which is based on the closed fuel loop and meant for the provision of the reactor recharging

The main components of the existing scheme are

- floating technical bases of reactor recharging equipped with the necessary apparatus for the works
  1. lift-transportation means,
  2. sets of the equipment for the unloading of the fuel rods from the reactor
  3. water-cooling storages for the temporary storage of the spent nuclear fuel
- coastal technical bases intended for the temporary storage of the spent nuclear fuel before its transportation for the processing.
- transportation packing complex consisting of a set of safe containers, packing complexes and special wagon containers intended for the transportation of the spent nuclear fuel to the place of the processing
- Temporary storage of the spent nuclear fuel at Production Union "Mayak" The spent fuel is transported by a special train and then after a certain storage period transported to the technological line for processing

At one time, for reactor recharging was conducted at 8 non-self-propelled floating technical bases (constructed in 1960) were used At present this equipment is outdated and decommissioned (tab 1 3).

Cargo-lifting equipment at these technical bases is also outdated but can be used in the future At the Pacific Fleet all the technical bases of the projects 326 and 326M have been decommissioned and do not participate in the process of spent nuclear fuel unloading The current technical facilities are not sufficient for the complete unloading of the spent nuclear fuel of the dismantled nuclear submarines The existing temporary transportation-technological schemes of spent nuclear fuel treatment in the North-Western Region provides spent nuclear fuel transportation to the "Mayak" only via transit stops in Murmansk and Severodvinsk

The schemes of spent nuclear fuel treatment in the Northern Region are shown in fig.2 3·

THE INFRASTRUCTURE OF DISMANTLEMENT OF THE NUCLEAR SUBMARINES AND SPENT NUCLEAR FUEL TREATMENT IN THE NORTHENRN REGION

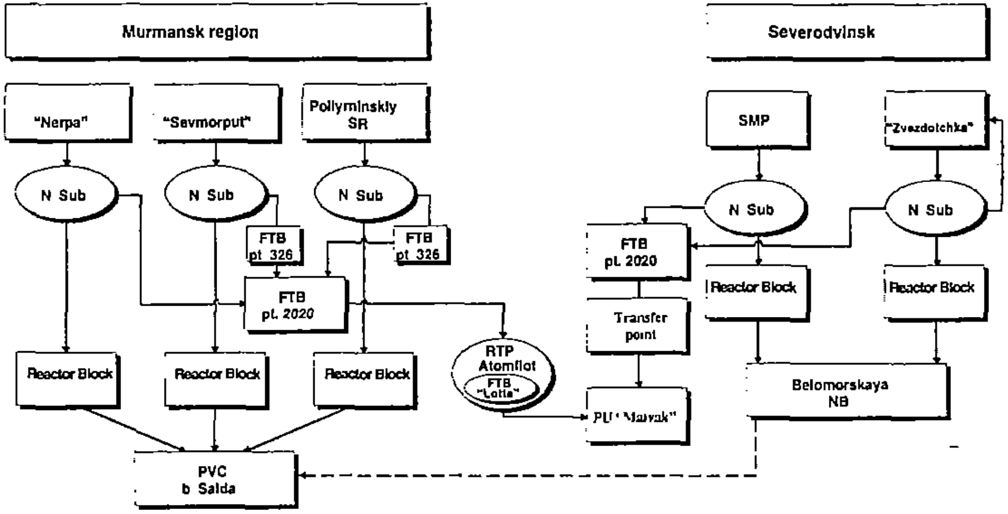

Fig 2.3.

Transportation from Severodvinsk

Spent nuclear fuel is taken out from the nuclear submarines being dismantled and loaded on containers (3 TK-18 containers per car) The container with the spent nuclear fuel loaded by coastal crane is then transported to the car of the special train and the spent fuel is delivered to the 'Mayak" on the special train.

Transportation from Murmansk

CTBs (Coastal Technical Bases) of project 2020 ,which are not equipped with the facility for container loading, transfers spent heat producing plant from its storage place to TK-18 container which is located at the loading place of CTB "Lotta" The container loaded by coastal crane is then transported to the car of the special train and the spent fuel is delivered to the 'Mayak" on the special train [9]

Transportation of the spent nuclear fuel from Gremikha settlement

The CTB of the basing place does not function Railroads and highway with special surface which would connect Gremikha settlement with transport network of the Kolskiy Peninsula are absent. Cargo transportation is conducted via sea Besides the spent nuclear fuel of the submarines with water-moderated reactors, spent parts of active zones of submarines with liquid-metal reactors are also kept at Gremikha. The unloading of the spent nuclear fuel from submarines located at Gremikha settlement is very dangerous due to the poor technical condition of the vessels. Besides the spent nuclear fuel of the submarines with water-moderated reactors, spent parts of active zones

Gremikha settlement is very dangerous due to the poor technical condition of the vessels. Besides

of submarines with liquid-metal reactors are also kept at Gremikha At present the scheme of spent nuclear fuel transportation from Gremikha does not function

Transportation of the spent nuclear fuel from Far Eastern region

The scheme of spent nuclear fuel handling of the decommissioned nuclear submarines is shown in fig.2 4

The infrastructure of dismantlement of the nuclear submarines and spent nuclear fuel handling in the Far Eastern region.

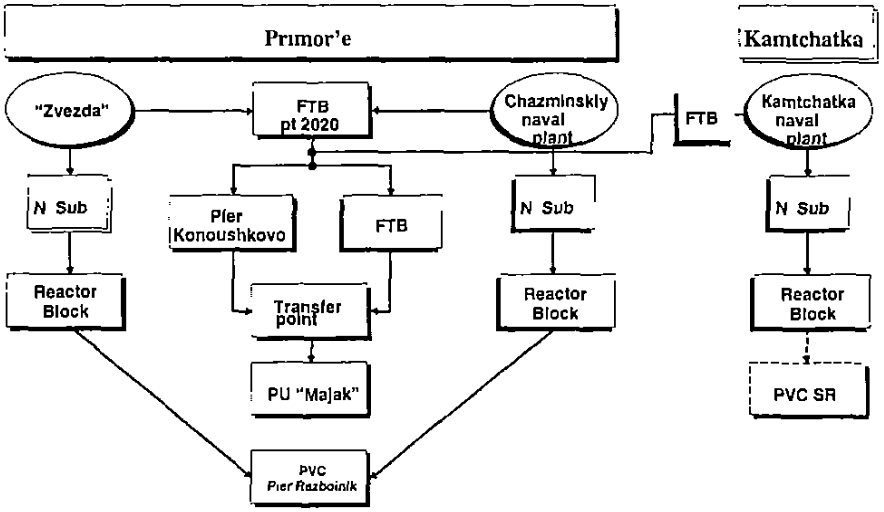

Fig. 2.4

The unloading of spent fuel can be conducted via CTB of 2020 project in 3 places

- "Zvezda"
- Kamchatsk sea plant
- Chazminskiy sea plant

CTB at Kamtchatka does not function ,so all the unloading procedures take place at Kamchatsk sea plant via CTB of 2020 project with the fuel transportation to the Seaside Region.

Spent nuclear fuel handling during its unloading at the plants of Seaside is conducted via CTB 2020 according to accepted technologies of spent nuclear fuel handling

Transportation of the spent fuel to "Mayak" is conducted through the following transportation-technological schemes:

1 CTB 2020 via Konoushkovo Bay by a floating crane of the deep water berth

Special containers are delivered to the deep sea pier of the Konyushkovo Bay and taken by trucks then uploaded into railway cars of the special train which delivers the containers to the production union "Mayak"

production union "Mayak"

The possible route of the special train is to the CTB with the unloading of the packing set at the accumulation ground for temporary storage

2 Through special train from the accumulation ground of the Sysoeva Bay to the special train to the production union "Mayak"

Via a train an empty container is delivered to the accumulation ground of the Coastal Technical Base. The loaded container from the accumulation ground is placed on the train platform of the train and transported to the transit place for the loading of the spent nuclear fuel on the train The cycle is repeated up to the full loading of the train which then heads for the production union "Mayak" As it can be seen form the above-mentioned facts , operations with the spent heat assemblages unloading of the nuclear submarines to be dismantled, presuppose repeated manipulations with the fission materials in case of a single heat producing plant or a set of some heat producing plants Taking into the account a large amount of the spent fuel to be unloaded,the analysis of the risks connected with accidents at different stages of the technological scheme of spent nuclear fuel handling becomes more actual

Factors influencing the speed of the spent fuel unloading from the submarine reactors during the process of dismantlement.

The analysis of the transportation-technological schemes of functioning of spent nuclear fuel handling has shown the following

The speed of the spent fuel unloading from the submarine reactors during the process of utilization depends on many factors The main factors are

- the quantity and technical condition of all the elements of the chain of spent nuclear fuel handling during its unloading from the reactors during the process of utilization (floating technical bases, transfer equipment used at the unloading of the heat producing plants, lift-transportation means which execute operations with the taking of the spent heat producing plants from the reactor and further operations to the car-container, containers and special trains for the transportation of the spent nuclear fuel for the procession);
- duration of the corresponding works for the reactor unloading,
- amount of the required unloadings of the active zones,
- volume of the spent nuclear fuel present at coastal and floating technical bases and the technical condition of the equipment,
- regulations of the floating base usage which provides the unloading of the spent nuclear fuel (transportation , interbase transfers and so on),
- total capacity of the spent nuclear fuel storages at CTB and FTB for the placement of the unloaded fuel, the degree of its filling;
- production facilities of the production unions "Mayak" on the procession of the arriving of the special trains (total capacity of the spent nuclear fuel storages, the productivity of the technological lines of the spent nuclear procession),
- amount of financing available and timeliness of the funding

technological lines of the spent nuclear procession),

The increase of speed of spent fuel unloading may be achieved via complex optimization of all above-mentioned factors

As an integral part of the problem of the spent fuel long-term storage , the problem of handling the defective nuclear fuel arises Defective spent heat producing assemblages are not accepted at industrial plants The storage of such assemblages is conducted in the fleet storages which are not fit for the spent nuclear fuel long-term storage

Handling of the defective nuclear fuel requires a special approach Taking into account the higher risk, associated with damaged assemblages, the main task seems to be the justification and development of the technical decisions on the reliable isolation of the units

The quantitative risk assessment connected with the handling of the spent heat assemblages is to be the task of the further research along with the substantiation and development of the technical decisions on their reliable isolation and risk substantiation of the chosen model of isolation and storage.

2.5. Technological scheme of dismantlement

The preparation of a nuclear submarine for dismantlement includes unloading of the weapons and reserve ammunition, spare parts, means of filtering of the air The fuel of the auxiliary energy unit along with combustion materials and battery are also unloaded The holds, tanks with water and special tanks are drained The cleaning of the fuel and oil tanks is carried out

The decontamination of the polluted areas of the constructions, equipment, pipe-lines is carried out

The preparatory works for the temporary afloat storage and further dismantlement on are conducted. The above-mentioned works are carried out (as a rule) at basing and storage places in the process of afloat storage

From the moment of the submarine transportation to the plant which carries out the dismantlement the dismantlement procedures begin The corresponding preparatory works are conducted for the unloading of the spent nuclear fuel from reactors and then the unloading of the fuel is carried out

Then comes the preparation of the reactor compartment for packing and long-term afloat storage.

Liquid radioactive wastes-the water of heat carriers of 1st and 3rd contours and water of the special tanks of the reactor compartment-are removed into coastal (floating) capacities The capsulation of reactor free from spent fuel and 1st contour is made Via the cleansing filters the gas of special systems of atomic heat-producing plant is removed

capsulation of reactor free from spent fuel and 1st contour is made Via the cleansing filters the gas

After spent fuel unloading the cutting and further formation of the reactor block is made.[8,11]

At present the following methods of nuclear submarine dismantlement have been developed and practically tested

Multi-compartment variant (temporary afloat storage without the cutting of the reactor compartment

Safety of the reactor compartment storage is secured at the expense of the floatability of the solid hull free from equipment, welding of the sea-cocks with bibs In such condition reactor compartment awaited the construction and putting into operation the facilities for long-term storage

As soon as such facilities are built the vessels are transported to this place for the cutting of the reactor compartment and its further preparation for a long-term storage

8 nuclear submarines of the Northern Fleet have been prepared for long-term afloat storage this way However this method was turned down as soon as there appeared methods of "deep" dismantlement

One-compartment variant (block module)

Cutting of the reactor compartment with attaching a floating capacity to it (to provide afloat position for the storage period)

Three-compartment variant (cutting of the reactor compartment consisting of three-compartment block) [10] The reactor compartment is cut out with adjacent compartments. The presence of 2 adjacent compartment free from equipment secures the necessary floatability for formed block The real afloat period of the block is defined by strength characteristics of the end partitions and amounts to no less than 10 years With the use of this exactly method the preparatory works for temporary afloat storage are carried in both regions [11] The technological scheme of submarine dismantlement according to the three-compartment variant is executed in the following sequence

The technological scheme of submarine dismantlement according to the three-compartment variant is executed in the following sequence

- transportation of the submarine to the plant which carries out dismantlement
- preparatory works for the start of the dismantlement process
- unloading of the active zones of the reactors
- setting on the ship-way
- cutting of the hull into pieces

- cutting of the hull into pieces

- formation of the reactor block (dismantlement of the adjacent compartments equipment which can be unloaded at the contamination levels not exceeding the normative values),encapsulation of the compartments and the whole block
- transportation of the three-compartment to the place of temporary storage
- temporary afloat storage of the three-compartment block

The main factor of the ecological risk at long-term storage of the reactor compartments is the radiation hazard equipment of the atomic steam producing plant and solid radioactive wastes from the industrial activity of the enterprise which executes dismantlement works

During the evaluation of the ecological risk connected with reactor compartment afloat storage it is necessary to take into account the possibility of block-module flooding due to the loss of capsulation of the solid hull.

A separate labor consuming and very expensive stage of the nuclear submarine dismantlement is the dismantlement of the end portions Equipment and solid hull dismantlement works are conducted at the plants according to the following technological stages:

- afloat equipment dismantlement;
- placing on ship-way,
- cutting preparation for transportation of the reactor compartment or reactor block;
- cutting of the submarine hull into large sections,
- equipment dismantlement,
- cutting of the dismantled equipment and large sections into scrap metal

Equipment dismantlement is conducted both on the water and after placing the submarine on the ship-way Nomenclature and number of the constructions and equipment dismantled on the water is restricted by the conditions of the submarine's tenacity

The cutting of the submarine includes 2 stages:

1 cutting of the hull into the transportable sections (max weight up to 30 tons) is made via acetylene-oxygen and plasma cutting The cutting of the sections takes place after the dismantlement of the rubber surface and the removal of the paint surfaces on the line of cutting with the use of filter units for collecting the harmful substances which form during the hull cutting.

2 Cutting of the sections of the hull and equipment dismantlement at the dismantlement work shops are made by a combined method (mechanical cutting with the help of the scrapping equipment-80%, gas and plasma cutting-20 %)

The technological process of utilization must guarantee safety (including the ecological one) in normal conditions and during the accidents Special attention should be paid to the technological processes with toxic, carcinogenic, chemical substances, explosive and radioactive materials

2.6. Legal basis for dismantlement of the nuclear submarine

The processes of decommissioning of nuclear submarines, their temporary storage and complex dismantlement must be accompanied by the protective measures for ecological, radiation and nuclear safety The main goal of these measures is to protect a human being and environment from the influence of ionizing radiation It takes an effective legal and normative basis to achieve this aim

The following federal laws and programs are considered to be legal basis for dismantled nuclear submarines in Russia :

The federal laws of the Russian Federation:

- "On the use of atomic energy"
- "On radiation safety of the population"
- "On sanitary-epidemic protection of the population"
- "On industrial and consummation wastes"
- "On ecological expert examination"
- "On the protection of the atmospheric air"
- "On the principals of labor protection"
- "Water Code of the Russian Federation"

Federal programs:

- "Unified federal program of nuclear and radiation protection in Russia"
- "Development and introduction of the state control system over nuclear materials"
- "Provision of the works on complex dismantlement of the nuclear submarines and vessels with nuclear units"
- "On radioactive materials and wastes treatment and their burial (1996-2005)"
- "Creation of the unified automated control system over the radiation background"

There is also a list of many federal and departmental normative documents, which create a legal field for the activities in the sphere of radioactive objects handling at all stages of decommissioning, dismantlement and storage (burial) The existing state legal and normative basis at the moment provides for marginally sufficient level of nuclear and radiation safety at the Russian enterprises, which carry out the works on dismantlement [12]

However, there are many gaps in existing Laws and legal acts, federal programs and technologies

During the process of dismantlement there rose many problems which required normative-legal regulations The principal question is the absence of the unified federal Concept of the nuclear submarine dismantlement and the Concept of reactor compartment treatment of the nuclear submarines, surface vessels and ships The Concept is currently being developed

legal regulations The principal question is the absence of the unified federal Concept of the nuclear
submarine dismantlement and the Concept of reactor compartment treatment of the nuclear

The absence of the unified federal Concept of reactor compartment treatment does not allow a choice of the methods of further handling (long-term storage , burial of the reactors and other radioactive wastes, treatment of the defective spent nuclear fuel and so on) From the view of nuclear and radiation of safety the "status" of the reactor compartments and reactor blocks (whether it is a container with radioactive wastes or metal which should be further spliced or it is an object which requires corresponding maintenance) is not defined

The "status" of the spent nuclear fuel which is not intended for further processing is not defined as well [13].

Reactor compartments prepared for transportation and long-term storage represent a package set inside of which there are materials with total activity of 120-350 kCi The principal document regulating transportation of such reactor compartment is "The rules of sea-transportation of dangerous cargos" However, to technically prepare the reactor compartment for the transportation in accordance with these rules is no easy task [13]

The existing normative-legal basis for the organization and complex dismantlement of the nuclear submarines requires correction and perfection in regards to the questions of the provision of nuclear and radiation safety of the temporary afloat storage (submarine sediment and floating modules) and formation of the reactor compartments

The following normative-legal documents on reactor compartment treatment are absent

-unified requirements on radiation safety provision of the reactor compartments of the nuclear submarines of different projects,

-special radiation-hygienic requirements for the reactor compartment and reactor block [13]

The absence of the corresponding normative-legal regulation is strongly felt in the ecological sphere Legally set levels of the control concentrations of all significant nuclids in water and sea-floor sediments are absent The knowledge of these levels will help forecast the consequences and plan protective measures and quickly define the interference level in case of the accidents [14]

In 1999 in Russia the Norms of Radiation Safety (NRS-99) were introduced These norms meet the requirements of both Russian and international legislation Before the adoption of these Norms there existed Norms of Radiation Safety (NRS-76/87) and Principal Sanitary Rules (PSR-72/87) The introduction of the new documents will take a certain amount of time as there will exist difficulties in clear regulation of the requirements and rules on radiation safety provision That fact raises worries during the conduction of the dismantlement works as a large volumes of radioactive wastes of different origin, aggregate condition and specific activity are handled

wastes of different origin, aggregate condition and specific activity are handled

In accordance with the resolution of the Russian Government (from 28.05 1998 N518) on the transfer of the decommissioned submarines to the plants conducting the dismantlement , it is necessary to create a normative-legal basis providing the transfer, afloat storage till the dismantlement , conduction of works on spent fuel treatment, nuclear and radiation safety

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3. WASTES SOURCES AND IDENTIFICATION OF WASTE STREAMS AT ALL DISMANTLEMENT STAGES

In this section the pollution wastes sources and potential hazards are discussed at the stages of nuclear submarines handling after their decommissioning It is emphasized that the main sources of nuclear-radiation threats are reactor compartments and active zones of the reactor compartments with the spent nuclear fuel. The quality characteristic of other sources of potential hazards-the service objects- is also given The hazards from nuclear submarines with damaged Atomic Steam-producing Plant are also discussed

3.1. General Information

The main pollution sources at the process of nuclear submarines decommissioning and utilization are not only the vessels to be utilized and their reactor compartments. A significant potential hazard comes from the technical facilities and equipment of the infrastructure related to this work The hazard level of the above-mentioned objects has risen due to the depreciated and outdated equipment The potential hazards from the decommissioned and dismantled nuclear submarine exist at all stages of handling from the moment of decommissioning up to the moment of reactor burial and utilization This period ,according to existing estimations ,may amount to 70-100 years For the further analysis of the hazards and risks this period may be divided into 7 stages

Stage1. **Preparation for the spent nuclear fuel unloading.** Includes the period of atomic energy unit cooling (should there be such a necessity), the unloading of the ammunition and technical equipment, fuel, storage before the unloading, transportation of the nuclear submarine to the place of the spent nuclear fuel unloading

Stage2 **Unloading of the spent nuclear fuel.** Includes the period of the preparation for the spent nuclear fuel unloading, preparation of the vessel for the dismantlement, including its re-deployment.

Stage2a **Spent nuclear fuel handling.** Includes a temporary storage of the spent nuclear fuel, reloading of the spent nuclear fuel from the storages(should there be such a necessity) and delivery to the place of processing.

Stage3 **The formation of the reactor block.** Includes nuclear submarine storage after spent fuel unloading, preparation for the beginning of the dismantlement , cutting out of the reactor compartment, formation of the reactor block for the temporary afloat storage, dismantlement of the end compartment blocks

Stage4 **Afloat storage (storage) of the reactor block.** Includes reactor block transportation to the place of temporary afloat storage, transportation to the place of the reactor compartment cutting.

Stage5. **Cutting and formation of the reactor compartment.** Includes cutting out of the reactor compartment, preparation of afloat storage of the reactor compartment, preparation of the reactor compartment for the long-term storage, dismantlement of the adjacent compartments

compartment, preparation of afloat storage of the reactor compartment, preparation of the
reactor compartment for the long-term storage, dismantlement of the adjacent

Stage6 **Long-term storage.** Includes the period of the reactor compartment storage The presumable storage period is 70-100 years

In general the sources of the potential hazards at the stages of nuclear submarines handling after their decommissioning are the following

- reactor compartments of nuclear submarines before and after the unloading of the spent nuclear fuel;
- spent nuclear fuel at all stages of its handling up to the moment of its delivery to the processing facility,
- damaged nuclear submarines and service vessels;
- places of the accidents of the nuclear submarines and places of their storage,
- coastal storages of the spent nuclear fuel,
- containers with the spent nuclear fuel,
- special railway train delivering the spent nuclear fuel to the processing place,
- technological cycle of the nuclear submarine cutting and dismantlement of the non-radioactive compartments,
- transportation-technological cycle of the reactor compartment to the place of long-term storage,
- the place of long-term storage of the reactor compartment

It is obvious that the above-mentioned sources carry the hazards of different levels but none of them can be neglected

Below will you find the description of the all mentioned sources in the order of decreasing potential hazards The exceptions are the last 3 as there is no information for them and the location of the places of the permanent storage of the reactor compartments in the regions is not determined The information on the special railway train is discussed in the section of the given report.

3.2. Reactor compartments of the nuclear submarines

Reactor compartments of the nuclear submarines (especially before the unloading of the spent nuclear fuel) represent the most harmful impacts on population and nature

In reactor compartments of the nuclear submarines the equipment of the atomic steam-producing plant which consists of nuclear reactor (one or two), steam generators the main circuits of the heat system, main and auxiliary circuit pumps, biological protection, armature, control system is installed

From the moment of the physical reactor start-up, the whole equipment of the atomic steam-producing plant along with the solid hull of the submarine in the reactor compartment are exposed to different levels of radiation from the reactor core In this very zone there develops a process of the accumulation of the fission fragments This process is proportional to the reactor power As a result of this process the whole equipment of the atomic steam-producing plant becomes

the accumulation of the fission fragments This process is proportional to the reactor power As a

radioactive The maximal activity of the zone and equipment is achieved by the end of the operation period of a nuclear submarine that is why at the moment of its decommission and start of the dismantlement process. It is determined that before the spent nuclear fuel unloading from the active zone the total activity of the reactor compartment amounts to ~ 10^6 Ci (3,7 10^{16} Bq), more than 90 % of activity is concentrated in the fission products, that is in the active zone [1]

In fig. 3 1 the distribution of activity on the elements of the reactor compartment equipment is shown It is evident from this figure that the activity of all other elements outside the reactor frame amounts to a little more than 1 %

Distribution of activity in the equipment of the atomic steam-producing plant, in the protection materials and construction of the reactor compartment after the active zone unloading.

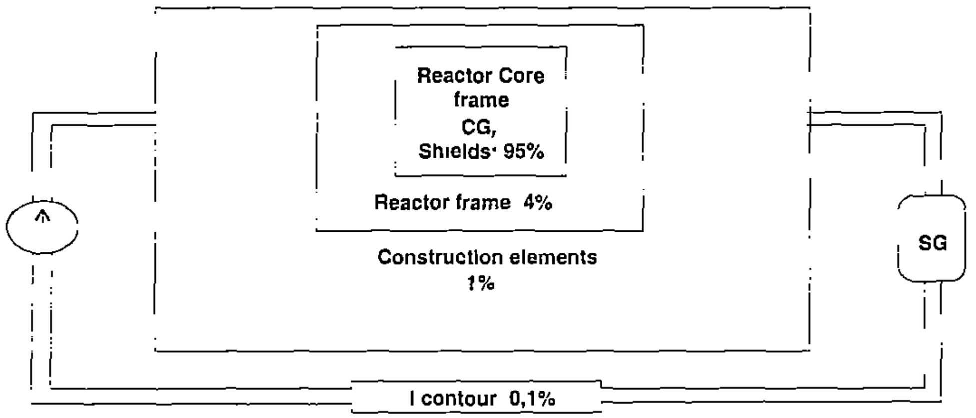

Fig 3.1

The reactor frame, internal screens and organs of the control and protection systems are the elements which were not unloaded As a result, after active zone unloading about 10 % of the initial activity is left in the reactor compartment, that is around 10^5 Ci (3,7 10^{15} Bq). This can be seen in Fig 3.2 [1]

The accumulation of the activity in the reactor compartment 6 months after reactor's shut down.

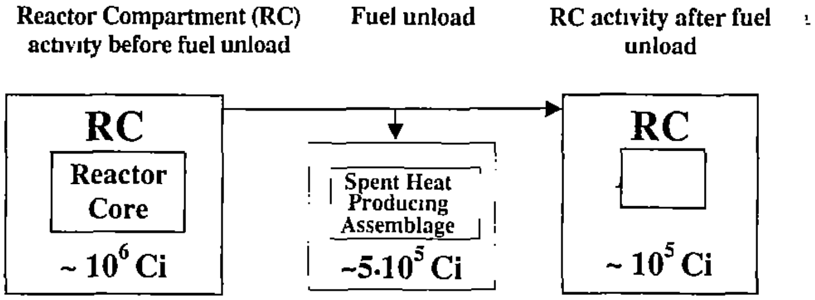

Fig. 3.2

In the course of the reactor's working a large amount of different radionuclids- radiators are accumulated inside and outside of the active zone The main radionuclids- radiators which determine the activity of the materials are shown in tables 3 1 and 3 2 In tab 3 1 will you find data on the atomic steam-producing plant with 2 water-moderated reactors after 40000 hours of work [7] In tab 3 2 (in a more generalized form) data on the atomic steam-producing plant with a liquid metal reactor in which heat carrier was Pb-Bi [8]

The activity of the radionuclids in the construction materials the atomic steam-producing plant (2 Ru,Tp- 40000 h), Ci

Σ - all types of radiators	Exposure time, years					
	0.5	5	10	30	70	100
^{51}Cr γβ	4 2 10^{+3}	6 0-15	—	—	—	—
^{54}Mn γβ	6 6 10^{+3}	1 7 10^{+2}	3 0	2 7 10^{-7}	2 3 10^{-21}	—
^{55}Fe β	1 6 10^{+5}	5 0 10^{+4}	1 4 10^{+4}	8 5 10^{+1}	3 2 10^{-3}	1 5 10^{-6}
^{59}Fe γβ	4 0 10^{+2}	4 2 10^{9}	2 8 10^{-21}	—	—	—
^{60}Co γβ	3 5 10^{+4}	1 9 10^{+4}	9 9 10^{+3}	7 1 10^{+2}	3 7	7 2 10^{2}
^{58}Co γβ	4 3 10^{+3}	4 4 10^{-4}	7 7 10^{-12}	—	—	—
^{59}Ni β	1 2 10^{+2}	1 2 10^{-2}	1 2 10^{+2}	1 2 10^{-2}	1 2 10^{-2}	1 2 10^{+2}
^{63}Ni β	9 2 10^{+3}	8 9 10^{-3}	8 6 10^{-3}	7 5 10^{-3}	5 7 10^{+3}	4 6 10^{+3}
^{93}Mo γβ	6 8 10^{-2}	6 8 10^{-2}	6 7 10^{2}	6 7 10^{-2}	6 6 10^{-2}	6 6 10^{-2}
^{99}Tc β	1 9 10^{2}	1 9 10^{2}	1 9 10^{-2}	1 9 10^{2}	1 9 10^{-2}	1 9 10^{2}
Sum of γβ	5 0 10^{-4}	1 9 10^{+4}	9 9 10^{+3}	7 1 10^{-2}	3 8	1 4 10^{-1}
Sum of β	1 7 10^{+5}	5 9 10^{-4}	2 3 10^{-4}	7 7 10^{-3}	5 8 10^{+3}	4 7 10^{+3}
Sum of Σ	2 2 10^{-5}	7 8 10^{+4}	3 3 10^{+4}	8 4 10^{+3}	5 8 10^{-3}	4 7 10^{-3}

Note:β- pure beta-emitters, γβ – mixed beta-emitters

Table 3.1

Note:β- pure beta-emitters, γβ – mixed beta-emitters

Radioactivity in the reactor compartment dependent on the exposure time, Ci.

Calendar Year components	1996	2000	2050	2100
Actinoids	3 38 10^{+3}	2 89 10^{+3}	5 78·10^{-2}	3 40 10^{+2}
Fission products	2.70 10^{+5}	2 39·10^{+5}	7.16 10^{+4}	2.22·10^{+4}
Europium	1 51 10^{+5}	1 19 10^{+5}	6 91 10^{+3}	4 76 10^{+2}
Pb-Bi(alpha-radiation)	1 95	1 57	4 90	3 40 10^{-1}
Construction frame	1 14 10^{+3}	6 90 10^{+2}	1 47 10^{+2}	1 14 10^{+2}

Tab. 3 2.

Below in the tables data on the radioactivity decrease in different elements of reactor compartment according to the years of exposure after the latest reactor stop. In tab 3.3 one can find reactor compartment activity and dose quantities near the reactor frame for the nuclear submarine of 1st generation after 40000 hours of working [7]

Changes in time of the full directed activity in the reactor compartment and power of exposure dose near the reactor frame of the nuclear submarine of 1st generation after 40000 hours of working.

Exposure time, years	Activity, Ci	Dose power, µ R/s
0 5	1 1 10^{+5}	2 0·10^{-4}
5	3 9 10^{+4}	5 9 10^{-3}
10	1 6 10^{+4}	3 0 10^{+3}
30	4 2 10^{+3}	2 2 10^{+2}
70	2 9 10^{+3}	1 3
100	2 4 10^{+3}	3 5 10^{2}
200	1 2 10^{+3}	2 4 10^{2}
500	2 0 10^{+2}	2 2 10^{2}
1000	6 2 10^{+1}	2 0 10^{2}

Tab. 3 3.

In tab 3 4 one can see more detailed data for the nuclear submarine of 2nd generation [10]

Tab. 3 3.

Activity of the construction materials of the reactor compartment of the nuclear submarine of 2nd generation (Ci)

Source	Nuclid	Exposure time, years						
		0	1	5	10	25	50	100
1 Solid hull Nuclear sub	Co-60	5,4 10^{-1}	4,7 10^{1}	2.8 10^{1}	1,5 10^{-1}	2.0 10^{-2}	7,4 10^{4}	1,0 10^{-6}
	Mn-54	1,3 10^{-1}	5.8 10^{-2}	2 3 10^{3}	4,1 10^{-5}	-	-	-
	Fe-55	28	22	7.7	2,1	4.5 10^{-2}	7,4·10^{5}	-
	Ni-59	7.9 10^{-4}	7,9 10^{4}	7.9 10^{-4}	7,9 10^{-4}	7,9 10^{4}	7,9 10^{-4}	7.9 10^{-4}
	Ni-63	9.0 10^{-2}	9,0 10^{2}	8.8 10^{-2}	8,5 10^{-2}	7,6 10^{-2}	6,4 10^{2}	4.6 10^{2}
	Total	**29,0**	**22,0**	**8,1**	**2,4**	**1,4·10^{-1}**	**6,6·10^{-2}**	**4,6·10^{-2}**
2 Reactor frame Bottom and caisson of the tank	Co-60	2,0 10^{2}	1,8 10^{2}	1.0 10^{2}	54	7,5	2.8 10^{-1}	3.8 10^{4}
	Mn-54	6,5 10^{2}	2,9 10^{2}	12	2,1 10^{-1}	1,2 10^{-6}	-	-
	Fe-55	3.5 10^{4}	2.7 10^{4}	9 7 10^{3}	2,7 10^{3}	57	9,3 10^{-2}	-
	Ni-59	2,8·10^{-1}	2.8 10^{1}	2,8 10^{-1}	2.8 10^{1}	2,8 10^{-1}	2.8 10^{-1}	2,8 10^{1}
	Ni-63	32	31	31	30	27	22	16
	Total	**3,6·10^{+4}**	**2,8·10^{+4}**	**9,8·10^{3}**	**2,8·10^{3}**	**91**	**23**	**16**
3 Internal reactor construction	Co-60	1,3 10^{4}	1.1 10^{4}	6 7 10^{3}	3.5 10^{3}	4.8 10^{2}	18	2,4 10^{-2}
	Mn-54	9 1 10^{3}	4.1 10^{3}	1,6 10^{2}	2.9	1.7 10^{-5}	-	-
	Fe-55	2.5 10^{5}	1,9 10^{5}	6.9 10^{4}	1,9 10^{4}	4.0 10^{2}	6 5 10^{-1}	1,7 10^{-6}
	Ni-59	17	17	17	17	17	17	17
	Ni-63	2,0 10^{3}	1 9 10^{3}	1,9 10^{3}	1.8 10^{3}	1,6 10^{3}	1.4 10^{3}	9,8 10^{2}
	Total	**2.7·10^{5}**	**2.1·10^{5}**	**7,7·10^{4}**	**2,4·10^{4}**	**2.5·10^{3}**	**1,4·10^{3}**	**1,0·10^{3}**
	Total	**3,1·10^{5}**	**2,4·10^{5}**	**8,7·10^{4}**	**2.7·10^{4}**	**2,6·10^{3}**	**1.4·10^{3}**	**1,0·10^{3}**

Tab 3 4.

The analysis of the data of tab. 3 1 shows that Cobalt-60 isotope is the most active in the reactor compartment The period of this isotope's decay amounts to 5.27 years This radionuclid emits sharp gamma-radiation and actually defines the radiation situation near reactor compartment in the first 50-70 years

emits sharp gamma-radiation and actually defines the radiation situation near reactor compartment

In terms of significance of the radiation impact then comes Nickel-63 nuclid It emits only beta-particles. To protect from these particles is a more simple task [7]

In tab. 3 5 one can find data on the specific activity of Cobalt-60 and Nickel-63 in different places of the reactor compartment 5-500 years after the reactor shut down Also in this table one can find the admissible quantities of the specific activity of these elements from the Russian normative documents as well as from the documents of the International Committee on Radiation Protection (111 0-1-5)

Specific activity of radionuclids Co-60 and Ni-63 in the constructions of the reactor compartments

Exposure time, years	Reactor screen		Reactor frame		Metal constructions in 50 cm away from reactor		SOLID SUBMARINE HULL UNDER REACTOR	
	Co-60	Ni-63	Co-60	Ni-63	Co-60	Ni-63	Co-60	Ni-63
5	8 1 10^{-1}	2.7 10^{-1}	2 7 10^{-2}	1 3 10^{-3}	9 8 10^{-4}	3 2 10^{-4}	1 3 10^{-5}	3 0 10^{-6}
70	1 6·10^{4}	1 7·10^{-1}	5 2 10^{-6}	8 7 10^{-4}	1 9 10^{-7}	2 0 10^{-4}	2 5·10^{-9}	1 9 10^{-6}
100	3 0 10^{-6}	1 4 10^{-1}	1 0 10^{-7}	7 3 10^{-4}	3 6 10^{-9}	1 7 10^{-4}	0	1 5 10^{-6}
150	3 9 10^{-9}	9 7 10^{2}	1 3-10	4 9 10^{-4}	0	1.2·10^{-4}	0	1 1·10^{-6}
500	0	7 6 10^{6}	0	3 8 10^{-5}	0	9 1 10^{-6}	0	8 4 10^{-8}

Regulating document	radionuclid	
	Co-60	Ni-63
OSP-72/87	1.2·10^{-7}	2.0·10^{-6}
N 111.C-1-5 IAEA	2.0·10^{-8}	4.0·10^{-4}

Tab. 3.5

In tab 3 6 one can find the experimental data on the specific activity of Co-60 and Ni-63 in the samples taken from the reactor elements [7]

Radionuclid content in the samples of reactor elements, Ci/kg

The number of the sample	Element of the reactor construction реактора	Co-60	Ni-63
1	Shield	$7\ 3\ 10^{1}$	$2\ 7\ 10^{-1}$
2	Shield	$6\ 5\ 10^{-1}$	$2\ 7\ 10^{-1}$
3	Coating	$7\ 8\ 10^{-1}$	$1\ 3\ 10^{-1}$
4	Coating	$6\ 5\ 10^{1}$	$1\ 1\ 10^{-1}$
5	Hull	$8\ 7\ 10^{-2}$	$9\ 5\cdot10^{-3}$
6	Hull	$4\ 9\cdot10^{-2}$	$5\ 4\ 10^{-3}$
7	Hull	$3\ 2\ 10^{-2}$	$1\ 3\cdot10^{-3}$
8	Hull	$2\ 4\ 10^{2}$	$1\ 3\cdot10^{3}$

Tab. 3 6

The analysis of all above-shown data shows that any works on reactor compartment dismantlement can be carried out only in course of 50-70 years after reactor shut down Only by using this tactic one can reduce the risks to the admissible quantities The nuclear reactor and its corresponding elements should be buried for the period of more than 500 years

The real radiation situation in the reactor compartment (RC) at the moment of the submarine decommissioning and dynamics of the changes in the course of years were the major arguments during the development of the Concept of the Complex Dismantlement of the Russian Nuclear Submarines

At the end of the given section we will dwell on the role of beta-emitters which begin to play a significant role at the distant storage period of RC and determines the impossibility of RC's dismantlement in the feasible future According to normative documents, beta-active solid wastes are considered radioactive if their specific activity on beta-emitters exceeds 2 10-6 Ci/kg In the reactor elements (straight after dropping of the emergency protection) the specific activity of Ni-63 may reach 1 0 Ci/kg Taking into account that decay period of Ni-63 amounts to 92 years, the time of its natural decay to the admissible level can be easily defined This time amount to the hundreds of years

of its natural decay to the admissible level can be easily defined This time amount to the hundreds

The conclusion about the inevitability of the long-term storage of the reactor in the burial ground becomes more evident if one takes into account one more radionuclid-Ni-59. It possesses a twice less activity than cobalt-60 or nickel-63 but has a decay period of 80000 years.

The theoretical analysis and the results of the activity measurements at the decommissioned submarines show that in 2 years after the shut down of the nuclear reactor and spent nuclear fuel unloading the only significant quantities for the dismantlement risk evaluation are : isotopes of Ferrum-55, Cobalt-60, Nickel-63, Strontium-90, Caesium-134 and 137 and radionuclids of europium-152, 154 and 155.

Radionuclids of europium are present in the control rods of the reactor and are left in the hull after spent nuclear fuel unloading. Four of the 9 enumerated isotopes are beta-emitters. They do not pose the threat of the external radiation at the equipment dismantlement. However, they express themselves at mechanical procession of the materials and direct contact of the personnel with these materials.

All the information given in this subsection gives a general idea of the reactor compartment as a main source of the potential threats, the affection of which is felt for many years. Taking into the account the number of the submarines to be decommissioned and the equal number of the reactor compartments, the importance of the protection provision problem becomes even more evident.

3.3. Spent Nuclear Fuel (SNF)

As it follows from fig. 3.2 after nuclear submarine decommissioning spent nuclear fuel (SNF) takes 90 % of the whole activity of the reactor compartment. SNF is the main source of nuclear-radiation hazard at all stages of handling up to the moment of its unloading from the reactor, in the period of unloading and after it. It is exactly because of this, the SNF is taken out of the reactor compartment as a separate potential hazard source.

The maximum heat power of the reactors amount to 180 MW. The active zone of such reactors contain up to 252 of spent heat producing assemblages (fuel rods). According to the estimations [1] during first 6 months after decommission the total radionuclid activity in fueel rods may amount to $5 \cdot 10^5$Ci ($2 \cdot 10^{16}$ Bq). This activity is distributed between 15 radionuclids shown in Tab. 3.7.

Activity of several radionuclids in the active zone after reactor decommission

Nuclid	Activity ,Ci
Fe-55	3514
Co-60	1595
Ni-63	119
Cr-85	12972
Str-90	75675
Ruth-106	24054
Caesium-134	94595
Caesium -137	83784
Cerium-144	2648
Prom-147	202703
Plut -241	8378
Plut -242	0 023
Americium-242M	0 04
Americium-243	0 045
Curium-243	0 013

Tab. 3.7.

Radionuclids defining the activity of the SNF have different decay periods. Due to the natural decay the total activity of SNF is reduced and its quantity may be calculated at any moment after reactor stopping For example, activities of the radionuclids of the above-discussed reactor will have the following quantities in 15 year's period (Ref Tab 3 8) [5,9]

Activity of several radionuclids in the SNF after 15 years of reactor shut down

Nuclid	Activity, Ci
Cripton-85	1274
Str-90	11651
Ittrium-90	11654
rhodium-106	2 5
ruthenium-106	2 5
Caesium-134	470
Caesium-137	12999
Barium-137M	12297
Prom	2221
Uran	23
Plut-241	992
Curium-244	0 1105

Tab 3.8

As one can see- despite the large period of time activity of the SNF continues to stay very high.

As one can see- despite the large period of time activity of the SNF continues to stay very

Knowing the radionuclid content and the amount of the SNF at any time gives one a chance to analyze different situations which may arise at the stages of unloading, storage and transportation of the SNF. The above-mentioned data on SNF is sufficient for qualitative modeling of any situations during the handling period (up to the moment of processing)

3.4. Damaged nuclear submarines and service vessels

Over the period of the atomic fleet operation there have been some accidents with submarines and service vessels The technical conditions of those vessels still poses a threat to the personnel and territory in the region of their location The list of the damaged submarines and vessels is presented in the Introduction section of the given report

The most striking difference of the damaged nuclear submarines as sources of the potential threat lies not only in the activity level but also in this threat distribution on the vessel The radioactivity of the most of decommissioned submarines is concentrated only in reactor compartment The radioactivity of the damaged submarines is distributed on the whole vessel

In tab 3 9 one can find data on radioactive situation on non-damaged and damaged submarines which were decommissioned [6].

Average data on non-damaged and damaged submarines which were decommissioned 10-15 years ago.

Place of measurement	Rate of exposure dose of gamma-radiation, mR/h	
	Non-damaged subs	damaged subs
Light hull (outer hull)		
- reactor compartment	0,01-0,1	100-300
- adjacent compartments	0,005-0,02	0 1-0.5
Solid hull (inner hull)		
-reactor compartment	0,03-15,0	200-500
- adjacent compartments	0,005-0,02	0,1-30
Internal facilities		
- reactor compartment	0.1-50	200-10000
- adjacent compartments	0,005-0,01	0 1-50

Tab 3.9.

A long storage of the nuclear submarines with damaged zones is accompanied by penetration of the radioactive substances into the sea The concentration of the artificial nuclids in the place of the damaged submarine's storage do not decrease and constantly exceeds the maximum admissible concentration levels The pollution near the damaged nuclear submarines has a local character Radionuclids are distributed anisotropically in the air covering the squares of hundreds of

character Radionuclids are distributed anisotropically in the air covering the squares of hundreds of

meters (fig 1 8 of the Introduction section). In the sea water , flora and fauna the nuclid concentration stays at the level of 0.1-0.3 of the maximum admissible quantity.

In the places of the long storage of the damaged nuclear submarines and in the places of the submarines utilization there is a constant increase in the anthropological influence on the ecological system One of such regions is Pavlovskogo Bay in which 3 damaged submarines are located along with damaged technical tanker “Vala”(filled with liquid radioactive wastes) and three Coastal Technical Bases of 326 project

Also, this is the location of storage for the nuclear submarines with the active zones still on board.

The decision of how to handle the problem of the compartments (containing damaged reactors) handling requires new , reliable methods and technologies of unloading of the active zones from the reactor frames which would exclude inadmissibly high dose loads on the personnel

3.5. Service vessels

Service vessels are considered the objects of the potential radiation threats The following objects are connected with the radioactive wastes handling

- floating technical bases of the reactors recharging (11 units of total displacement of 74000 tons, total volume of SNF storage- around 6000 assemblages)
- Special technical tankers (12 units of total displacement 45000 tons)
- Floating capacities PEK-50(total displacement 2000 m3)

Out of 23 service vessels 19 have been worn out and others are outdated The project of the vessels did not presuppose the systems which would provide for the safe storage of the spent nuclear fuel

During the dismantlement process a large number of defective heat producing assemblages have been accumulated These assemblages cannot be eliminated by the ordinary measures Long-term presence of the defective assemblages in the water led to the penetration of significant amount of long-lived radionuclids Sr-90 and Cs-137 As a result of this , wastes with the activity from 10-4 to 10-1 Ci/l have been formed The most serious situation with liquid radioactive wastes is at one of the floating technical bases at which 47 tons of wastes have been accumulated with the total activity of more than 5.5 thousands Ci The general data on the amount of the liquid radioactive wastes is presented in tab 1 3 of the Introduction section

All the floating technical bases 326, 326 M are worn out (30 years of service period) The repair of these bases is restricted by the high levels of radiation and pollution They do not meet demands on nuclear and radiation safety and thus cannot provide the guaranteed safety of the works. The maintenance of these vessels in operation mode requires significant financial resources

repair of these bases is restricted by the high levels of radiation and pollution They do not meet

The problem of safety provision of the service vessels is a separate specific task of both operation and utilization stages. The decision of the problem may be realized in the programs of ATRP-R.

3.6. Storages of the spent nuclear fuel, solid radioactive wastes and liquid radioactive wastes on coastal technical bases (CTB)

The coastal technical bases (CTB) along with nuclear submarines and floating objects are the sources of radio-ecological hazards. A special threat is posed by the technical condition of the storage facilities of the spent nuclear fuel, solid radioactive wastes and liquid radioactive wastes on coastal technical bases

The CTB at present were constructed between 1962-65 with worn-out equipment of the physical and radiation control As a result of this situation , there develops a constant penetration of the radionuclids into the environment For example, the latest research at the Pacific Fleet has shown that all the technical territory of the coastal technical bases (part of the sea territory of Sysoev bay and Strelok Gulf) are polluted with artificial radionuclids (mainly caesium-137 and cobalt-60), the content of which in separate places significantly exceeds the admissible concentration levels [6]

Radiation situation at coastal technical bases of the Pacific Fleet

Bay parameters,	Area of water				Territory				Housing blocks
	Zone of radiation safety			Sanit. zone	Zone of radiation safety			Sanit. zone	Sanit. zone
	Rate of the exposure dose µGy/h								
	background + 0.1	0,6	2,4	background + 0.1	background +0.1	0,6	2,4	background + 0.1	background + 0.1
Primor'e B Sysoev Polluted area % Soil, allowable concentration share	35	25	15	none	45	25	7	none	none
-Cs-137	0 01-0 1	0 1-1 0	1-35	0 005	0 01-0 1	0 1-1	10-100	< 0 005	< 0 005
- Sr-90	< 0 001	<0 01	0 1-5 0	< 0 003	<0 01	0 01-0 1	1-10	< 0 003	< 0 003
- Co-60	0 1-1 0	1-5	5-360	0.07	0 01-0 1	0 1-10 0	10-2000	< 0 001	< 0 001
- fauna, flora	0 01-0 05	0 05-0 1	0 1-0 5	< 0 01	0 01-0 1	0 1-1 0	1-5	< 0 001	< 0 001
Kamtchatka B Krasheninnikov Polluted area % Soil, allowable concentration share	< 1	<0 1	<0.01	none	<0 1	none	none	none	none

Polluted area
% Soil, < 1 <0 1 <0.01 none <0 1 none none none none

Bay parameters,	Area of water				Territory				Housing blocks
	Zone of radiation safety			Sanit. zone	Zone of radiation safety			Sanit. zone	Sanit. zone
	Rate of the exposure dose µGy/h								
	background + 0.1	0,6	2,4	background + 0.1	background +0.1	0,6	2,4	background + 0.1	background + 0.1
-Cs-137	< 0 005	< 0 01	0.01-0 1	< 0 005	0 0-0 1			< 0.01	< 0 005
- Si-90.	< 0,003	< 0 005	<0 01	< 0 003	<0 01			<0 01	< 0-003
- Co-60	0 01-0 1	0,1-1,0	1-20	< 0 001	0 1-0,5			<0 01	< 0-001
- fauna, flora	< 0 001	<0 01	<0 01	< 0 001	<0 01			< 0 001	< 0 001

Tab 3.10

From the above-shown table one can see that the most polluted is the water area and territory of the zone of radiation safety of Sysoeva Bay. Similar radio-ecological problems are characteristic of the other coastal technical bases of the Pacific and Northern Fleets Pacific and Northern Fleets The measures on radioactive pollution prevention of the territories of coastal bases, which have been undertaken over the last few years, have brought poor results and have not met the modern requirements

At the Northern Fleet special places for the temporary storage of the solid radioactive wastes do not meet existing safety requirements They are open, not protected from atmospheric precipitations, not equipped with the groundwater treatment systems. The soil around these storages is polluted by radioactive substances The total activity of the accumulated solid radioactive wastes amount to 5000 Ci Taking into account the increase in the volume of works on the dismantlement of the nuclear submarines ,the amount of solid radioactive wastes may rise twofold

At the Andreev base the construction of the new storage for solid radioactive wastes has just been finished (construction 67), however its putting into operation can be carried out only upon the expert examination of the Ministry of Nuclear Energy.

There are no capacities for the conditioning of solid radioactive wastes at fleets All the wastes are kept in ecologically hazardous conditions which do not meet the modern requirements

At present 102000 m3 of solid radioactive wastes and 142000 m3 are accumulated at the objects of the Russian Navy Annual amount of technological liquid wastes is 44000 m3 Annual accumulation of these wastes amount to 905 m3 Around 70 % of the accumulated and current liquid radioactive wastes are concentrated in Kolskiy Peninsula and 10 % in Severodvinsk Region. Around 80 % of the accumulated and current solid radioactive wastes are concentrated in Kolskiy Peninsula and 20 % in Severodvinsk Region

Around 80 % of the accumulated and current solid radioactive wastes are concentrated in Kolskiy

The special group of the liquid radioactive wastes is low-active waters of special laundries The amount of these waters greatly exceeds the volume of the technological liquid radioactive wastes and their specific activity exceeds the quantity of 1*10-8 Ci/l only for 10-20 % of the water volume

The waters of the special laundries are formed at all facilities and their total amount is 112000 m^3 per year. The major part of this amount is formed at special laundry “Zhvezdotcka”- up to 100000 m^3 and “Nerpa” up to 3000 m^3, Coastal Technical Bases-up to 2000 m^3 and at the Northern Machine Plant- up to 2000 m^3

Amount of liquid radioactive wastes accumulated at the Northern region facilities of the Russian federation as of 1998 and forecast till 2020 according to groups.

Name of the facilities	Wastes volume in thousands of m^3 1998 2020			
	Total volume (special laundries are not included)	Wastes volume of groups		
		Operational	Decommissioned	Special laundries
Navy sites	9 85 132 2	9,85 110,6	- - - 21,6	- - - 2640
“Atom Fleet”	0 564 27,3	0 564 27,3	- - - - -	- - - 7 2
Kolskaya Atomic Nuclear Station	6,39 165,4	6 39 55,59	- - - 109,8	- - - - -
“Radon”	0 2 0,2	0,2 0,2	- - - - -	- - - - -
Total	17,0 325,1	17 0 193,69	- - - 131,4	- - - 2647,2

Tab. 3.11.

Amount of solid radioactive wastes accumulated at the Northern region facilities of the Russian Federation as of 1998 and forecast till 2020 according to groups.

Name of the facility	Volume in thousands of m^3, 1998 2020			
	Total volume	Wastes Volume of activity groups		
		1	2	3
Navy sites and facilities of the Russian ship-building Agency	10,2 36,292	3,9 9,073	5 6 21,775	0,7 5,444

of the Russian ship- | 36,292 | 9,073 | 21,775 | 5,444

Name of the facility	Volume in thousands of m^3, 1998 2020			
	Total volume	Wastes Volume of activity groups		
		1	2	3
"Atom Fleet"	0.826 5.365	0.33 2.145	0.472 3,065	0.024 0.155
Kolskaya Atomic Power Station	6.606 17,74	5.517 15.15	1.017 2,48	0,072 0,21
"Radon"	0.35 0.35	Concentration on the activity groups is not known		
Storage "Mironova Gora"	0,26 0,26	Concentration on the activity groups is not known		
Total	18.242 60,947	—	—	—

Tab 3.12

At "Atom Fleet" 1200 m3 of the liquid radioactive wastes and 300 m3 of solid wastes are formed during the process of the recharging and repair of the civil vessels with atomic units.

Solid radioactive wastes are formed in the quantity of 250 m^3 per year. At present 500 m^3 of technological solid radioactive wastes and 760 m^3 of liquid ones are accumulated at 'Atom Fleet" (including the wastes resulting from burning of combustion wastes)

3.7. TUK MBK VMF CASK.

Unloading of the spent nuclear fuel from the decommissioned nuclear submarine reactors takes place in 3-10 years after the stopping of the nuclear reactor By this time the initial activity is reduced but still stays at a very high level The character of the fall of the exposure total activity and the activity of the radionuclid Caesium-137 is shown in fig 3 3 [9] One can see from fig 3 3. (The dynamics of the fall of the radionuclid activity in the spent nuclear fuel) that the twofold fall of the initial activity takes place in 18-19 years, fourfold-in 50 years

The dynamics of radionuclids activity fall in the spent nuclear fuel

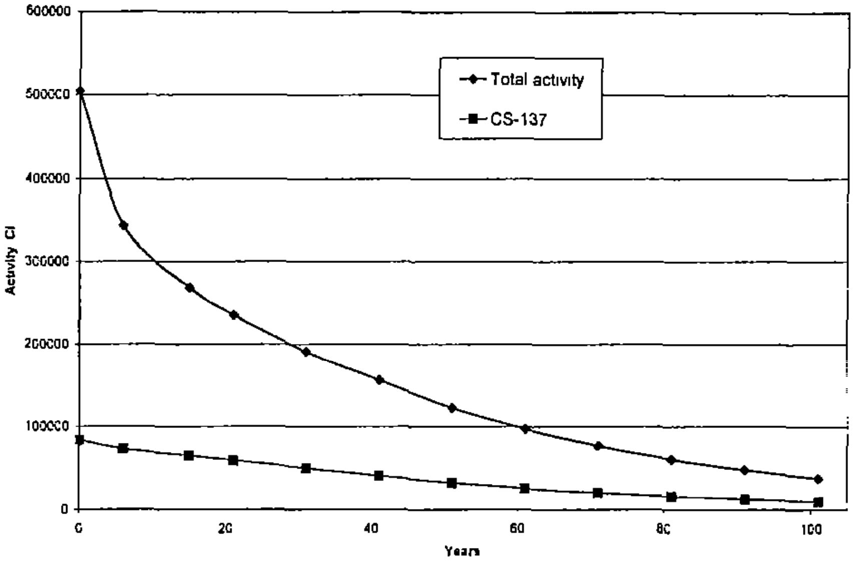

Fig. 3.3.

In accordance with the technical conditions the cask includes 25-49 of the spent heat producing assemblages which amounts to 10-20 % of the spent heat producing assemblages in the active zone. Thus , the total activity of the radionuclids for packing set in a year and a half may amount to (5.5-11)*10^4 Ci The activity of Cesium-137 amounts to (8-16)*10^3 Ci In 15 years the activity of the packing set may amount to (2 7-5 4)*10^4 Ci (total) and (6 5-13)*10^3 Ci of Cesium-137

The tests of the casks conducted in accordance with the packing set requirements of the B type have shown that in the circumstances of the project accident the release of the radionuclids into environment is not significant [9]

During the extra project accidents connected with the destruction of the protective capsulation of the cask the amount of outlet greatly depends on the degree of the heat affection and destruction character of the packing set The analysis of the accidents with the packing sets having spent nuclear fuel is one of the tasks of the further research

3.8. Technological cycle of the non-radioactive compartments dismantlement

Nuclear submarine dismantlement causes (along with the radiation hazards) the appearance of chemical ecologically harmful factors (EHF) which are classified according to the character of their effect on environment and the mechanisms of their manifestation

Radioactive irradiation acts at practically all stages of dismantlement Electromagnetic radiation, outlet of harmful chemical products, acoustic, mechanical and heat impacts mainly manifest themselves at the stage of submarine dismantlement, formation of the reactor block and its preparation for a long-term storage

Harmful substances appearing at the cutting process are considered to be dispersal aerosols and represent a dispersal system of plasma-forming gas and products of its bonding with air: oxides of nitrogen, carbon, ozone These gases (having a high level of toxicity) are formed as a result of working gases dissociation in the arch as well as of their active bonding in atomic condition. They cause irritation of the mucous membranes of the respiratory tracts, asphyxia, poison of the human organism [4]

Pollutants appearing at steel processing

Pollution source	Evolved substances or pollution components	Specific releases of pollutants g/m	Places of long-term storage for the evolved substances, mg/m^3
Oxygen-acetylene cutting, air-arch steel gouging of the types AK, MS (material width is 10mm)	Dust Chrome oxides Manganese and its compounds	4,90 0,23 1,20	0,4000 0,0015 0,0010

Tab. 3.13.

Dust (Tab 3 13) has a high degree of dispersion and is capable of penetration into respiratory tracts Especially dangerous during cutting of chromic, chromic-nickel and manganese steels are aerosol particles of chrome anhydride, manganese oxides and oxides of mechanical nickel

The cutting of one nuclear submarine with the use of gas-oxygen and plasma cutting is accompanied by the outlet of highly toxic substances of 1 and 2 hazard classes into environment-oxide chrome and manganese of 6-23 and 3-12 kg Respectively. There is an outlet of the substances with sharp affection mechanism –carbon oxide 120-500 kg and nitrogen oxide-40-650 kg

It is known that high-alloy steels from which the hulls of the nuclear submarines as well as the electrodes for welding and cutting works are manufactured, contain the metals Cr, Ni, Co and others

In the working zone during the hull utilization the concentration of chrome exceeds 30 times the maximum admissible level, manganese-3 times, nickel-15 times, lead-16 times and zink-4 times At the dismantlement of the submarine hulls (as a result of the thermal affection on the metal

the maximum admissible level, manganese-3 times, nickel-15 times, lead-16 times and zink-4

and non-metal surfaces the harmful combustion products penetrate into the air An extremely high content of the solid aerosol phase of industrial dust (exceeds maximum allowable concentration 8-17 times) as well as welding aerosol should be also noted. Several harmful chemicals which are part of the non-metal surfaces have allergic , narcotic effect on organisms.

It is known that a long contact with manganese and chlorine leads to the reduction of the protective-adaptation powers of the organism, to the development of the illnesses of the respiratory organs and increases the risk of the cancer The manganese accumulation in the organism is the factor of the development of the grave professional disease, chronic manganese intoxication. The analysis of the hair bio-tests of the workers of the production union "Sever" has shown that the content of Mn and Cr is 3 4-4 times higher than that of the control group. [5]

Currently,the cutting of the reactor compartment or 3-compartment block is carried out via gas welding For the cutting of austenitic weld seams and some steels and alloys the plasma cutting is used The speed of the plasma cutting is two-threefold faster that of the gas –however this speed with the width increase of the metal to be cut falls sharply

The evolving of the harmful chemical substances at laser cutting is practically equal to that of the gas and plasma cutting.

At present there exists a supposition that the principal method of the dismantlement of the vessels with nuclear reactors will be gas-cutting works which are connected with the evolving of a large amount of welding aerosols which contain metals-allergens Mn, Cr, Ni, Co and others. This factor may cause the appearance and progress of the specific changes the personnel's health People with low metabolism speed may develop pathological reactions and illnesses

It is considered to be very important to conduct a complex of works on the more accurate definition of the classes of the toxic wastes during dismantlement process

The Ministry of Health of the former Soviet Union and The State Committee on science issued and approved in 1987 the Temporary classifier of the toxic industrial wastes This classifier stands in line with the International Register

In tab 3 14 one can find a list and classification of the toxic wastes formed during the process of nuclear submarine dismantlement.

The list of non-radioactive wastes formed at the dismantlement of nuclear submarines

Toxic wastes			
1st hazard class	**2nd hazard class**	**3rd hazard class**	**4th hazard class**
1 wastes containing the compounds of lead, chromium	1 liquids after regeneration	1 wastes not containing the compounds of lead	1 special surfaces (rubber)
2 fluorescent lamps	2 electrolyte (sulphuric acid)	2 Rigid plates(FS-7-2-100)	2 absolete plates, asbestos, glass-fiber, asbestos-fiber
3 thallic cartridges (from the oxygen measuring equipment)	3 wastes from handling the hull construction (oxide manganese, hydrofluorine, nitrogen dioxide)	3 foam plastic plates (ПС-1)	3 Ionic resins
4 liquid oxidant and fuel	4 alkaline electrolyte of the freeze machines	4 wastes from handling the hull construction (dust)	4 wastes from handling the hull construction (carbon oxide)
5 wastes from handling the hull construction (chromium oxide)	5 hydrogen sulphide, surmane hydrogen	5 mastic (BR-20)	5 oils, fuel, water with oil products remains
		6 copper	6 chladone-12, chladone 22
			7 epoxy filling
			8 cement
			9 linoleum
			10. plastic

Tab. 3.14.

The total of the evolved pollutants which penetrate into the air at the gas cutting of the hull into large sections and further cutting into smeltert-sized pieces for one submarine of “Delta” type is shown in tab. 3 15

Delta type nuclear sub hazardous atmospheric emissions during cutting procedures

Substances	Weight (kg)
Dust Including	73
Oxide manganese	43
Oxide chrome	1
Other substances	29
Gas aerosols Including	411,5
Oxide carbon	250
Nitric oxide	161
Fluorine carbon	0.5

Tab. 3.15.

The amount of wastes formed during the process of stripping procedures is shown 3.16.

Delta type nuclear sub waste generated during stripping procedures

Wastes	Weight (kg.)
Wastes of the special surfaces of the hull	275000
Wastes of filing (coatings)	7200
Isulation wastes	17000
Wastes of paint surfaces	6760

Tab 3 16

The quantity of the toxic materials of hazard class 1-4 generated during the dismantlement of one sub of DELTA type is shown in tab 3 17

Delta type nuclear sub toxic wastes resulting from the dismantlement procedures

Toxic materials	Weight (kg)
Hydro-acoustic surface	275000
Paint surface	7800
Filing	8120
Linoleum	3000
Ceramic surface	580
Fiber-glass plastic	860
Heat-isolation of solid hull and mine	14000
Linoleum	3000
Ceramic surface Heat sound isolating mats	580 15000

Toxic materials	Weight (kg)
Tube isolation	8200
Cable rubber	103200
Fluorescent lamps	2000 units
Plastic compound	100
Used oil	40000
Liquid of hydraulic system	20000
Chladones	100
Sulphuric acid	22000
Diesel fuel	2000
Impure water with remains of oil and cleansers	2000
Frother of the fire extinguish system	400

Tab. 3.17.

In the ecological documentation LD50 chemical hazard classification with the calculation of the cumulation coefficient K is used [Tab 3 18]

LD50 chemical hazard classification

Value C, received on the LD50 basis	Hazard class	Hazard degree	Examples of the substances taken as the leading components
less than 1,2	1	Extreme hazard	Mercuric chloride, potassium cyanide, chromium
from 1,2 to 2,2	2	High hazard	Copper chromide
from 2,3 to 10	3	Moderate hazard	Acetophenone, tetrachloride carbon
more than 10	4	Low hazard	Calcium chloride

Tab. 3.18

Note

LD50 – lethal dose of the chemical substance which at the penetration into organism causes death of 50% of animals, mgr/kg

C – cumulation coefficient – relation of dose or concentration, which causes a definite toxic effect after a single usage towards the summated dose or concentration of the substance causing the same effect when used several times

For the control of the industrial disposals of the chemical substances people use different values, including those of Maximum Permissible Concentration (MPC), Permissible Residual Value (PRV), Estimated Safety Level Of Influence (ESLI), Estimated Permissible Concentration (EPC)

For the sanitary estimation of the atmosphere about 14 indicators are used. Very often the following indicators are used

For the sanitary estimation of the atmosphere about 14 indicators are used. Very often the

MPC w.a.- Maximum Permissible Concentration of a chemical substance in the atmosphere of the working area, mgr/m³. This concentration at 8 hour working day (not more than 41 hours a week) can't cause a disease or lead to a worsening of one's health during the whole working period The working area is considered to be a space at the height of 2 meters above sea-level or a working ground on which there are the sites of temporary or permanent location of the workers

MPC dc- Maximum Permissible Everyday Concentration of a chemical substance in the atmosphere of the populated areas, mgr/m³ This concentration is not supposed to cause either direct or indirect harmful affection at an unlimited period of inhalation

MPD- Maximum Permissible Disposal of the pollutants into the atmosphere at which all the hygienic norms are observed in the populated areas with the most unfavorable conditions for dispersion, kg/day

PDKav standard represents the maximum concentration value of the hazardous elements in the air of the public access areas and stands for the concentration of the admixture in the air which when regularly or constantly reacting with the human organism does not incur any negative implications neither for the latter nor the environment

The PDKw standard stands for the maximum concentration value of the hazardous elements in the public water areas, which do not have neither direct nor any other bearings on the public health (on the basis of the standard human lifecycle period) and do not jeopardize the hygiene conditions of the water usage in such areas

A very important task for the direction described in the Task 4 is to make a quantitative evaluation of the pollutant compounds in each place of storage and utilization of the nuclear submarines as well as in case of accident arising

3.9. Potential hazards from pollution and radiation sources.

Pollution and radiation sources may manifest themselves only under certain circumstances, posing a threat for the personnel , population and nature All the hazards can be divided into 4 types

1 The hazard of a spontaneous chain fission reaction (rise of the critical mass and acceleration of the heat-producing process of the prompt neutrons, thermal explosion)
2 The hazards from toxic radioactive wastes and materials with directed activity
3 The hazards from radionuclids present in the spent nuclear fuel, aerosols and liquid radioactive fuel
4 The hazards from non-radioactive but toxic or carcinogenic compounds of the dismantlement products

4 The hazards from non-radioactive but toxic or carcinogenic compounds of the

Spontaneous chain fission reaction is the most dangerous emergency situation which could hypothetically happen only at first and second stage of the dismantlement.

The hazard of 2nd type is present at all stages of dismantlement

The hazards of 3 and 4th types may be present at all stages except 6th one

As it has been mentioned above the hazard of the first type arise only in case of an accident The other types of hazards exist at the process of planned dismantlement as well as at the time of different accidents At planned dismantlement all the existing hazards (with exception of "small doses" about which the heated discussions amongst the scholars still continue) can be qualitatively forecast and controlled. In case of different accidents the hazards are difficult to forecast as they depend on many factors. The scenarios of such situations will be treated in the next section. A special emphasis will be made on the spontaneous chain fission reaction and radionuclids outlet from the spent nuclear fuel.

About the hazards from the induced activity.

The degree of the induced activity of the construction materials of the reactor compartment is defined by the duration of nuclear reactor operation and the quantity of the energy produced The induced activity of the some elements and the equipment of the reactor compartment is presented in tab 3.1, 3 2 , 3 3. [1]

For 3 year storage after the reactor stopping induced radioactivity per weight unit of caisson amount both on Co-60 and Iron-55 to 6 MBq/gr Total quantity of the each isotope radioactivity in caisson amounts to 3 TBq [11]

In surface layer of the reactor hull (from the side of the caisson) the activity of Iron-55 isotopes will amount to not more than 5 MBq/gr, Co-60- 0 2 MBq/gr [11]

In case of reactor compartment sinking its contact with water will lead to the development of the corrosion processes The penetration of the all nuclids into the water will be defined by the processes of the general corrosion The speed of the general corrsion of the stainless steel at the temperature of 5-10 C amounts to 1 μm/year and for the surface sediments and pearlite steel of the reactor hull- 50 μm/year

Thus ,besides the danger for the personnel from working with active equipment , the induced activity may stipulate hazards at the material corrosion and transfer of the corrosion products in water, air and soils

The data presented in the tables gives the idea about the comparative levels of danger of the equipment with the induced activity For the calculations of the real hazards and consequences it is necessary to know the energy characteristics of radiation and their doses calculations (in Gy, Sv) It can be possibly conducted for the concrete scenarios at the next stage of works

consequences it is necessary to know the energy characteristics of radiation and their doses

About the hazards of the radionuclids spreading.

Radionuclids formed as a result of nuclear fuel fission, activation of different liquids and gases pose a main threat for nature and human being. They can concentrate in live organisms, can be transferred according to food chain, spread to the distant territory from the place of the formation It is exactly this category of pollution that was the main tragic consequence of the accident at the Chernobyl Nuclear Station, accident at nuclear submarine in Chazma Bay and many other cases For example, in 8 years after the heat explosion of the reactor in Chazma Bay there were registered high dose rates-from 0 3 up to 157 mSv/hour In 11 years after the accident on the light hull of the nuclear submarine the rates reached the level of 2 9 mSv/hour The maximum levels of dose rates at the sea bottom (in place of accident) reached 0 26-1 4 mSv/hour

Such levels of radioactive pollution of the metal constructions stipulates three traditional methods of the welding and cutting works conduction (formation of aerosols with total activity of (10^3-10^6)Bq/m^3 which exceeds 5-7 times the admissible norms)

The peculiarity of this threat is that even small (admissible) concentrations of the radioactive elements in the water or air may, with the course of time, be concentrated in vegetation or human organisms. The possibility of their spreading over great distances has been proven In contrast to the non-radioactive chemical pollutants, radionuclids are not neutralized by natural processes This category of hazard requires the most meticulous analysis even for the cases of the regular development of this process

At the analysis of the nuclids leaving the active zone one can define activity of each radionuclid in spent nuclear fuel as the product of specific activity (which is received according to the same calculation model) on the quantity of the maximum energy producing for the submarine of the given type Such approximation allows for evaluation of the accumulated activity with the accuracy sufficient for the solution of the given task because

- total activity of the spent nuclear fuel is defined by the activity of the fission products,
- the outlet of the fission products does not have a strong dependence on the content and enrichment of the fuel, that is why the accumulation of the fission products is defined by the energy producing of the reactor

For the evaluation of the radiation and radio ecological hazard of the radioactive isotopes one should take into consideration [2]

- total quantity of the isotopes A0 (Bq) in the researched object as a characteristic of radiation harmful object;
- the quantity of the dose coefficients E (Sv/Bq) as a criterion of their radiation hazard;
- coefficients of their accumulation CA (l/kg) as a criterion of their biologic hazard,
- their physical properties (half-decay period T1/2 (Years) or the constant of the radioactive
- the quantity of the dose coefficients E (Sv/Bq) as a criterion of their radiation hazard;
  decay λ) as a criterion of their ecologic hazard

The most hazardous threat for environment pose the nuclids which are characterized by small maximum quantities of first 3 of above-mentioned characteristics That is why the most ecological significance have nuclids for which the quantity of the ecological coefficient has the maximum indicator

$$\text{Ecological Coefficient of Hazard (ECH)} = A0*E*CA/\lambda$$

Out of all potential hazard sources the most hazardous is the one for which the sum of the Ecological Coefficients of all nuclids reaches the maximum quantity

Over each period of time T, from the moment of the accident , the most significant is that nuclid for which partial ecological coefficient of hazard is maximal

$$\text{Partial Ecological Coefficient of Hazard (PECH)} = A0*E*CA*(1-e^{-\lambda t})$$

It is known that non-exceeding of the set dose limits is considered to be a hygienic approach to the provision of the safety for the human being and society.

As far as other part of the natural environment is concerned, the answer to this question lies in the assertion which has become an axiom amongst scientists·" if a human being is protected, then nature is protected as well" This axiom is the basis for the existing normative acts regulating the outlet of the industrial wastes and defining the measures to be undertaken in case of accident.

Nature which has been under anthropological affection serves as a model and allows to evaluate the seriousness of the changes as a result of the anthropological activity Below will you find some objections to the hygienic approach to the safety provision

- impossibility of applying the hygienic norms for the ecological substantiation of the admissible man-caused activity in the places distant from those with high population,
- impossibility of the evacuation of the ecological systems which are in poor condition because of the accidents,
- creation of the highly polluted zones with higher mutagenic background which can potentially cause the appearance of the harmful living forms

It should be noted that the research of the radiation influence on the animals and plants allow to assert that doses of 1 Gy are not dangerous for the majority of the live organisms. However, these levels of radiation may lead to the change of the ecological system structure because of

- obtaining an advantage of one group over another,
- general weakening of the live organisms and as a result of it inability to withstand other harmful factors ;
- reduction of the productivity of the ecological system at the expense of the loss of some resources which would normally allow it to overcome the consequences of the radiation

- reduction of the productivity of the ecological system at the expense of the loss of some

Such affects can manifest themselves at the level of radiation equal to 0 1 Gy that is at significantly low than those considered not dangerous for the live organisms (1 Gy) This means that in case the potentially hazardous activity is conducted in places distant from populated areas the damage to the health of the population (even in case of the maximal accident) will be insignificant while the natural environment can suffer significant damages.

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4. RISK SCENARIOS

In this section originators of the feasibility study review potential risk scenarios for dismantlement operations A special emphasis is made on the emergency situations resulting in substantial discharge of radio nuclides In the course of further research it is planned to define the particular feasibility of each scenario as developed and presented in this chapter for further risk assessment purposes, following the established risk assessment methods and mechanisms.

4.1. Emergency situations at all dismantlement stages - Overview

Following the concept developed by the Russian Ministry for Nuclear Energy (Minatom), the actual life period of the nuclear submarine upon its decommissioning constitutes 70-100 years, which are concluded by the liquidation (utilization) of its reactor compartment Evidently, each stage of the nuclear submarine life period as described in the Section in the above entails a particular risk of potential emergency situations

The schedule of the potentially dangerous activities in the course of the nuclear submarine regular dismantlement operations is shown on Tab 4 1, which presents assessment of the potential risk as broken down into several major categories(i e "minor", etc)

These operations entail potential emergency situations, the assessment of which is targeted as the main objective of this section

Schedule of risks at various dismantlement stages

Dismantlement stages	Description of works performed	Potential Risks			Potential emergency situations
		Nuclear hazard	Radiation hazard	Environmental hazard	
Stage 1 **1.1** Dismantlement enterprise receives the nuclear submarine from the Navy	The sub is to be shut down - nuclear reactor compression unit is fixed in the lower position.	Minor	Minor	Minimal	1 Chain reaction with the resulting radiation pollution 2 Liquid radioactive waste spill 3 The nuclear submarine, sinks and pollutes the water area
	- Stopping the hand drive of nuclear reactor compression unit through welding.	Minor	Minimal	Minimal	

compression unit

Dismantlement stages	Description of works performed	Potential Risks			Potential emergency situations
		Nuclear hazard	Radiation hazard	Environmental hazard	
	- Cables are disconnected from the electrical engines	Minimal	Minimal	Minimal	
	- Systems and equipment prepared for storage	Minor	Minor	Minimal	
1.2 Nuclear submarine is towed to the dismantlement enterprise	Nuclear Steam Production Unit Control	Minimal	Minimal	Minimal	Nuclear submarine sinks and pollutes the sea
1.3 Lay-up (storage) of the nuclear sub at the enterprise	No works performed on the nuclear steam production unit, nuclear steam production unit and Frame I control	Minimal	Minimal	Minimal	The nuclear submarine sinks and pollutes the water area
	Combustive-lubricating materials unloaded, oil tanks steamed			Minor	
Stage 2	General use workspaces unloaded			Minor	
	Storage batteries unloaded			Minor	
				Minor	
2.1 Concurrent dismantlement operations for the used nuclear fuel unloading ops	Transportation (towing) of the submarine to the spent fuel unloading site	Minimal	Minimal	Minimal	1 Chain reaction 2 Liquid radioactive waste spill, radioactive gas emissions into the atmosphere 3 Nuclear submarine sinks
	Reactor and Frame I drained	Minor	Minor	Minor	
	Main Hull & External Special Coating Stripping		Minimal		
	Submarine Hull Heat retention layer dismantlement		Minimal	Minor	

Dismantlement stages	Description of works performed	Potential Risks			Potential emergency situations
		Nuclear hazard	Radiation hazard	Environmental hazard	
	Superstructure and submarine hull detachable plates dismantlement above reactor compartment		Minimal	Minor	
	Dismantlement of pipes and equipment in the Superstructure and reactor compartment		Minimal	Minor	
	Gas blowing from high pressure gas containers	Minimal	Minor	Minor	
	Dismantlement of the executive mechanism of protection system control and thermometers on the reactor lid	Minor	Minor	Minor	
2.2 Unloading of the spent nuclear fuel	Dismantling the fastens,undermining and unloading of the reactor lid	Major	Major	Minor	1 Chain reaction 2 Liquid radioactive waste spill
	Unloading of the heat discharge assembling from the reactor	Minor	Minor	Minor	3 Nuclear submarine sinks and contaminates the water area
Stages 3 & 5	Placing and fastening of the reactor lid	No	Minor	Minimal	
	Frame I conservation	No	Minor	Minimal	
	Welding in the detachable plates over the reactor compartment	No	Minor	Minor	
3.1 Cutting out and formation of the reactor block	Docking the nuclear sub (on the ship-ways)	No	Minor	Minimal	Radioactive waste spill
5.1 Cutting out and works on the reactor compartment	Conservation of the nuclear steam production unit and reactor chamber	No	Minor	Minimal	
5.1 Cutting out	Conservation of the	No	Minor	Minimal	

Dismantlement stages	Description of works performed	Potential Risks			Potential emergency situations
		Nuclear hazard	Radiation hazard	Environmental hazard	
	Dismantling of the heat insulation and special coats	No	Minor	Minimal	
	Liquid radioactive waste discharge	No	Minor	Minor	
	Dismantling the equipment, piping and tubes from the chambers adjacent to the reactor compartment	No	Minor	Minor	
	Cutting the superstructure, light and firm hull	No	Minor	Major	
	Damping the openings in the firm hull and rebuilding the reactor compartment	No	Minor	Minor	
	Formation of the block with the reactor compartment	No	Minor	Minor	
	Launching the reactor compartment block into the water	No	Minimal	Minimal	
	Reactor compartment transportation to the long time storage facilities	No	Minimal	Minimal	
		No			
3.2 Cutting of the frontal and rear compartment blocks	Dismantling of the heat insulation and special coats	No	Minor	Great	
5.2 Cutting of the compartments adjacent to the reactor compartment	Cutting the nuclear sub hull	No	Minor	Great	
	Dismantling the equipment and piping	No	Minor	Major	
compartment					

Dismantlement stages	Description of works performed	Potential Risks			Potential emergency situations
		Nuclear hazard	Radiation hazard	Environmental hazard	
5.3 Transportation and cutting of the hull structures	Dismantling of the cables	No	Minor	Minor	
		No	Minor		
	Transportation of the hull structures, equipment and piping to the cutting sites	No	Minor	Minor	
	Hull structures splicing	No	Minor	Great	
	Equipment and piping splicing	No	Minor	Great	

Tab. 4 1.

Note (Tab.4 1) the 4th stage which is not connected with the spent nuclear fuel unloading and hull cutting and which represents a separate stage for analysis has been omitted

For further assessment of the radiation and environmental hazard from the list of the most likely emergency situations as suggested in the Tab 4 1, applicable to both decommissioned nuclear submarines and other vessels with nuclear power units on board, there have been singled out the particular emergencies resulting in the depressurizing of the core regions and liquid radioactive waste/spent nuclear fuel storage units/facilities

The assessment of the emergency emissions and implications for the local population has been based on the most conservative assumptions pertaining the emergency situation scenarios, including the quantity and nuclide composition of the discharges and pollutants, radioactive waste streams in air and water, as well as irradiation degree of the human population

It has been estimated [2] that in the case of the unlikely developments the variation between the real figures and the calculated values is inversely as the square root of the probability of such a development Experts have therefore estimated the probability of the Regular emergencies at 10^{-3}- 10^{4} year $^{-1}$, non-regular emergencies - 10^{-5} year $^{-1}$ and lower. With such an approximation the difference between the realistic and estimated values may come to 2-3 orders A consistent conservative approach as applied at all stages of the scenario building process up to the calculation of the radiation values of the potential accidents provides for the most extreme values, therefore clearing such a vagueness Such an approach allows to substantially breach the gap between the calculated values and the practical data for such situations.

In the future after we have calculated the estimations of the potential consequences of the accidents, it will become feasible to conduct the comparative analysis of such estimations for

situations

each emergency (Tab 4.2) with the International Atomic Energy Agency size scale for the nuclear accidents and emergencies [3]

Schedule of major regular and non-regular accidents For scenario building purposes (in threat ascending order).

№	Description of the accident	Possible major causes	Emergency class
1	Spill of the liquid radioactive wastes into the water during the transferal of the latter to special vessel	Breach in technological process, human factor, bad weather conditions	Regular accident
2	Sinking of the cut-out rector compartment in the water area of the shipyard	Breach in technological process, safety regulations breaches, human factor	Regular accident
3	Ignition (local fire) within the reactor compartment during the dismantlement operations	Breach in transportation and technological procedures, human factor, bad weather conditions, navigation failures	Max Regular accident at enterprise
4	Accident with the loss of the heat-carrier on the vessel with the spent nuclear fuel on board	Technical failure, human factor	Max Regular accident on board of the ship
5	Sinking of the vessel with the unloaded core region in the naval base water area	Navigation failure, extreme weather conditions human factor, subversive activities	Non-regular accident
6	Spontaneous nuclear chain reaction on board of the nuclear vessel	Breach in technological process in the course of the core region transferal operations, human factor subversive activities	Regular accident (max potential accident)
7	Destruction of the liquid radioactive waste storage facility	Subversive activities aircraft crash, extreme weather conditions	Regular accident with the max spill in water areas
8	Fire (general fire) in the course of the nuclear vessel dismantlement operations	Breach in technological process, safety regulations breaches, human factor	Non-regular accident

Tab 4.2.

Estimations show that the maximum radiation consequences may result from the Regular accident with either the spontaneous chain reaction or the loss of the heat carrier on the nuclear vessel within the naval base or shipyard water areas

Considering that there are no substantial differences between the accident scenarios for the on-water-surface floating nuclear submarines and the other nuclear vessels, such scenarios as described below are applicable to both types, if not specified otherwise. The precise radiation implications for particular types of vessels will need to be developed in the course of the further works on the project in compliance with the scenarios as presented in this report

described below are applicable to both types, if not specified otherwise. The precise radiation

In order to assess emergency implications for the local population and environment for various scenarios it is essential to undertake the calculation of the resultant doses of the exposure of the latter through the radiation cloud, inhaled radio nuclides, underlying terrain contamination stream, as well as estimate the beta field irradiation skin exposure At the same time it seems reasonable to disregard human exposure to the radio nuclides through food, as naval bases for nuclear ships and other vessels are as a rule sufficiently distanced from the agricultural and fishing areas All further environmental implications will therefore be assessed on the bases of the underlying surface contamination (for both all radio nuclides combined and the major ones particularly singled out) All the accidental discharges are considered to be of short duration, in other words in the course of emissions the atmosphere stability conditions, direction and force of the wind are presumed to have constant values Such a conservative approach corresponds to the maximum axis values of the land concentration in the course of the emissions

Evaluation of the consequences of the accidental emissions shall be conducted [5, 6] for the early, medium and final phases of the accident [14]

The early phase of the accident shall be assumed equal to 48 hours During this period there is estimated the total irradiation external dose from the cloud, underlying terrain, as well as the internal dose of the inhaled radio nuclides from the passing cloud

The medium phase of the accident corresponds to 240 hours and the final phase covers the remainder of 1 year after the accident has occurred During these phases researches assess the effective dose of the external irradiation through the radio nuclides, as accumulated on the underlying terrain As it has been earlier described there are no calculations performed for the radio nuclide exposure through food items.

Human population and environment exposure through radioactive emissions is primarily conditioned by the admixture dispersion in the atmosphere These processes depend both on the emission parameters (height, etc) and the stability of the atmosphere itself at the time of emission In the case of the lengthy (continuous) emissions the average meteorological conditions are applied to the admixture dispersion calculation (average annual wind rose, wind speed, atmosphere stability weighted average value, etc) In the case of the brief (accidental) emissions all calculations are based on the precise meteorological parameters at the time of emission

While calculating the values of the accidental emissions and their environmental implications the real meteorological conditions at the time of each emission are calculated within the framework of the local Paskville – Gifford model [7], which is based on the six classes of the standard atmosphere states

Subsections below suggest some of the most hazardous accidents as listed in the Figure 4 2.

the framework of the local Paskville – Gifford model [7], which is based on the six classes of the

As far as the scenario of emergency situation with the loss heat carrier is concerned the following must be mentioned:

In accordance with the safety rules the emergency situation with the loss heat carrier is considered to be the maximum project accident for the atomic vessel

Through the heat carrier (because of the encapsulation defects) the product fissions come out.

During the accident out of the heat carrier 100 % of rare gases, 10 % radioactive iodines in organic form and 1 % of the fission product are released into the atmosphere of the reactor compartment.[10].

In tab 4 3 will you find the Composition and discharges on the nuclear sub as a result of the fire

Taking into account that this emergency situation can hardly be a result of the nuclear submarine decommission, the given situation will not be treated at length in this report

Composition and discharges on the nuclear sub as a result of the fire

Radio nuclide	Half-Life	Gamma-constant, r·cm²/g·m Ci	Atmosphere emissions, Ci (Bq)
Krypton-85m	4,48 h	1,12	300 (1.11 10^{13})
Krypton-87	76.3 min	3,72	320 (1,18 10^{13})
Krypton-88	2,84 h	9 7	460 (1,70 10^{13})
Xenon-133	5.245 days	0,51	2600 (9.62 10^{13})
Xenon-135	9,08 h	1,32	1300 (4.81 10^{13})
Xenon-138	14 1 min	5,23	220 (8,14 10^{12})
Iodine-131	8.04 days	2,16	2 8 (1,04 10^{11})
Iodine-132	2,3 h	12.6	35 1,30 10^{12})
Iodine-133	20,8 h	3,36	24 (8.88 10^{11})
Iodine-134	52.6 min	13.9	73 (2,70 10^{12})
Iodine-135	6,61 h	8,44	46 (1 70 10^{12})
Rubidium-88	17,8 min	3,16	4.6 (1.7 10^{11})
Strontium-91	9,75 h	6,1	8,0 10^{-3} (2,96 10^{8})
Strontium-92	2.71 h	6,34	1.6 10^{-3} (5,92 10^{7})
Zirconium-95 + Niobium-95	64,05 days	4,14	1 1 10^{-2} (4,07 10^{8})
Ruthenium-103	39,35 days	2.98	1,3 10^{-2} (4,81 10^{8})
Ruthenium-106	368 days	1,15	1.9 10^{-2} (7,03 10^{8})
Cesium-134	2,062 years	8,72	2 0 10^{-2} (7,40 10^{8})
Cesium-137	30,17 years	3,24	2,5·10^{-2} (9,25 10^{8})
Cesium-138	33.41 min	11,16	6,1 (2,26 10^{11})
Barium-139	84.9 min	0,243	0,5 (1.85 10^{10})
Barium-140	12,79 years	1,14	1,9 10^{-2} (7.03 10^{8})

Cesium-138 | 33.41 min | 11,16 | 6,1 (2,26 10^{11})
Barium-139 | 84.9 min | 0,243 | 0,5 (1,85 10^{10})

Tab. 4.3.

4.2. Emissions of the radio nuclides as result of reactor compartment fire on nuclear submarine

As all of the works performed on the open stockpile slab during the dismantlement of the nuclear vessels (gas or plasma cutting) are highly fire and explosion dangerous, the fire accident scenario probability has always been considered extremely high

The radiation consequences of the fire are determined by its category and development dynamics, as well as the values of the atmosphere at the ignition point

The following data is generally assumed for the assessment of the of the potential discharge in the reactor compartment of the dismantled ship, including further atmosphere pollution as a result of the fire [10]

- Integral activity of the contamination sources in the power compartment with the lay-up period of 1-3 years amounts to $(3\text{-}5)\cdot 10^4$ Ci (approximately $1{,}5\ 10^{15}$ Bq),
- Over 90 % of the indicated value is localized in the internal compartment structures, which account for approximately 5-7% of the total amount of the materials containing radio nuclides within the power compartment,
- The integral surface of the contaminated structures, which may emit active elements into atmosphere from the power compartment, is assumed at $4\ 10^3$ Ci ($1{,}5\cdot 10^{14}$ Bq), as shown on Figure 4 4,
- Radio nuclide composition of the pollution is shown on Tab 4.4,
- Coefficient of the radio nuclide emissions from the contaminated equipment into the air inside compartment depends on the physical and chemical features of the radio nuclides, similar to the meltdown of the core region [10]

Nuclide composition and activity values as emitted into the compartment air during fire

Radio nuclide	Approximate participation share in total activity, %	Nuclide activity on the surface of equipment, Ci (Bq)	Emission coefficient in compartment air	Activity in the compartment air, Ci (Bq)
Cobalt-60	70	$2{,}8\ 10^3$ $(1\ 10^{14})$	$3\ 10^{-3}$	$8.4(3.1\ 10^{11})$
Cesium-137	20	$8\ 10^2$ $(3\ 10^{13})$	0,8	$640(2{,}4\ 10^{13})$
Manganese-54	5	$2\cdot 10^2$ $(7.5\ 10^{12})$	0.03	$6\ (2.2\ 10^{11})$
Strontium-90	3	$1.2\ 10^2$ $(4{,}5\ 10^{12})$	0,1	$12(4{,}4\ 10^{11})$

Tab. 4.4.

The given values of the active elements emissions in the power compartment during fire represent a most conservative evaluation and are feasible only at relatively high temperatures (approximately. 1000° C and more)

(approximately. 1000 C and more)

While assessing the scale of the potential radiation implications of the ignition in the power compartment it is essential to distinguish this risk into two particular types of fire, i e local and general fire accidents [12]

Local fire ignition occurs in the environment of little oxygen and the combustion products remain inside the burning premises for a considerable period of time. Under these conditions certain active elements in the compartment air tend to form a sediment on its internal walls Following the most conservative assessment, the discharge of the active elements into outside the facilities on fire does not exceed 10 % of the elements remaining inside the compartment space

However in the case of a general fire all the burning occurs with sufficient or even redundant oxygen The combustion products and therefore the active elements are emitted into the external atmosphere in much greater quantities Only a small percentage of the active elements remain inside with the rest being discharged externally, i e almost 100 % of all of the active elements (set value for assessment purposes)

The results of the radioactive emissions during fire are shown on Tab. 4 5

Active elements, Ci (Bq) taken outside during fire

Radio nuclide	Local fire	General fire
Cobalt-60	0,17 (6,3 10^{9})	8,4 (3,1 10^{11})
Cesium-137	12,8 (4,7 10^{11})	640 (2,4 10^{13})
Manganese-54	0,12 (4,4 10^{9})	6 (2,2 10^{11})
Strontium-90	0,24 (8 8·10^{9})	12 (4,4 10^{11})

Tab 4.5

While calculating the values of the potential radiation consequences from both local and general fire behind the territory of the nuclear submarine dismantling enterprise, it is reasonable to concentrate on defining the following potential risks

- Effective irradiation dose for each human person, with the position of the latter fixed along the fire axis (including external irradiation from the cloud. inhaled radio nuclides, irradiation from the contaminated underlying terrain),
- Contamination density of the underlying terrain

4.3. Accidents related to spontaneous chain reaction with radio nuclide discharges

A nuclear accident of spontaneous chain reaction can occur for various reasons in the course of recharging of the core regions of the reactors of the nuclear power units

A nuclear accident of spontaneous chain reaction can occur for various reasons in the

Such accidents, however regarded as the non-regular emergencies, have occurred on a number of occasions in the course of reloading of the nuclear fuel One of the most illustrative examples is the accident in the Chazhma Bay in 1985 The heat explosion at the nuclear submarine of the Echo-2 type occured in 1985 during the conduction of the works on reloading of the reactor core After the loading of the new heat producing assemlages in the reactor core, the cover of the reactor was lifted for the substitution of the reactors's washer During the lifting of the reactor cover, the reactivity compensation unit also lifted which led to an explosion.

At the moment of explosion an assemblage with heat producing elements was thrown out of the reactor The main metal construction of the assemblage dropped near the cover of the 2nd reactor There was seen a flash raising to the height of 6 meters The orange-grey smoke was formed which raised to 20 meters There formed a cloud which began moving with the wind. Right after the explosiion a fire began in the compartment The cabels, coatings and paint were burning The combustion products were formed along with the explosion products and in the form of grits were released in the surface Grits release could be seen withing 50 meters of the accident place

The most grim consequences for the human population and local environment for this scenario stem from the spent core region, which represents a vast number of the long life fission products that have accumulated during the operational mode of the power unit The total activity of these fission products, even after the core region has been laid up without operation for a lengthy period of time, substantially exceeds the activity of the fission products resultant from the actual spontaneous chain reaction

Spontaneous chain reaction consequences outside the bases depend on the character and intensity of the fission products emission into the atmosphere

The following chain reaction scenario and the resultant discharge values are suggested as the most probable

- Spontaneous chain reaction occurs on the cold or cooled reactor with the opened reactor compartment, i e after the shielding detachable plate has been already removed Reactor has been unsealed or is being unsealed (e g the lid is being blown off),
- Because of the brief duration of the flash the chain reaction terminates as a result of the local boiling and water surge from the core region with the resulting core region geometry breach,
- The main energy discharged in the course of the spontaneous chain reaction flash accumulates in the active zones (core regions) Due to the low thermal conductivity of the water and the water steam. the heat carrier receives only a modest share of the energy (not more than 0,01 of the total chain reaction heat portion),
- Flash is brief and the energy discharge is considerable, so the heat carrier in the thin layer next to the heat discharge elements shell turns into steam which at this point is condensed into a highly compressed state (with the temperature of approx 1000°K the pressure in the shell layer may reach several hundred Barr). Another possible mechanism of the local

- Flash is brief and the energy discharge is considerable, so the heat carrier in the thin layer

pressure hike may become the enlargement of the heat discharge elements (certain estimations show evidence of up to 5 % of the initial capacity),

- Because of the indicated heat carrier, the overheat steam is being momentarily discharged together with overheated water from the reactor Fission products accumulated in the core region (and those having come into existence during the spontaneous chain reaction) do not timely proceed into the heat carrier and an immediate discharge of water and steam is comparatively low-active,
- As practically all the chain reaction energy is accumulated in the core region (heat discharge elements), core region partially melts down,
- The water remaining inside the reactor (as well as in the Frame I), reacts with the overheated core region, evaporates and takes fission products out from the core region meltdown into the atmosphere The fission product emission constant lasts several minutes. This discharge is not instantaneous in its nature and is terminated as a result of either the entire water supply evaporation or of the core region cooling down Fission product discharge may continue even after all water evaporates, however not as intensively.

As a result, the major portion of the active elements is emitted into the atmosphere through evaporated heat carrier directly after the spontaneous chain reaction occurs.

The intensity of the atmosphere discharge depends on two factors amount of the actual fission products (both accumulated in the core regions and as resultant from the spontaneous chain reaction) and the power of the chain reaction flash (the discharged energy determines the degree of destruction of the core region and discharge dynamics)

The total number of fissions value in chain reaction (flash power) is assumed equal to 10^{20} Such a characteristic of the chain reaction is calculated by the international RELAP-5/mod3 standard, however minding the specifics of the particular nuclear power units of the vessels. Within the entire feasible variation scope, the integral fission value is below 10^{20}, so this 10^{20} value is taken as the extreme energy surge for the spontaneous chain reaction for the water-based nuclear power units

In the further research the following parameters of the atmospheric discharge may be used as the benchmark reference

1 Discharge occurs while the nuclear submarine is docked at the berth within the fully controlled naval base,
2 Discharge is brief in time,
3 The discharge height makes up 100 meters above the water area surface While establishing the discharge height there has been employed the Morgon, Tailor and Turnei model [10], which has been experimentally tested for the nuclear explosions of various capacity,
4 The radio nuclide discharge share from the melted part of the core region in compliance with [10] makes up

- For radio nuclides of the rare gas - 0,9,
- For the volatile radio nuclides (Imodium, Cesium, Rubidium) - 0,8,

[illegible]

For radio nuclides of the rare gas - 0,9

- For Barium - 0,10;

- For heavy aerosols - 0,03,
- For Cesium - 3 10^{-3}.

5. For all of the radio nuclides with the exception of the rear gases, the separation coefficient (sediment) in the reactor shaft, the cool structures of the nuclear submarine around the shaft and the fuel-handling device is estimated at 0,5

For the suggested parameters the fission product discharge into the atmosphere at various lay-up periods is shown on Tab. 4 6

In the future stages of work on the project these parameters will be used to calculate the implications of the spontaneous chain reaction for human health and environment beyond the territories of the naval base.

4.4. Fire in the liquid radioactive waste storage facility.

The maximum discharge into the atmosphere from the storage facility with the liquid radioactive wastes occurs during the fire, when the liquid evaporates completely (radio nuclide solution) Such an accident is highly improbable as for the evaporation of the large quantity of water substantial amount of thermal energy is essential, i e 2500 kJ/kg with the initial water temperature reaching up to 20C For the conditioned storage of the highly active liquid storage waste (100 m^3 of volume), considering that there occurs only partial consumption of the combustion heat this amounts to at least 3 10^8 Kj This is equivalent of burning 30-50 tones of the regular diesel fuel in the direct vicinity of the liquid fuel storage facilities The following conservative premises must also be met for such an accident to occur

- Oxygen flow (fresh air) to the seat of fire is unrestricted,
- During the entire period there are no liquid radioactive waste spills.

The height of the flame is conditioned by the two following factors

- Intensity of the burning,
- Weather conditions.

Quantity-wise the height of the fire may change from several dozens to several hundred of meters For the stable weather conditions, when the transferal of the active elements occurs for greater distances, with the burning speed of the equivalent fuel of 1 kg/c, the limit height of the flame averages at about 100 m

Accumulation of the radio nuclides in the core region and the spontaneous chain reaction flash for different lay-up periods (full discharge into atmosphere)

Radio nuclide	Maximum amount in the core region after chain reaction for various lay-up time intervals, Ci (Bq)			Discharge into atmosphere right after spontaneous chain reaction for various lay-up time intervals, Ci (Bq)		
	30 days	90 days	180 days	30 days	90 days	180 days
Krypton-85m	1,09 10^{3} (4,03 10^{13})	1,09 10^{3} (4,03 10^{13})	1,09 10^{3} (4,03 10^{13})	98 (3,63 10^{12})	98 (3,63·10^{12})	98 (3,63$10^{12}$)
Krypton –85	2,38 10^{4} (8,81·10^{14})	2,36 10^{4} (8,73·10^{14})	2,31·10^{4} (4,03 10^{13})	2140 (7,92 10^{13})	2124 (7,86 10^{13})	2080 (7,70 10^{13})
Krypton 87	1,0 10^{4} (3,70 10^{14})	1,0 10^{4} (3,70 10^{14})	1,0 10^{4} (3,70 10^{14})	900 (3,33 10^{13})	900 (3,33 10^{13})	900 (3,33 10^{13})
Krypton -88	6,26 10^{3} (2,32 10^{14})	6 26 10^{3} (2,32 10^{14})	6,26 10^{3} (2,32 10^{14})	563 (2,08 10^{13})	563 (2,08 10^{13})	563 (2,08 10^{13})
Rubidium 88	5 17 10^{3} (1,91 10^{14})	5,17 10^{3} (1,91 10^{14})	5,17·10^{3} (1,91$10^{14}$)	207 (7,66 10^{12})	207 (7,66 10^{12})	207 (7,66 10^{12})
Krypton -89	2,0 10^{5} (7,40 10^{15})	2,0 10^{5} (7,40$10^{15}$)	2,0 10^{5} (7,40 10^{15})	1,8 10^{4} (6,66 10^{14})	1,8 10^{4} (6,66 10^{14})	1,8$10^{4}$ (6,66 10^{14})
Rubidium 89	6,5 10^{4} (2,41 10^{15})	6,5 10^{4} (2,41 10^{15})	6,5 10^{4} (2,41 10^{15})	2600 (9,62 10^{13})	2600 (9,62·10^{13})	2600 (9,62 10^{13})
Strontium-89	6,0 10^{5} (2,22 10^{16})	2,7 10^{5} (9,99 10^{15})	8,3 10^{4} (3,07 10^{15})	3000 (1,11 10^{14})	1350 (4,99 10^{13})	415 (1,54 10^{13})
Strontium-90	2,2 10^{5} (8,14 10^{15})	2,2 10^{5} (8,14 10^{15})	2 2 10^{5} (8,14 10^{15})	1100 (4,07 10^{14})	1100 (4,07$10^{13}$)	1100 (4,07 10^{13})
Ruthenium-103	3,4 10^{5} (1,26 10^{16})	1,2$10^{5}$ (4,44 10^{15})	2,4 10^{4} (8,88 10^{14})	510 (1,89 10^{13})	180 (6.66 10^{12})	36 (1,33 10^{12})
Ruthenium-106	6,1 10^{4} (2,26 10^{15})	5,5 10^{4} (2,05 10^{15})	4,6 10^{4} (1,70 10^{15})	92 (3,40 10^{12})	83 (3,07 10^{12})	69 (2,55 10^{12})
Iodine-131	6,0 10^{4} (2,22 10^{15})	371 (1,37 10^{13})	28 (1,04 10^{12})	2400 (8,88 10^{13})	15 (5,55 10^{11})	1,1 (4,07 10^{10})
Iodine –132	2520 (9,32 10^{13})	100 (3,70 10^{12})	100 (3,70·10^{12})	100 (3,70 10^{12})	4 (1,48 10^{11})	4 (1,48 10^{11})
Iodine –133	782 (2,89 10^{13})	782 (2,89 10^{13})	782 (2,89 10^{13})	31 (1,15 10^{12})	31 (1,15 10^{12})	31 (1,15·10^{12})

<table>
<tr><th rowspan="2">Radio nuclide</th><th colspan="3">Maximum amount in the core region after chain reaction for various lay-up time intervals, Ci (Bq)</th><th colspan="3">Discharge into atmosphere right after spontaneous chain reaction for various lay-up time intervals, Ci (Bq)</th></tr>
<tr><th>30 days</th><th>90 days</th><th>180 days</th><th>30 days</th><th>90 days</th><th>180 days</th></tr>
<tr><td>Iodine –134</td><td>1,92 10^{4}
(7,10 10^{14})</td><td>1,92 10^{4}
(7,10 10^{14})</td><td>1,92 10^{4}
(7,10 10^{14})</td><td>770 (2,85 10^{13})</td><td>770 (2,85 10^{13})</td><td>770 (2,85 10^{13})</td></tr>
<tr><td>Iodine –135</td><td>4750 (1,7610^{14})</td><td>4750 (1,76 10^{14})</td><td>4750 (1,76 10^{14})</td><td>190 (7,03 10^{12})</td><td>190 (7,03 10^{12})</td><td>190 (7,03 10^{12})</td></tr>
<tr><td>Xenon-133</td><td>4,4 10^{4}
(1,63 10^{15})</td><td>20 (7,40 10^{14})</td><td>2,7 (9,99 10^{10})</td><td>3960 (1,47 10^{14})</td><td>1,8 (6,66 10^{10})</td><td>0,24 (8,88 10^{9})</td></tr>
<tr><td>Xenon –135</td><td>422 (1,56·10^{13})</td><td>422 (1,56 10^{13})</td><td>422 (1,56 10^{13})</td><td>38 (1,41 10^{12})</td><td>38 (1,41 10^{12})</td><td>38 (1,41 10^{12})</td></tr>
<tr><td>Xenon –137</td><td>1,7 10^{5}
(6,29 10^{15})</td><td>1,7 10^{5}
(6,29 10^{15})</td><td>1,7 10^{5}
(6,29 10^{15})</td><td>1,53 10^{4}
(5,66 10^{14})</td><td>1,53 10^{4}
(5,66 10^{14})</td><td>1,53 10^{4} (5,66 10^{14})</td></tr>
<tr><td>Xenon 138</td><td>7,9 10^{4}
(2 92 10^{15})</td><td>7,9 10^{4}
(2,92 10^{15})</td><td>7,9 10^{4}
(2,92 10^{15})</td><td>7110 (2,63 10^{14})</td><td>7110 (2,63 10^{14})</td><td>7110 (2,63 10^{14})</td></tr>
<tr><td>Cesium-137</td><td>2,2 10^{5}
(8,14 10^{15})</td><td>2,2 10^{5}
(8,14 10^{15})</td><td>2,2 10^{5}
(8,14 10^{15})</td><td>8800 (3,26 10^{14})</td><td>8800 (3,26 10^{14})</td><td>8800 (3,216 10^{14})</td></tr>
<tr><td>Cesium 138</td><td>3,2 10^{4}
(1,18 10^{15})</td><td>3,2 10^{4}
(1,18 10^{15})</td><td>3,2 10^{4}
(1,18 10^{15})</td><td>1280 (4,74 10^{13})</td><td>1280 (4,74 10^{13})</td><td>1280 (4,74 10^{13})</td></tr>
<tr><td>Cesium –139</td><td>1,07 10^{5}
(3,96 10^{15})</td><td>1,07 10^{5}
(3,96 10^{15})</td><td>1,07 10^{5}
(3,96 10^{15})</td><td>4280 (1,58 10^{14})</td><td>4280 (1,58 10^{14})</td><td>4280 (1,58 10^{14})</td></tr>
<tr><td>Barium-139</td><td>1,79 10^{4}
(6,62 10^{14})</td><td>1,79 10^{4}
(6,62 10^{14})</td><td>1,79 10^{4}
(6,62 10^{14})</td><td>90 (3,33 10^{12})</td><td>90 (3,33 10^{12})</td><td>90 (3,33 10^{12})</td></tr>
<tr><td>Barium -140</td><td>2,87 10^{5}
(1,06 10^{16})</td><td>1,12 10^{4}
(4 14 10^{14})</td><td>193 (7,14 10^{12})</td><td>1435 (5,31 10^{13})</td><td>56 (2,07 10^{12})</td><td>1,0 (3,70 10^{10})</td></tr>
<tr><td>Cerium-141</td><td>6,18 10^{5}
(2,29 10^{16})</td><td>1,72 10^{5}
(6,36 10^{15})</td><td>2,5 10^{4}
(9,25 10^{11})</td><td>93 (3,44 10^{12})</td><td>26 (9,62 10^{11})</td><td>3,8 (1,41 10^{11})</td></tr>
<tr><td>Cerium -143</td><td>861 (3,19 10^{13})</td><td>861 (3,19 10^{16})</td><td>861 (3,19 10^{13})</td><td>0,13 (4,81 10^{9})</td><td>0,13 (4,81 10^{9})</td><td>0,13 (4,81 10^{9})</td></tr>
<tr><td>Cerium -144</td><td>9,6 10^{5}
(3,55 10^{16})</td><td>8,3 10^{5}
(3,07 10^{16})</td><td>6,6 10^{5}
(2,44 10^{16})</td><td>144 (5,33 10^{12})</td><td>125 (4,63·10^{12})</td><td>99 (3,66 10^{12})</td></tr>
</table>

Tab 4.6.

4.5. Unsanctioned discharge of the liquid radioactive wastes into the water area

Unsanctioned discharge is possible in the course of transferring the liquid radioactive waste onto the vessels or from such vessels to the storage facilities The reason for the unsanctioned discharge may be the depressurizing (or breach) of the liquid waste transferal hose. The total discharge is determined by the operational time of the working pump after the depressurizing of the hose has occurred. For estimation purposes it is assumed that the pump is to be switched off by the operator and such switch-off occurs in 10-20 minutes after the breach With the pump output of a 25-30 m^3/h the waste discharge will therefore make up not more than 10m^3 Specific activity of the liquid radioactive waste is assumed at $5 \cdot 10^{-4}$ Ci/l (2 10^7 Bq/l) The radio nuclide composition of the liquid radioactive waste and the discharge intensity for particular nuclides is as shown in Tab. 4 7 Following the suggested scenario the total activity of the accident discharge will therefore make up 5 Ci (2 10^{11} Bq), while at the same time all the active elements will be dumped in the water area within the fully controlled naval base premises at full sea

Radio nuclide composition of the salt-free liquid radioactive waste and their combined discharge into the bay

Radio nuclide	Amount, %	Discharge, Ci (Bq)
Chromium-51	0,15	$7{,}5\,10^{-1}$ (2.78 10^{8})
Manganese-54	0,3	$1{,}5\,10^{-2}$ (5,55 10^{8})
Iron-59	0,1	$5\,10^{-3}$ (1,85 10^{8})
Cobalt-58	0,7	$3{,}5\,10^{-2}$ (1,30 10^{9})
Cobalt-60	0 15	$7{,}5\,10^{-3}$ (2.78 10^{8})
Strontium-89	1.5	$7{,}5\,10^{-2}$ (2.78 10^{9})
Strontium-90+Ittrium-90	1.5	$7{,}5\,10^{-2}$ (2 78 10^{9})
Zirconium-95+Niobium-95	10	0,5 (1,85 10^{10})
Ruthenium-103+Niobium-95	10	0,5 (1,85 10^{10})
Ruther	5 5	0,275 (1.02 10^{10})
Cesium-134	5 5	0.275 (1,02 10^{10})
Cesium-137+Barium-137	15	0.75 (2.78 10^{10})
Cerium-141	10	0,5 (1,85 10^{10})
Cerium-144+Promethium-144	30	1,5 (5,55 10^{10})
Gadolinium-153	5	0,25 (9,25 10^{9})
Europium-152	1,0	0.05 (1,85 10^{9})
Europium-154	1,0	0,05 (1,85 10^{9})
Terbium-160	2,0	0,1 (3,70 10^{9})

Tab 4.7.

Tab 4 7

4.6. Sinking of the cut out reactor block during transportation

In this section we develop the scenario and determine the implications of sinking of the reactor block, which has been cut out from the submarine hull and is being loaded, unloaded or transported by water to the lengthy storage facilities In the course of preparation for the burial of the reactor blocks they are pressurized and no sea water can find its way inside. Any radiation implications of the sinking of such a block can result only from the corrosion of the submarine hull, which has been actively hit by the neutron flux while in operational mode

The corrosion velocity of the steel combination, which makes up the hull of the submarine, is assumed at 5 10^{-3} cm/year The resulting discharge of the radioactive agents into the sea water can be assessed under the following assumed conditions

- The corrosion products fully dissolve in water,
- Reactor compartment remains pressurized;
- The surface and both front and rear sealing of the reactor compartment are free from the radioactive contamination

Only the most considerable radio nuclides, i e those of long life and possessing the maximum discharge, are taken into account The results of the calculations performed are shown in Tab 4 8.[14]

The data suggested in the Figure below has been accumulated by the means of calculation on the basis of the hardest maintenance models and extremely high loads operational modes of the nuclear submarine; therefore such assessments represent the worst case scenario

Discharge velocity of the radioactive corrosion agents through the reactor compartment hull (compartment remains pressurized)

Generation of the sub	Lay-up period in years	Discharge speed, Bq/hour				
		Fe-55	Co-60	Ni-63	Ni-59	Total
1	3	5000	203	50	0.4	5200
	10	840	81	48	0.4	970
	50	3 10^{-2}	0,4	36	0,4	37
	100	6 10^{-8}	6 10^{-5}	24	0.4	24
2	3	8,3 10^{5}	3.3 10^{4}	8500	60	8.7 10^{5}
	10	1,4 10^{5}	1.3 10^{4}	8100	60	1,6 10^{5}
	50	4,8	69	6000	60	6100
	100	1 10^{5}	0,1	4000	60	1000

Tab.4.8.

	100	1 10^{5}	0,1	4000	60	1000

4.7. Sinking of the nuclear submarine with the unloaded core region

In this section we assess the consequences of the sinking of the nuclear submarine with the unloaded core region (active zone) within the water area of the naval base The worst case scenario is assumed: the accident occurs while they are works performed on the vessel, the reactor compartment is unsealed and the reactor is depressurized. The submarine has been previously laid up for 180 days, in other words the active zone primarily contains the long life radio nuclides Activity values of the essential radio nuclides are as shown in Tab 4.9.

As a result of the nuclear submarine sinking the heat carrier of the first contour (i e reactor mainframe or Frame I) reacts with the water of the bay. After a minor one-time discharge, the nuclear fuel begins to slowly experience the corrosive effect in the seawater The speed with which the fission products find their way from the core region into the seawater is determined by the following factors:

- The time period after sinking when heat discharge elements actually begin to react with the seawater,
- Temperature of the heat discharge elements shells at the moment of sinking (after the first contact with the sea after) and the dynamics of its fluctuation as time progresses,
- State of the heat discharge elements shells at the moment of sinking

Activity values of the long life fission products as of the moment of the submarine sinking (prior lay-up period – 180 days)

Radio nuclide	Half-life	Half-life constant, 1/hour	Activity, Ci (Bq)
Strontium-89	50,5 days	$5.480\ 10^{-4}$	$8{,}34\ 10^{4}$ ($3{,}09\ 10^{15}$)
Strontium-90	29,12 years	$2{,}857\ 10^{6}$	$2{,}18\ 10^{5}$ ($8.07\ 10^{15}$)
Ruthenium-103	39.28 days	$7{,}312\ 10^{-4}$	$2{,}43\ 10^{4}$ ($8{,}99\ 10^{14}$)
Ruthenium-106	368,2 days	$7{,}848\ 10^{5}$	$4{,}61\ 10^{4}$ ($1{,}71\ 10^{15}$)
Cesium-134	2.062 years	$3.834\ 10^{-5}$	$2{,}56\ 10^{4}$ ($9{,}47\ 10^{14}$)
Cesium-137	30 years	$2{,}638\ 10^{-6}$	$2.17\ 10^{5}$ ($8{,}03\ 10^{15}$)
Cerium-141	32,5 days	$8{,}880\ 10^{-4}$	$2{,}53\ 10^{4}$ ($9{,}36\ 10^{14}$)
Cerium-144	284.3 days	$1.017\ 10^{4}$	$6{,}63\ 10^{5}$ ($2.45\ 10^{16}$)

Tab. 4.9

4.8. Destruction of the liquid radioactive waste storage facilities

As a general rule the receiving tanks are very strong in nature, they have cylinder shape and are placed in the reinforced concrete facilities with the underseal metal coating. When the receiving tank is destroyed (as a result, for example, of aging or corrosion) the liquid wastes flow

As a general rule the receiving tanks are very strong in nature, they have cylinder shape

out into the internal facilities, which can accommodate all the liquid waste inside all tanks From such a facility the liquid waste can then be pumped into new tanks and will never find its way into the surrounding environment The discharge of these wastes outside the facilities is therefore possible only if the receiving tanks and concrete walls of the facilities are destroyed simultaneously Such a massive destruction of both the concrete and metal structures can occur only as a result of the extreme external force: explosion of a powerful charge in the direct vicinity of the facility buildings (subversive activity), crash landing and explosion of a heavy aircraft with a substantial amount of fuel on board and/or ammunition (air bombs, missiles), random hit by an air bomb, missile.

The highest possible specific activity of the liquid radioactive wastes accounts for distillates and represents $5\ 10^{-4}$ Ci/l ($2\ 10^{7}$ Bq/l), which considerably exceeds the activity of other liquid wastes As an extreme case here it can be assumed that both the tanks and the facilities have been completely destroyed and all of the active agents have been dumped into the water area of the bay During the discharge some of the liquid wastes will remain in soil in the form of wet terrain and small spills condensing in the terrain irregularities. The water in such spills may evaporate soon after the accident, and the firm residue will make up the surface contaminant layers which with time will be washed away with the atmospheric precipitation and sink deeper into the terrain The assessed contamination layer makes up the tenths of a mm, however for conservative assessment it is assumed at 1 mm

If the accident occurs in winter or late fall the water on the surface will remain in the snow cover; during the snow melting it will be washed into the water area with the water from the melted snow For this reason the remaining radio nuclides in the soil will under no reasonable condition be greater than if such accident occurs in the spring or summer seasons

The discharge of the liquid radioactive waste is assumed as being brief in time For the bay contamination assessment purposes it is assumed that the active agents of the tanks with the distillate are all washed away into the water area at the full sea

4.9. Reason for the probable emergency situations

The aforementioned accident scenarios are far from covering the entire contingency scope A special attention should be paid to the analysis of the spontaneous chain reaction implications or the radio nuclide discharge resulting from other fission (nuclear) reactions. The initial reloading stage has here the foremost significance

When the nuclear fuel is unloaded from the submarine, the hull of the submarine is unsealed and the external lifting crane removes the lid from the reactor. With the reactor compartment wide open and the reactor lid lifted away the following accidents can occur·

When the nuclear fuel is unloaded from the submarine, the hull of the submarine is

1 Sudden (hypothetical) water overflow finds its way into the reactor, preliminary dried up during a lengthy lay-up interval, the active zone reaches the critical condition and a highly improbable spontaneous chain reaction flash occurs,

2 Over the nuclear submarine, a helicopter (plane or other aircraft) experiences malfunction, crashes and its kerosene fuel spills inside the reactor compartment directly into the reactor, it then ignites and causes a fire inside the reactor compartment

Both hypothetical accidents result with the spent nuclear fuel emitting radioactive substances into the outside atmosphere, where then form a contaminated cloud, which poses a potential threat for the local population and environment as both the external and internal irradiation source

The actual concentration of the radio nuclides (admixtures) in the atmospheric train is calculated on the basis of the Gauss double dispersion equation. The dispersion parameters are fixed considering the stability of the atmosphere and terrain specifics (valley, hills, urban territories) All of this is undertaken on the basis of the existing IAEA recommendations

Variation of the terrain specific features and atmosphere types results in the necessity to conduct the variation calculations minding the correlation between the final results (determination of the admissible dose) and the variety of the initial data A concrete result of the analysis of the radiation implications of the spontaneous chain reaction during the spent nuclear fuel unloading operations was presented at the international seminar of 1998 in Nizhniy Novgorod.

There it was specifically emphasized that the anticipated discharge of the radio nuclides into the atmosphere during the chain reaction resultant from the unloading of the spent nuclear fuel will be at least 3 times less than what had been emitted into the atmosphere from the Reactor 4 of the Chernobyl Nuclear Power Plant in 1986 Within the 5 km footprint of the residue from the pollution cloud all of the local population will need to be evacuated With the annual unloading of about 10 nuclear rectors from the dismantled submarines, the actual possibility of the spontaneous chain reaction at the first generation reactor, which has not been sufficiently laid-up, can be estimated at the value of 3 10^{-5} a year^{-1} For the dried up reactor such possibility is of course lower [15]

Handling the spent nuclear fuel, which will then need to be delivered to the processing enterprise of the Minatom, constitutes a major general challenge in the entire nuclear submarine maintenance system This task has been assigned to the Ministry of Nuclear Energy of the Russian Federation, which has recently taken additional measures to secure that such fuel is speedily delivered to the processing points as well as increased the safety precautions for the entire procedure of unloading the fuel from the nuclear submarines till its very delivery to the industrial enterprises

speedily delivered to the processing points as well as increased the safety precautions for the
entire procedure of unloading the fuel from the nuclear submarines till its very delivery to the

It should be emphasized that for various accidents there can be identified various discharges and waste streams of the radio nuclides. It is therefore suggested that in the course of assessing the environmental implications of the decommissioned Russian nuclear submarines a special research targets the following tasks

- Identification of the radio nuclide discharge from the residue on the internal rector stainless steel structures into the sea water,
- Identification of the radio nuclide discharge from steel itself after the surface residue has been cleaned away through the chemical deactivation procedures,
- Identification of the radio nuclide waste streams from the heat discharge assembling, submersed into sea water,
- Identification of the radio nuclide waste streams from the heat discharge assembling on fire from the burning kerosene on the external surface of the heat discharge assembling funnel cover

Evaluation of the environmental security implications requires a number of various additional criteria, which need to be taken into account The originators of this feasibility study believe that among such criteria there should be considered the research of the "Standard concentrations of the technical radio nuclides in the sea water", as applied to the water areas of the enterprises where the nuclear submarines and reactor blocks are being laid up As of the date of this feasibility study such a research does not exist, yet it is essential for the purposes of this survey

As a result, the following occurrences can potentially lead to the suggested hypothetical accidents

- Natural calamities, which damage the hull of the reactor compartment of the nuclear submarine (earthquakes, tsunami, hurricanes, tornados, etc);
- Technical accidents as a result of carelessness, low morale or exceptional tiredness of the personnel (e g navigation errors), with the resulting damage to the hull structures of the submarine reactor compartment,
- Technical calamities (aircraft crash with the detonation of the ammunition), with the resulting damage to the hull structures of the submarine reactor compartment,
- Intentional destruction operations (diversions, terrorist attack, military action)

The natural calamities are not directly linked to the human activities and are conditioned by the natural and climatic environment of the suggested storage and lay-up site for the nuclear submarine with the used nuclear fuel on board We can suppose that the frequency of the natural calamities, which can create damage to the hull structures of the submarine reactor compartment, makes up 10^{6} per year in the Russian North and 5 times that much in the Far East of Russia due to the high probability of tsunami, typhoons and the high seismic activity in this region As a result such an accident can occur in the North not more than once in one million years, and in the Far East – once every two hundred thousand years However considering the strength of the

to the high probability of tsunami, typhoons and the high seismic activity in this region As a

reactor compartment we can make a safe assumption that not even every accident of the described natural cause can sufficiently destroy the safety barriers (shielding structures) which separate the spent nuclear fuel on board of the submarine from the outside environment Consequently the aforementioned potential frequencies of such an occurrence have an even less implicational value

Anthropogenic accidents depend on the intensiveness of the human operations, which can be assessed in several different ways, e.g. by conducting the analysis of the electric power consumption in this region or the statistics for the local population of the region These accidents have the human factor as the main cause for their occurrence

Intentional actions of destroying the shielding barriers inside the reactor compartment maybe caused by the military actions, subversive activities, terrorist attacks, etc Their potential frequency depends on the social and political situation in the region The total risk of the events, which can result in the emergency sinking of the nuclear submarine with the nuclear fuel on board with the simultaneous depressurizing of the nuclear steam production unit first contour, can be assumed at 10^{-3} year.

If we assume that the total lay-up period of the nuclear submarine in the floating state is 10 years, than the total risk of the event which may sink the nuclear submarine with the nuclear fuel on board will make 10^{-2} year ^{1}, which represents a considerably high chance

Literature

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5. INTEGRATED MONITORING SYSTEM

In this chapter we analyze the existing Russian environment monitoring system, as applicable to the nuclear submarine naval bases, including the analysis of the methods for the waste stream control This section reviews the guidelines for an integrated monitoring system for the territories of the nuclear submarine dismantlement operations

5.1. Existing environmental control system

The sites which provide for the decommissioning and dismantling of the Russian nuclear submarines are primarily located in the Northern and Far Eastern regions of the country, with a substantial amount of other sources of contamination situated in the same territories

As such, in the Northern region alone there have been estimated approximately 4,4 thousand sources of atmospheric pollution, which together with ships, other vessels and car transport produce on the annual basis up to about 578 thousand tones of hazardous elements

All the control over the surrounding environment in the regions of the Russian Federation, that including North and the Far East, is carried out on the federal, regional and institutional levels simultaneously Following the "Manual on the control over atmosphere contamination"[5] (RD 04 -1 86-89) there has been created the general governmental service to survey and control the contamination of the environment (OGSNK), with headquarters at the State Committee on Hydrometeorology of the Russian Federation (Roshydromet) A substantial number of the controlling functions thereto have been assigned to the Service of the Sanitary Supervision of the Russian Ministry of Health The territories of the enterprises and military companies are usually independently supervised by the appropriate institutions and authorities (ministerial) Tab 5 1-5 4 show the description of the parameters (substances) as analyzed in the Russian regions, as well as the data on the researches conducted in 1998 in the Kamchatka region, Archangelsk region and the North-West of Russia [5,14, 15]

Description of the parameters watched in the Russian regions

№	Name	№	Name	№	Name
1	Nitrogen dioxide	17	Xylol	33	Toluol
2	Nitric oxide	18	Manganese	34	Mercury
3	Acrolein	19	Methyl mercaptan	35	Carbohydrates
4	Ammonia	20	Arsenic	36	Carbonic oxide
5	Aniline	21	Naphthalene	37	Solid phenols
6	Phosphoric anhydrite	22	Penicillin	38	Phenol
7	Acetone	23	Hydrogen sulphide	39	Formaldehyde

№	Name	№	Name	№	Name
8	Benzol	24	Carbon bisulfide	40	Furfural
9	Airborne dust	25	Sulfur dioxide	41	Chlorine
10	Hydrogen chloride	26	Technical carbon soot	42	Chrome (VI)
11	Hydrogen cyanic	27	Isopryhil alcohol	43	Epichlorgidrin
12	Hydrogen fluoride	28	Methyl alcohol	44	Ethyl acetate
13	Dimethyl-teftalat	29	Styrene	45	Ethyl benzol
14	Caprolactam	30	Lead	46	Alkali
15	Sulphuric acid	31	Soluble sulphates		
16	Nitric acid	32	Trichloroethane		

Tab. 5.1.

Admixture concentrations in 1998 (for the Kamchatka peninsular)

Admixture description	Number of observations		
	Dep. Of hydromet. service	Sanitary control	Industrial enterprises
Airborne dust	3106	-	-
Sulfur dioxide	3623	-	-
Carbon oxide	3635	-	-
Nitrogen dioxide	3625	-	-
Nitrogen oxide	1307	-	-
Phenol	605	-	-
Formaldehyde	1988	-	-
TOTAL	**17889**	**-**	**-**

Comments. There has been no continuous analysis performed on the basis of the automated gas analyzers.

Tab. 5.2.

Admixture concentrations in 1998 (the Arkhangelsk region)

Admixture description	Number of observations		
	Dept. of hydromet. service	Sanitary control	Industrial enterprises
Airborne dust	13065	-	1437
Sulfur dioxide	11889	-	1786
Carbon oxide Airborne dust	13940 13065	- -	1013 1437

Admixture description	Number of observations		
	Dept. of hydromet. service	Sanitary control	Industrial enterprises
Nitrogen dioxide	14959	-	2468
Nitrogen oxide	2262	-	-
Hydrogen sulphide	12997	-	737
Carbon bisulfide	4806	-	-
Fenol	2859	-	-
Carbon sate	-	-	1040
Hydrocarbons	-	-	1037
Ammonium	4416	-	-
Formaldehyde	10061	-	-
Methyl mercaptan	1940	-	88
Methyl alcohol	-	-	713
Furfural	-	-	590
TOTAL	93194	-	10909

Tab. 5.3.

Admixture concentrations in 1998 (North West region)

Admixture description	Amount of surveys		
	Dept. Of hydromet. service	Sanitary control	Industrial enterprises
Airborne dust	14204	1346	1950
Sulphur dioxide	13969	-	847
Soluble sulphates	1645	-	-
Carbon oxide	14375	-	1070
Nitrogen dioxide	18643	1346	2034
Nitrogen oxide	4642	-	-
Hydrogen sulphide	2249	340	985
Carbon sulphide	1331	-	-
Phenol	2974	-	449
Hydrogen fluoride	909	707	-
Hydrogen chlorine	2866	-	199
Mercury	860	320	-
Ammonia	3998	-	-
Hydrogen chlorine	2866	-	199

Admixture description	Amount of surveys		
	Dept. Of hydromet. service	Sanitary control	Industrial enterprises
Sulphuric acid	-	710	-
Formaldehyde	2944	-	722
Benzol	3001	-	-
Xylol	3001	-	-
Toluol	3001	-	-
Ethylbenzene	3001	-	-
TOTAL	97613	4769	8256

Tab. 5.4.

It should be noted that despite a great number of the measurements taken, these measurements have not been taken in a synchronized nor automated order, the reason for this being that as of today there is no integrated monitoring system of the environment even within a single region of the Russian Federation The programs and monitoring systems that are currently being developed on the federal level, including those covering the potential nuclear and radiation threats, are far from completion and lack financing As a result the major responsibility for the control over the environmental situation in the aforementioned territories falls on the Navy, Ministry of Nuclear Energy of the Russian Federation and the Roshydromet

5.1.1. Radiation monitoring

Roshydromet currently controls (checks) the radiation in the Russian Federation at 1349 testing sites, most of which analyze gamma radiation only The radiation measurements are taken simultaneously with the standard meteorological measurements from 2 to 8 times each day, lasting 10 minutes each. The primary radiation equipment used for this purpose at Roshydromet sites is as follows DRG-01T, DBG-01H, DBG-06T и DP-5 (A,B,V) dosimeters. Right now the out-of-date dosimeters are being generally substituted by the new models of DRG-01T

Nuclear fall-out collectors (horizontal gauze platforms without sides) are located at 458 of the aforementioned sites There are no platforms with side walls or adhesive tapes currently employed at the Roshydromet sites Exposure periods of the platforms vary from 24 hours to a quarter of a month Usually in the vicinity of the potentially radiation hazardous sites this time interval makes up one day and one week The daily platforms are then packed into blocks (5 in each) and forwarded to the regional laboratory for further evaluation At the laboratories experts carry out the spectrometric gamma analysis of the received blocks to determine the volatile radio nuclides, such as iodine-131 and other If the admissible norm is not exceeded, the sample is then

each) and forwarded to the regional laboratory for further evaluation At the laboratories experts

incinerated and tested for beta radiation Five days later the measurement of the sample is repeated. In case the received value does not exceed 110 Bq/m^2 per day, it is then combined to make up the monthly sample, quarter and annual In case the specified value is exceeded, a special warning notice is telexed to the regional center The combined samples undergo spectrometric gamma analysis Strontium-90 tests are made on the basis of the combined monthly samples On the regular basis the combined monthly samples are being forwarded to the Typhoon scientific research center, which supervises all of the Roshydromet sites from the radiation-monitoring standpoint

Filter ventilation units are located at 53 sites Realistically, in order to save the electrical energy, these units operate only 12 hours each day, instead of the required continuous round-the-clock operational mode In order to evaluate the concentration of the radioactive aerosols in the atmosphere there are special vertical gauze platforms (cone-shaped) employed, however rarely actively used Exposure lasts from 24 hours to a week The filters are examined in the way similar to the platforms, as described above, with the only difference being that here the spectrometric gamma analysis, incineration and assessment of the combined beta radiation is performed on the basis of the daily filter samples The max admissible value here makes up 0,037 Bq/m^3 - if it is reached the local experts launch the radio nuclide composition analysis and send a warning notice to the regional center

Water samples and initial (concentrating) operations are usually carried out at the hydrological sections at the Roshydromet sites The samples are concentrated (combined) either through evaporation or priming a particular amount of water through sorbents or ionite exchangers As such, for assessing Strontium-90 there is required a water sample 20-40 liters of volume. Such small samples are usually concentrated through evaporation, however ionite exchanger is also employed in some cases In order to determine Cesium-137 it is essential to employ 500-2000 liters of water. Such quantities of water need to be pumped through the sorbent All the precipitation and snow are steamed The Radiochemical analysis of the sample condensations is again carried out at the Typhoon scientific research center and the appropriate regional radiation and chemical laboratories in Vladivostok, Novosibirsk and Ekaterinburgh

Soil sampling is undertaken once every several years by special mobile units formed on the basis of the regional laboratories There are usually no soil samples taken at the actual Roshydromet sites Few of such sites are equipped with special platforms for the background radiation tests and background sampling While assessing the recent contamination the soil sampling is undertaken in the sampler (special collar, 14 cm in diameter and 5 cm high) While assessing the total amount of the radio nuclides in soil, the actual soil samples are taken by the cylinder shaped sample sorter, 8 cm in diameter, which is immersed into the ground for 30 – 40

sampling is undertaken in the sampler (special collar, 14 cm in diameter and 5 cm high) While

cm, depending on the ground type Evaluation of the soil samples is undertaken in the regional laboratories in Vladivostok, Novosibirsk, Ekaterinburgh and Obninsk

All the spectrometric and most of the radiometric measurements are taken at the regional radiometric laboratories In the following cities of the Russian Federation there exist the necessary equipment and facilities for the gamma field spectral analysis: Barnaul, Bryansk, Vladivsotok, Voronezh, Ekaterinburg, Irkutsks, Kaluga, Kemerovo, Krasnoyarsk, Kursk, Moscow, Murmansk, Nizhniy Novgorod, Novosibirsk, Obninsk, Omsk, Oryol, Penza, Petrozavodsk, Pskov, Postov-on-Don, Samara, St Petersburg, Smolensk, Tver, Tomsk, Tula, Ulyanovsk, Chelyabinsk, Chita, Yakutsk. As a rule, a semi-conduct detectors are employed for these purposes At the regional laboratories after the radio chemical isolation, a special examination for Sr-90 till Y-90 is undertaken on the basis of the beta count methodology Only a limited number of laboratories have the ability to determine the radio nuclides through the alfa spectral analysis method The beta spectral analysis method to determine the beta emitting radio nuclides is unfortunately rarely practiced at the Roshydromet sites The currently practiced attempts to determine Strontium-90 without the radiochemical analysis in the Potassium-40 environment on the plastic detector result in extreme overvaluations

5.1.2. Russian Navy Environmental Control Program

As most of the sites which provide for the decommissioning and dismantling of the nuclear submarines remain within the competence of the Russian Navy, this is the particular institution that is held responsible for the control over the territories where such site are dislocated. However the capabilities and technical equipment of the existing environmental contamination control system are quite limited, and they allow to receive only a modest share of the necessary data This data is then usually used for the internal reference purposes by the very institution, which has conducted and supervised the research

Below there are described the primary objectives of the environmental control, as set forth at various fleets, companies, military units, enterprises and different institutions of the Russian Navy

- Environmental control for the results of the military related activities in the area,
- Examination of the compliance to the environmental protection code and norms at various military institutions,
- Examination of the execution of the curriculums and guidelines for the protection and enhancement of the surrounding environment,
- Control over the execution of the resolutions and instructions of the state environmental expertise,
- Examination of the fulfillment of the fixed standards, maximum doses and discharges, other
- Control over the execution of the resolutions and instructions of the state environmental waste streams and pollution sources, formation, distribution and storage of wastes;

- Checking of fulfillment of the earlier issued instructions and procedures, assigned by various governmental and military ecological control institutions

The governmental environmental monitoring is performed following the existing "Regulations on the state environmental control in the closed administrational and territorial units, secure, highly secure and classified sites of the Armed Forces of the Russian Federation and the state ecological expertise of the armament and military equipment at military sites and other military activities", approved by the Resolution of the Government of the Russian Federation № 461 of 18 05.98

The military environmental monitoring in the military units of the Russian Navy is carried out by the Office of the Chief of the environmental security of the Armed Forces of the Russian Federation, Environmental Service of the Russian Navy, the Regular Committee On The Prevention of the Harmful Environmental Implications and the officers responsible for the environmental security, signed in each military unit or company

Below there are suggested the currently primary goals for the instrumental environmental monitoring

- Determine the contamination level (physical and chemical parameters) of the air, soil, lakes and water areas as a part of the surrounding environment monitoring complex,
- Control of the discharges, emissions of the contaminants into the surrounding environment as fixed by the admissible norms
- Control of the effectiveness of fulfilling the schedules and curriculums for the protection of the surrounding environment, following the existing environmental regulations

Instrumental environmental monitoring is usually carried out on the basis of the standard equipment by the environmental officer, as well as on the basis of the mobile and stationary laboratories of various environmental services of the Armed Forces of the Russian Federation

The document and instrumental environmental monitoring supervisions are carried out by the Environmental service of the Russian Navy

As a mandatory requirement for the instrumental environmental control it is assumed that the employed equipment has undergone all the necessary governmental testing and has been officially accepted by the appropriate authorities or the Committee on Norms and Standards of The Russian Federation The appropriate procedures and manuals have to undergo a special examination with the appropriate metrological authorities, before they are distributed and adopted on the local basis

5.1.3. Allowable discharge levels in the Russian Federation

The maximum allowable values of the hazardous substances and the list of the hazardous substances which can not be discharged within the economic territory of the Russian Federation, both have been adopted for the regular operational mode of ships, other naval vessels, aircrafts,

The maximum allowable values of the hazardous substances and the list of the hazardous

artificial islands, facilities and units through various federal Resolutions of the Government of the Russian Federation. The categories of such hazardous elements are described following the standards of the International Convention on prevention of the sea contamination from naval vessels 73/78 Depending on the environmental implications of such elements they are split into several major categories, i e A, B, C, D

Category A – hazardous liquid elements, which present a considerable danger for human health and living species of the sea, the discharge of which is therefore strictly prevented,

Category B – hazardous liquid elements, which when discharged into sea present a particular amount of danger for the human health and living animals of the sea and therefore require certain measures to be taken to prevent the inadmissible pollution of the latter;

Category C – hazardous liquid elements, which when discharged into sea present minor danger for the human health and living animals and therefore are to be handled in a designated manner,

Category D – hazardous liquid elements, which when discharged into sea present little danger for the human health and living animals of the sea and therefore require particular precautions when such a discharge occurs.

Tab 5 5 shows the extreme admissible concentrations of the hazardous substances which can be discharged with the economic zone of the Russian Federation

Following the Resolution of the Government of the Russian Federation № 251 of 24 03.2000 Category A hazardous elements can not be discharged with the economic zone of the Russian Federation.

The rules for the development and approval of the admissible concentration norms and admissible values for water areas and the surrounding natural environment within the Russian Federation were approved by the Resolution of the Government of the Russian Federation № 208 of 10. 03 2000

Admissible concentrations of hazardous substances for the discharge within the economic zone of the Russian Federation

Hazardous category	Admissible concentrations per each discharge (mlg/l)	
	Outside designated areas	In designated areas
Category B	1.0	1.0
Category C	10.0	1.0
Category D	1 unit of substance for 10 water units	
Oil and oil products	15,0	15.0

Tab 5.5

Oil and oil products 15.0 15.0

The maximum values of the hazardous substances in the working area air and the consumable water reservoirs, as well as for the air in civilian and other settlements are fixed in the Official Standards Act of the Russian Federation № 12 1 005-88, under the title of "General sanitary and hygiene requirements for the air in working areas".

The amount of hazardous substances in the air of the working area and the water of the consumable water and other public access lakes, as well as the air of the public territories, must under no circumstances exceed the maximum values

Al list of parameters for sanitary evaluation water and atmospheric environment in the working zones is shown in the section 3 7

5.1.4 Control of radioactive contamination.

The periodical control of the contamination sources and waste streams is carried out in the course of the standard environmental inventory and control of the admissible discharges at the sites and facilities of the Russian Navy

All the activities for the control of the radioactive contamination are described in the existing "Manual for the control over the radioactive contamination of the environment and the irradiation of the over the radioactive contamination of the environment and the irradiation of the personnel on board of the nuclear naval vessels "

The control volume over the radioactive pollution of environment is presented in tab 5 6

Volumes of monitoring over radioactive pollution of environment

Object of monitoring	Spot of the monitoring	Periodicity	Parameter monitored
Sea Water	At ship-yards	Once a day	Volumetric activity of the sum of artificial beta radiation nuclids
	At ship yards of service vesels		
	At the exits of sewage		
	In the region of radiation works conduction	Not less than once a day At the suspicion of the nuclids penetration, straight away	Volumetric activity of the sum of artificial beta radiation nuclids at its exceeding 100 times gamma analysis is conducted At the exceeding of the v/ activity of Cesium-137 radiochemical analysis of Strontium-90 is conducted
Sea algae, bottom sediments	In the area of sea water pollution and radiation works conduction	When the sea water pollution above the admissable concentration	Volumetric activity of the sum of artificial beta radiation nuclids Gamma spectrum analysis At the exceeding of the v/ activity of Cesium-137 radiochemical analysis of Strontium-90 is conducted
Sea fish	In the polluted area	At constant pollution	Specific activity of the sum of artificial beta radiation radionuclids in catable and non-catable parts Gamma spectrum analysis At the exceeding of the v/ activity of Cesium-137 for drinking water radiochemical analysis of Strontium-90 is conducted
Aerosol	At parking places of the vessels with nuclear reactors	Once a day	Volumetric activity of the sum of artificial beta radiation nuclids Gamma spectrum analysis At the exceeding of the v/ activity of Cesium-137 radiochemical analysis of Strontium-90 is conducted
	In the area of radiation works conduction		Volumetric activity of the sum of artificial beta radiation nuclids Gamma spectrum analysis At the exceeding of the v/ activity of Cesium-137 radiochemical analysis of Strontium-90 is conducted

Object of monitoring	Spot of the monitoring	Periodicity	Parameter monitored
Atmospheric(precipitations)	At parking places of the vessels with nuclear reactors	Once a week	Volumetric activity of the sum of artificial beta radiation nuclids Gamma spectrum analysis
	In sanitary-protective zone		
	In the area of radiation works conduction	Once a day	
Surfaces	Technical territory	Not less than once a week	Rate of gamma radiation dose
	Military towns	Once a month	
	In the area of radiation works conduction - in sanitary units, - on the roads and pedestrian lanesna	Not less than once a day	Pollution levels with the help of smear methods Gamma spectrum analysis from the maximal square
Soil, vegetation	In the area of radiation works conduction	at the suspicion of pollution	Volumetric activity of the sum of artificial beta radiation nuclids
Drinking water	From water pipes	Once a month at the suspicion of pollution	Volumetric activity of the sum of artificial beta radiation nuclids Gamma spectrum analysis At the exceeding of the v/ activity of Cesium-137 radiochemical analysis of Strontium-90 is conducted
Staff, population	According to the special plan	Once a year	Effective radiation dose

Tab. 5.6.

The control over the radioactive contamination is usually done by means of portable radiation assessment sets, radiometric and spectrometric equipment, as well as by means of the stationary automated control systems

As a good illustration of such a system is the Peanut (Orakhis) multi channel radiometric unit for the control over the radioactive contamination (for water areas) This system is used for the control over the dose and its capacity in the water areas, it can automatically collect large samples of air and water, followed by the specific weighting procedure of the radio nuclides in the samples

As the Russian Navy does not have the complete listings of its laboratory equipment, which as a rule is represented by some most outdated units Moreover, the list of parameters to be watched in the appropriate Naval curriculum of "Manual for the control over the radioactive contamination of the environment and the irradiation of the over the radioactive contamination of the environment and the irradiation of the personnel on board of the nuclear naval vessels" represents merely a set of recommendations This is why the issue of developing a unified integral environmental monitoring system becomes especially essential by the day

Moreover, such system is particularly crucial to secure the environmental safety of the nuclear submarine lay-up and dismantlement sites, so as to provide the data on the particular territories where these procedures are carried

The reasons for including these sites as a particular indispensable component of the monitoring system are as follows.

- The ecosystems of the Northern and Far Eastern regions are particularly sensitive to anthropogenic burdens,
- The environment of the specified regions is particularly contaminated and polluted,
- For the surrounding environment the nuclear submarine dismantlement sites represent potential radiation and chemical hazards,
- Such sites represent a potential threat of emergencies and accidents, resulting with the environmental discharge of various hazardous elements with severe negative implications for the personnel, maintenance crews, public and ecosystems of such regions,
- To a substantial degree the environmental security of such regions and the nuclear submarine dismantlement, lay-up and dismantlement procedures depend on a number of hydro meteorological, climatic and other geophysical parameters of these territories,
- Establishing of a system to watch and assess the particular parameters to represent the condition of the surrounding environment and the implications of the nuclear submarine dismantlement operations for the latter is possible in principal and physically feasible

At this point it is essential to broaden and intensify the current measures of controlling the contamination of the surrounding environment, as well as achieve some of the new objectives, such as set up watch and control procedures on the basis of the automated stationary and mobile units, undertake mapping, environmental change forecasting, classification of the

the contamination of the surrounding environment, as well as achieve some of the new

contamination sources by their association with various activities of the Navy or industrial enterprises, global changes or natural calamities, etc All of these operations will allow to produce an entire (integral) picture of the environmental situation at the various submarine lay-up and dismantlement sites, adjacent water and land territories, maintenance areas, as well as the prospects for the future Such a system will secure a timely and continuous flow of sufficient data through a system of regular measurements, tests and samplings

5.2. Environmental control methods

At this point the environmental analysis in this country is carried out on the basis of the 4 major tracking methods land, water, aircraft and space, which are reviewed below

The initial data as acquired as a result of the environmental monitoring operations must specifically identify

- The type and concentration level of the contaminants and waste streams in atmosphere, hydrosphere and lithosphere;
- Contamination sources and discharge parameters,
- The physical state of the atmosphere, hydrosphere and lithosphere.

Following the land (water) tracking method the initial data is acquired through both stationary and mobile control and testing units Due to the specific features of the data acquisition procedures for these methods this data is local in nature This drawback is usually eliminated through the lengthy aerospace tracking methods

5.2.1. Land methods

The land methods allow for conducting the assessment of the parameters of all types of contamination of the air over the land, soil, certain types of water surface pollutions, as well as to carry out the analysis of the chemical, biological and radiation contamination of the water samples

In general, the land tracking methods are further broken down into several major types: discrete, mobile and remote

A substantial number of assessment procedures currently employed, are based on the contact type of the land tracking method, as it has traditionally developed in the Russian Federation Following the adopted practice these procedures can be either continuous and are performed by various automated systems in two stages· on-site sampling and analysis of the samples in the stationary laboratories, including calibrating. statistics control and assessment, etc The contact type of the land tracking method allows us to obtain environmental data in specific points of space when the stationary equipment is used, and the data following specific

etc The contact type of the land tracking method allows us to obtain environmental data in

routes (waste streams, etc) when the measurement instrumentation is placed on mobile units or carried as in the portable equipment sets.

Mobile methods allow to obtain the integral characteristics of the particular contamination parameters along particular directions, while the remote type methods enable us to acquire the environmental data in the areas distant from the actual sampling sites The visual control over the air, water and specific area contamination can in principal also qualify as the distant type of the land tracking method

In order to acquire the data on the quality and quantity of the contaminants and waste streams there are over 200 original physical and chemical techniques available, which determine the concentrations of the hazardous elements in the air, sewage and natural water, industrial facilities and territories All the major ones are described in Figure 5 7 [7]

In order to assess the parameters of chemical contamination, the aforementioned types of land methods are most widely employed, all complying to the official Russian state standard documentation [8].

Methods of pollutants analysis

Ametnalysis method	Sample	Equipment	Relative selectiveness	Duration,hour	Sensitivity	Accuracy of the analysis, %	Notes
netry Gravemetry	S L - G	Standard laboratory	Good	1 2	0,1 - 1 gr 10 m/kg	0 005 - 0 01 0 1 m/kg	Main components
tion Titration	S - L - G	Same	Same	0 25 -0 5	10^{7} m/l 10^{3} m/l10^{6} - 10^{7} m/l	0 01 0 1 0 2-1 0	Main and semi micro components
Spiompectrophotometry	S - G	spectrophotometerp	Satisfactory	05-1 07	10^{3} - 10^{7} 5'10^{7} - 10^{5}	1 - 5 5 -10(0 1)	semi micro components (metal traces)
Ul spectra violet spectrum ry metry	S - L - G	spectrophotometer	Satisfactory	0 5 - 1 0	10^{3} - 10^{7} 5'10^{7} - 10^{5}	1 - 5 5 -10(0 1)	semi micro and micro components for organic compositions
Plssidisma emission of metr spectrometry	S - L	Plasma photometer and spectrometer	Good	0 25 - 0 5	10^{2}- 10^{3} 10^{7} - 10^{5}	0 5 - 3 5 - 10	micro components for acid and some transitional metal
Asorltomic absorbent rmetspectrum metry	S L	AA Spectro-photometer	Excellent	0 25 0 5	10^{2}- 10^{3} 10^{7} - 10^{5}	0 5 - 3 5 - 10	micro components for some transitional metal and some semi-metals
Gatogns chromatography	L G	Gas chromatograph	Excellent	0 25 - 0 5	Main component 1 2 0 1-1 10^{3}- 10^{3} 10^{3}	0 1 0 2-0 5 0 5-0 1 5 10 10	From main up to micro components organic and metal-organic compositions
Volmetr|t amper metry with celin anode peeling	I	Impulse polarograph of the constant current	Good	0 25 - 0 5	10^{1}-10 2 10^{5} 10^{3} 10^{7}	1-2 3 5	micro components (metal traces) Ag Bl, Cd, Fe In, Pb, Sb, Sn Zn
Spirmpectroflourimetry	S-L	Registering spectroflourimeter	Same	0 25-0 5	10^{7}-10^{3}	0 5-10	Micro components for organic and non-organic admixtures

Ameinalysis method	Sample	Equipment	Relative selectiveness	Duration,hour	Sensitivity	Accuracy of the analysis, %.	Notes
Rduroeentgen fluorescent meti spectrometry	S-L	RF-SPECTROMETER	Same	0 25-0 5	10^{3}-$2 \cdot 10^{2}$	1-2	Semi micro components for elements in soils
nd Liquid ograpchromatography	S-L	Liquid chromotograph	Good	0 5-1	$10^{7}10^{4}$	2-20	micro components mainly for organic substances
graph Polarography	L	Multi-functional polarograph	Same	0 25-0 5	10^{-3}-10^{2}	1 2	Micro components for organic and non-organic substances and many elements
analInfrared analysis	S-G L	Infrared spectrometer	Satisfatory	0 5-2 0	Main component	5	Main and micro components gases, organic substances
iolog Microbiology	S L	Microbiological equipment	Same	1-2	10^{3}-10^{2} 10^{7}-10^{4}	5-10 20	micro components (metal traces)

: -w Note -with the use of accurate methods S- solid, L-liquid, G-gaseous samples

'ese At present methods for the definition of the low concentrations of the toxic chemical substances in the air for 400 substances have belopeen developed and certified in Russia and USA

Tab. 5.7.

Table 5 8 specifically shows the capacities of certain particular techniques of the discrete method in the land tracking procedures While the independent means of the discrete control of the chemical pollution in the air are being further researched and developed, a particular emphasis has been recently placed on the complex automated multipurpose systems, with the ANKOS-AG unit [7] serving as one of the finest example of such installations This system has been particularly developed to provide continuous control over the fluctuating concentrations of chemical admixtures in the air basins of large cities and industrial centers, as well as for the most operative forecasting of the future contamination of such territories

The quantities of the minimal spotted concentration for different contact analytical methods for average time for analysis –20 min.

Analysis method	Threshold of spotting gr/m^3	Sphere of application
UF Spectrometry	10^{5}	All kinds of substances in gaseous phase
IK Spectrometry	10 [illegible]	
Atomic absorption	10^{-6}	Metals in aerosol
Mass- Spectrometry	10^{7}	All kinds of substances in gaseous form
Luminiscent spectrum analysis	10^{5}	Organic substances
Emission spectrometry	10^{-5}	Metals in aerosol
Polarography	10^{-4}	Metals in aerosol
Gaseous chromatography	10^{7}-10^{10}	All kinds of substances in gaseous phase
Chrome- Mass- Spectrometry	10^{-}	All kinds of substances in gaseous phase
Roentgen –flouriscent spectrometry	10^{7}	Metals in aerosol

Tab. 5.8.

The ANKOS-AG installation has two built-in assessment levels In the first (lower) level the system measures the concentrations of the contaminant substances and determines the quantities of each, converts them into the physical values, registers them in machine codes, organizes the data, stores it and forwards to the second (upper) level of the Data Processing Center (DPC) for further elaboration and treatment

The first level of the aforementioned system usually employs automated stations of the atmosphere control (ASKZA - G), which supply the second level with the appropriate data The second level also receives additional data from the mobile working groups and stationary gas analysis laboratory The data is here processed so as to allow the implementation of the practical tasks of contamination monitoring, forecasting, print-outs, data storage and forwarding to the end users

tasks of contamination monitoring, forecasting, print-outs, data storage and forwarding to the end

The second level basically represents an information-calculating complex system, which includes displaying options, data transferal, communication, registration, copying and other capabilities

The mobile type of type of the land tracking method allows fro the assessment of the concentration of the studied admixture, which is averaged both pertaining the wind direction and time, as well as the length of the optical line, which altogether result in the much more accurate data to describe the actual situation in the assessment points (even more precise, as fixing a particular boundary narrows down the assessed territory)

The remote type of the land assessment method allows to both evaluate the admixture concentration profile along the zoning line (inclined, horizontal or vertical) with the aide of a lidar or studying the self-radiation spectrum of the admixture, as well as to assess the general gas concentration in the air column (average concentration for the evenly distributed gases) on the basis of the spectral sun method

The land methods of the environmental (chemical and biological) control are currently based on the chemical and physical assessment of the samples by means of the "wet" chemistry techniques and a substantial number of the laboratory equipment and devices.

Today in order to conduct the control over the particular parameters determining the water quality, which vary in time and space, the ANKOS-W automated water watch and control system is most widely used in the Russian Federation This system can easily determine the contamination, waste streams and source of the water contamination, forward the acquired data to the data processing centers, where all the data is analyzed, systemized and qualified to determine the most dangerous trends and potential hazards Such an approach allows to timely take the necessary measures to protect the water areas, especially in the case of large discharges and emergency situations

Initially the ANKOS-W data originates at water surface control automated machines (AS KPV1) The contemporary model of each such machine can today measure and control over two dozens of water quality parameters, e g level, temperature, electro conductivity, turbidity, oxygen, weighted substances, carbon ions, its acidity and alkalinity

The land methods of the environmental control of soil are based on the soil samples analysis and their further assessment in laboratories

Among the remote types of the water control method there can be particularly singled out the visual technique of identifying the mechanical and oil contaminations, as well as the radiolocation technique (on the basis of both the horizon and over-horizon radiolocation stations). It should be noted that the informational value of both methods is quite low, as the radiolocation method only allows to identify the territory covered by the oil spill, but does not

radiolocation technique (on the basis of both the horizon and over-horizon radiolocation

provide the data on the thickness of the oil slick, which as a result does not allow to asses the volume of the spilled oil

The methods of the radiation environmental control (atmosphere, water, soil), as well as the analysis of the food stuffs and the objects in the public households are based on the registration of various radioactive radiations, neutrons, heavy ions, nuclear fission debris by means of a large spectrum of radiation control equipment, radiometers and nuclear physics equipment (alfa, beta and gamma spectrometers, neutron and heavy particle registration equipment, etc) All the issues of both the radiation control and radiation safety of the personnel and public access territories today have to fully meet the NRB-99 [12] and OSPORB-99 requirements [13]

Below, on the basis of the referenced materials [7,14], there is suggested the analysis of the current capacities of the existing, potential and widely used (that including military units) land portable, stationary, laboratory and distant types of the environmental radiation control units

The widely used IMD-1 dosage rate measuring instrument (as well as all models developed on its base) is intended for measuring the power of the equivalent dose of the territory as well as to determine the radioactive contamination of the personnel local population, food stuffs, water technical equipment – on the basis of the gamma radiation rates (plus beta radiation within the ~ 30% error margin).

To detect the radiation rates within the automated radiation watch system there can be used the multipurpose radiometric device or stationary semiconductor spectrometric installations with the autonomous power supply

The major technical characteristics of some of the devices for the radiation control are shown in Figure 5 9 (see after the list of literature)

Radiation control devices and their main technical data

Device	Type	Registered radiation	Range of the measured energies, MeV	Measurement limits	Power supply	Weight in kg
Microroentgenmeter						
medical	MPM-2	roentgen	0 025-3	0 01-30 μR/s	mains	4 0
pocket	PK-0 1	γ	0 2-3	0 08-1000 μR/s	battery	0 650
portable	Sputnik"	γ	-	-	same	1 5
Gammaradiometer			0 2-3	10-3000 μR/h		1 5
pocket	"Signal"	γ β	5 and higher	-	battery	0 45
portable			0 2-3			
gamma-dosemeter						
Roentgenmeter of high	"Cristal"	γ	0 05 and higher	0 10-3000 μR/h	battery	10 0
precision	"Svet			10-2500 μR/h	same	2 5
	'Kura'	γ	0 03-3	0 01-1000 μR/h		2 5
	PP-1	for checking of the equipment measuring the rate of roentgen or γ radiation	0 06-2 5	0 1-100 μR/s	mains	9 5
Universal radiometer						
	RUP-1	Heat neutrons Fast neutrons	0 025 eV	150-10^5 neutron/(cm ^{2} s)	battery	3
scintillating dosemeter		Registration of the continuous and impulse roentgen and γ-radiation	0 5-14 0	30-10^5 neutron/(cm ^{3})		
	Drgz 2 ("ARAX")		0 2-2 0	0 3-1000 μR/s		
			0 015-3	0 02-100 μR/s		
Neutron dosemeter						
	"Media"	heat neutrons interim neutrons	0 025 eV	1 10^3-4 10^9 neutron /(cm ^{2} s)	mains	
Radiometer universal scintillating			-	1 10^5-1 10^9 neutron /(cm^2 s)		
	RUS-5	γ β	0 5-14	-		

	Device	Type	Registered radiation	Range of the measured energies, MeV	Measurement limits	Power supply	Weight in kg
				0 1-2	0 3-1500 (cm^2 s)	battery	
			heat neutrons	0 1 and higher	1500-7500 imp/(150	same	
			interim		cm^2 s)		
				0 025 eV	150-7500 /(cm^2 c)		
bar	Wide band dosemeter of		fast		150-7500 neutron		
ons	neutrons			1 keV	/(cm^2 s)		
			neutrons of wide		150-7500 neutron		
ome	Radiometer		spectrum		/(cm^2 s)		
		DN-1			-		
				-		battery or mains	
al-m	Signal-measuring		the same				
mete	dosemeter unit	REB-0 1	-"		30-600 particles	-	
nger	Roentgenmeter		"-"	0 5 and higher	(cm^2 min)		
		REB -0 2			-	-	
		USID-0 3	-"	0 1	0 1-3000 μR/s	mains	
				0 1-3	0 1-1000 μR/s	mains	
				0 1-3		same	
		Kaktour'			0 1-30000 μR/s		
				0 1 3			

Tab. 5 9.

Analysis shows that the technical parameters of the existing and developed means of the radiation survey, watch and control do indeed allow for their employment for the radiological assessment at the sites particularly targeted in this feasibility study However, it will be necessary to additionally provide for the low-background radiometric installations, spectrometric analyzers, which allow to determine the radio isotope composition of the contaminants and evaluate the potential radioactive elements to be discharged into the surrounding environment

The careful analysis of the existing equipment and facilities, as well as the existing methodology for the acquisition of the environmental data, show that if the environmental monitoring system is constructed on their base, it will effectively allow to acquire the principal environmental data, covering the issues of the air contamination over land and water territories (if the prior sampling mechanisms are in place) by various contaminants and waste streams, as well as carry out the accurate radiation control of various sites Of all land method types as described above the contact techniques appear to be most informative and accurate, as they allow to determine the actual state of environment on-site In order to cover greater areas the environmental monitoring has to be aided by various aircraft and space means In order to provide for the automated control of the environmental parameters of the sea areas and bottom sediments, as well as the over-sea air, it is essential to aid the monitoring system with the special marine vessels and equipment

5.2.2. Marine methods and means of ecological data obtaining

The naval (marine) methods and means of acquiring the environmental data currently allow to measure all types of pollutants and contaminants of the seas, as well as lakes and rivers, bottom beds, atmosphere over vast sea territories, as well as surface pollution of the water areas

In general, all the marine equipment can be broken down into two types stationary (as placed permanently or for some time at the specific points in water areas) and the naval vessels

As a rule the stationary equipment represents automated naval buoy-based stations with a number of sensors for the continuous programmed automated measuring of the environmental and hydro meteorological parameters to be then transmitted via cable, radio or acoustic channels to the on-shore or other naval facilities for analysis

As to the naval vessels, the environmental monitoring is performed on the basis of the vessels (boats), which may be supplemented by the following optional equipment

- Underkeel or towed systems with an array of sensors for the measurement of the environmental parameters of sea water and for conducting the appropriate oceanographic measurements,
- Measurement equipment (anchored or drift) to be lowered from the board of the boat,
- Automated sensors for control over the air contamination,
- Water, bottom beds and atmosphere sampling equipment,

- Measurement equipment (anchored or drift) to be lowered from the board of the boat,

- Physics and chemical environmental laboratories for sampling and identification of the contamination parameters,
- Remote means of searching and identifying the surface contaminations of the water areas

Stationary marine equipment and vessels allow to conduct the environmental analysis both locally and at specifically designated points The acquired signal represents an average value over a certain period of time for certain territories (of any shape or size) along the direction of the sea currents Such analysis gives a pretty accurate picture of the water contamination of the studied water areas, with the only restraints on such assessment being the meteorological conditions and the bottom contour in the shallow water areas

While the ship is sailing, the naval environmental equipment on its board allows to identify the environmental picture along its route, as well as to undertake the area survey in the case of a more detailed study of the particular water areas

The naval means and methodology of assessing the environmental parameters of the atmosphere, as well as the lab tests of the air, bottom sediments and water are very similar to the aforementioned land methods and equipment, though certain automated equipment has been constructed specifically for the use on board of the naval vessels

For the environmental monitoring of the sea environment the hydro acoustic means can be principally used for the following purposes.

- Monitoring of the acoustic contamination of the water areas,
- Search, detection, determination and identification of the sunk naval vessels, which present potential threat to the surrounding environment,
- Control over the volume and development of the waste streams,
- Control over the migrations of the phyto- and zooplankton

The visual and radiolocation methods of detecting and evaluating the scope of the oil contaminations are still very actively used

5.2.3. Aerospace methods.

The usage of the aerospace means and methods for environmental purposes increases the visibility, efficiency and scale of the environmental data acquisition process, as such methods considerably expand the capabilities of the land and sea methods as described in the above by defining the development of the contaminants in time and space for the atmosphere, water and land alike However the environmental data acquired this way is less accurate and informative, which necessitates its usage only when combined with the data accumulated by means of the land and sea methods of environmental control and assessment

5.3. Establishing an integrated monitoring system

The problem of creating an integrated monitoring system, which stands for the system of the regulated observations and surveys of the surrounding environment, natural resources, anthropogenic environmental implications, assessment, analysis and forecasting of the environmental situation in the nuclear submarine dismantlement sites represents a major task for the originators of this feasibility study Such a system must be developed and launched simultaneously with the establishment of the system of control and survey of the dismantlement operations of the nuclear submarines The main objective for setting up the integrated monitoring system is to prevent hazardous and dangerous situations, which may potentially harm human health and other biological sites and objects, as well as support the development of the executive decisions in the field of environmental security

An integrated monitoring system is to consist of two major functional modules. the system for the collection of the environmental and other data, and the environmental information and analysis center (data processing).

The results of the analysis of the tasks for the integrated monitoring system for the territories of the decommissioning, lay-up and utilization of the nuclear submarines have allowed the originators of this feasibility study to identify the following primary guidelines for the construction and maintenance of the informational infrastructure of the suggested monitoring system.

1. Integrated monitoring system has to be created following the conceptual thesis of unified informational space of the Russian Federation
2. It should be designed as an automated mechanism, with most of its operational tasks preferably carried out in the automatic mode
3. Integrated monitoring system has to be compatible with other territorial automated informational databases and systems, which govern the usage of the natural resources and provide for the environmental security of the appropriate territories
4. In designing and creating of the integrated monitoring system all work needs to be based on the contemporary information technologies
5. It is essential to provide for the effective implementation of the up-to-date technologies of local area networks management and hypertext markup language databases, geo-informational technologies, etc

To provide for the mutual exchange of information, the integrated monitoring system must be horizontally compatible (on both informational and possibly technical levels) with the appropriate territorial systems of other state and ministerial institutions (Unified State Automated System of Radiation Control, Unified State Automated System of Environmental Monitoring, Ministry for Emergency Situations of the Russian Federation, Ministry for Nature of Russia, Sanitary and Epidemiological Supervision Committee of Russia, etc.).

System of Radiation Control, Unified State Automated System of Environmental Monitoring,

The IT basis for this system must be compiled on the geo-informational technology, represented by various software and hardware data processing units to store and process information on various territories and coordinates, interpretation of such data should be available in the format of cartographic imaging by means of machine graphics

Creating an integrated monitoring system of the surrounding environment for the territories where the decommissioning, lay-up and dismantlement procedures for the nuclear submarines occur calls for the resolution of a great number of organizational and technical issues and the substantial research activities, such as

1 Evaluation of the existing and developed radiation control projects at the military installations (in the framework of the EGASKRO Federal program), which operate in the environment of radioactive wastes and used nuclear materials, as resultant from the utilization of the Russian nuclear submarines

2 Evaluation of all works performed in the field of environmental monitoring systems on the territories adjacent to the sites, where dismantlement of the Russian nuclear submarines occurs in the North West and Far East regions of this country (in the framework of the EGSAM Federal program). Review of the existing models and suggestions for the new forecasting models for the calculation and prognosis of the environmental situations in emergencies for various contamination scenarios

3 Analysis and assessment of the implementation of the normative standards and other legislature of the Russian Federation, as well as international agreements pertaining the monitoring of contamination in the North West and Far East of Russia

4. The scientific and technical foundation for the basics and parameters of the informational system of the environmental monitoring for the territories, as adjacent to the sites, where dismantlement of the Russian nuclear submarines occurs in the North West and Far East of this country (in the framework of the EGSAM Federal program)

5 Definition of the main criteria for the integral system of environmental monitoring on the basis of the following research activities·

5 1 Specific features and inventory of the hazardous danger sources, classification of the latter and ranging by the degree of the existing/potential threats,

5 2 Formulating of the general objectives for the contamination monitoring

- In the standard operational mode within the fully controlled zone (with defining the criteria of the "normal environment" following the existing legislature and technical methodology of the national, institutional and international significance),
- In the emergency operational mode (with the introduction of the classification for the various states of emergency by their potential danger, to enable a more efficient approach towards identification, scenario evaluation and forecasting),

5 3. Definition of the standard parameters and types of contamination for the purposes of the environmental monitoring

- By the extent of control,
- By periodicity,
- By the range of measurements and (or) identification

- By periodicity,

5.4. Definition of the general requirements for the integrated system of environmental monitoring·

- Methodological basis for the wired-in check of the surrounding environment, as well as the radiation and chemical implications of the nuclear submarine dismantlement sites,
- Guidelines for an integrated monitoring system set-up and maintenance (integration of stations and analytical control laboratories, information and analysis centers for *data processing, environmental security centers, etc) for various geographic,* geological and environmental conditions in the Russian regions,
- Main functions,
- Principles of identifying the priority territories for the initial installation of the integrated monitoring system,
- General structure and content of the system,
- Maintenance crews requirements,
- Metrological securing (with the evaluation of the feasibility of the metrological securing with the help of methods and means, as currently employed by the Ministry of Defense of the Russian federation, as well as the reasons for the periodicity and extent of the environmental monitoring control parameters);
- Main operational modes,
- Compatibility requirements,
- Noise immunity and noise-proof feature

5 5 Definition of the main technical requirements for the instrument channels of the environmental monitoring system,

- Measuring ranges for the controlled parameters,
- Control periodicity and time characteristics,
- Unification and feasibility of integrating of the environmental monitoring system in EGSAM, EGASKRO and other systems,
- Reliability;
- External penetration and unsanctioned access prevention/control measures.

5 6 Definition of the requirements for the mathematic and informational provisions for the environmental monitoring system to resolve the tasks of identification, assessment and prognosis of the situation, including suggestions for the executive decisions and control scenario (efficient reacting and information analysis in the emergency conditions). Determination of the necessity, feasibility and algorithms of informational interaction with EGSAM, EGASKRO and other systems

5 7 Data exchange protocols on the basis of the existing and designed communication systems and military unit management guidelines Technical and organizational principles for the transferal of the information bulks between various military companies and units, which provide for the environmental security of the Russian Ministry of Defense Information exchange and integration methods with the EGSAM and EGASKRO federal systems

5 8 Suggestions on the modification and adaptation of the specialized geo-informational system and modeling block on the basis of the Russian Navy workstations for

Ministry of Defense Information exchange and integration methods with the EGSAM and EGASKRO federal systems

environmental monitoring of the contaminants Methods of preparing the basic cartographic and attribute information on the nuclear submarine dismantlement sites

5 9 Evaluation of the existing radiation control means and their feasibility in the designed system of environmental monitoring

5 10 Evaluation and suggestions for modifications and adaptation of the existing automated control systems to make up the basis for the environmental monitoring system

5 11 Suggestions on the structure of the information and calculation system of environmental monitoring for the territories, as adjacent to the nuclear submarine dismantlement sites, propositions on the data channeling, specialized geo-informational system, monitoring data displaying system, basic radiological and chemical models block for the prognosis of the environmental situation

5 12. Evaluation of efficiency of the suggested integrated monitoring system components, including mathematic guidelines and software

5 13. Suggestions on the list of the primary legislature of the state, institutional and international levels, which specifically define the monitoring systems for the sites as related to the utilization of the decommissioned Russian nuclear submarines in the North West and Far East of Russia

5 14 Suggestions for a network of technical crisis centers, all within the competence of the Russian Navy

5 15 easibility study of the current status and potential development of the environmental monitoring system at the nuclear submarine dismantlement sites, its role within the general task of securing the entire system of nuclear submarine dismantlement operations

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6. RUSSIAN RISK ASSESSMENT METHODOLOGY

The problem of risk assessment is discussed her along with its methodological legal aspects A special attention was paid to the questions of the radiological risk It has been pointed out that risk assessment methodology of the decommissioned nuclear submarines requires perfection according to the generally accepted approaches and guidelines

6.1. General guidelines

According to the Russia Law "On safety" [1], "safety"- is the state of protectability of vital interests of a personality, society and country from internal and external threats Vital interests- a total of requirements , the satisfaction of which secures the existence and possibility of the progressive development of a personality, society and country The "safety" is achieved by realization of a unified state policy on security provision via the measures of economic, political, organizational character which are adequate to the threats for the vital interest of a personality, society and country

For creation and maintenance of the necessary level of protection at facilities in the Russian Federation there is being developed a system of legal norms which regulate relations in the field of security and defined the principal activities for public authorities, formed or transformed security authorities and mechanisms of control over their activity

The assessment and declaration of the safety of a Russian industrial facilitie , the activity of which is connected with higher danger of production, is conducted in accordance with the Russian Law "On industrial safety of hazardous production objects" [2] aiming to ensure control over safety measures observation , to assess the adequacy and efficiency of the measures on emergency situation prevention and liquidation at an industrial object

The declaration of an industrial facility safety is a document which defines the possible character and scale of emergency situations at an industrial facility as well as the activities on their prevention and liquidation The declaration must characterized the facility safety at the stages of its putting into operation, operation and withdrawal and must contain

- risk analysis of emergency situations of natural and man-caused character, including the definition of hazard sources, the evaluation of the situation development and possible consequences of the emergency situations (incl pollutants penetration into the atmosphere),
- characteristic of the control system over the safety of the industrial production , the data on the volumes and content of organizational, technical activities on emergency situation prevention ,

It should be noted that in accordance with the decree of the President of the Russian Federation from 2 August 1999 N53 which confirmed the status of the Ministry of Emergency Situation (MES) MES is responsible for

It should be noted that in accordance with the decree of the President of the Russian

- development of the proposals on the formation of a unified state policy in the field of radiation catastrophes prevention,
- development of the legislations and normative documents in the field of radiation catastrophes prevention,
- development and realization of the federal destination programs in the field of radiation catastrophes prevention;
- the conduction of the methodological guidance over the activities of the Federal authorities, Executive authorities as well as organizations. concerning the questions of the protection of citizens who suffered from radiation catastrophes , the rehabilitation of the territories and control over the activities in this field,
- organization (along with the corresponding Executive authorities) of the design of the concepts and proposals concerning the routines of the nature protection,
- conduction of the international cooperation in the field of radiation catastrophes prevention

In 1995 The State Duma passed the law "On radiation safety of the population" [33 stipulating the legal foundations of the radiation safety provision for the population with the aim of its health protection According to this law the assessment of the radiation safety is made via the following main indicators:

- characteristic of the radioactive pollution of the environment,
- analysis of the provision of activities on radiation safety and execution of the norms, rules and hygienic standards in the field of radiation safety,
- probability of the radiation catastrophes and their scale,
- the level of readiness to the effective liquidation of the radiation catastrophes and their consequences,
- analysis of the radiation doses received by a select group of population from all sources ionizing radiation
- number of persons exposed to the radiation of higher than admissible doses

The law [3] sets the following principal hygienic standards (admissible doses) for the population of the Russian Federation

- averaged annual effective dose is 0 001 Sievert (Sv) or an effective life time dose (70 years)- 0 07 Sv
- higher dose indicators for separate years are admissible provided that averaged annual effective dose, calculated for 5 consecutive years does not exceed 0 001 Sv

After the publication of the radiation norms in 1987 (RSN-76/87 radiation safety norms) and main sanitary rules (MSR-72/87 for working with radioactive substances and other sources ionizing radiation) the new data on the impact of ionizing radiation on human organism was received and additional experience was accumulated on the conduction of the radiation control and efficiency of protective measures in corresponding institutions and environment, including the experience of the liquidation of the consequences of catastrophe at the Chernobyl Nuclear Power Station

the experience of the liquidation of the consequences of catastrophe at the Chernobyl Nuclear

In 1996 new radiation safety norms (RSN-96) were established based on the requirements of the Federal Law "On radiation safety of the population", on the recommendations of the International Committee of Radiation Protection (1990) and International Safety Standards (1996) Radiation safety norms (RSN-96) were remade and supplemented in accordance with the proposals of the regional Centers of Sanitary Inspection and some Ministries- Ministry of the Nuclear Energy, Ministry of Defense and others In their present form the norms were titled RSN-99 [4,10] In this document the radiation risk is determined as the probability of acquiring by a human being a concrete harmful effect as a result of radiation exposure. According to the same document , the effective dose (E)-the value used as a risk measure of distant consequences arising from radiation exposure of the whole human body and his separate organs with their radiation sensitivity taken into consideration This value presents the sum of the products of an equivalent dose in organs (H_t) and the corresponding weighting coefficients for organs or the tissue data

$$E = W_t H_t$$

Where H_t-equivalent dose in the tissue T over the time-t, W_T-a weighting coefficient for tissue T

Weighting coefficients for tissues and organs at the calculation of the effective dose-multipliers of equivalent dose in organs and tissues used for the radiation protection purposes for the consideration of the different sensitivity of different organs and tissues at the rise of accidental radiation effects These coefficients amount to

Gonads	0 20
Marrow (red)	0 12
Thick bowels	0 12
Lungs	0.12
Stomach	0 12
Urinary bladder	0.12
Mamma	0 05
Liver	0 05
Gullet	0 05
Thyroid gland	0 05
Skin	0 01
Cells of the bone surfaces	0 01
The rest	0 05

It should be noted that the norms requirements do not apply to the radiation sources creating individual annual effective dose not higher than μ Sv and collective annual dose not higher than 1 human-Sv, individual annual equivalent dose in the skin not higher than 50 m Sv and crystalline lens not higher than 15 m Sv in any conditions of their influence

higher than 1 human-Sv, individual annual equivalent dose in the skin not higher than 50 m Sv

For the calculation of the possible losses and substantiation of the expenditures on the radiation protection at the realization of the optimization and substantiation principle , the radiation of the group of people of any age in collective effective dose 1 human-Sv leads to the loss of 1 human-year life and minimal loss of one annual per-capita state income

6.2. Radiation risk for the crews of the Russian nuclear submarines

For the 40 year period of operation of the Russian vessel nuclear units there have been 7 major accidents which led to serious radio ecological and radiological consequences All of these accidents took place at the nuclear submarines, 5-while afloat and the other 2- at shipbuilding facilities during the period of the reactor recharging Two accidents were followed by the rejection of the radioactive substances into the atmosphere The frequency of the radiation accidents was equal to 10 % of all the accidents which took place on the vessels The total of the people exposed to radiation during the vessel accidents is over 1000, 193 of whom have radiation sickness of different degrees, 12 with a grave form of radiation sickness died over the short period after the accident, 10 people died from wounds after the reactor heat explosion in 1985 Besides, as result of the accidents during the conduction of the hazardous radiation works 26 people were exposed to a higher radiation level, 6 of these people have radiation affections [9]

Over the history of the Russian nuclear energy there have been more than 150 accidents which led to the development of radiation sickness of 456 people, 53 of whom died over the first 100 days after the radiation exposure With the accidents at nuclear submarines taken into consideration, the total number of the people injured amount to 657 The summarized radiological consequences of the vessel accidents are comparable to those of the nuclear power stations

The accident of 1960 (Northern Fleet)- the radiation exposure of the whole crew without the development of the radiation affection

The accident of 1961(Northern Fleet)-5 people with radiation exposure of the grave degree,4-medium, 122- light The first 8 people died

The accident of 1965 (Severodvinsk, plant)-higher radiation exposure of 9people without radiation affection

The accident of 1968 (Northern Fleet)-5 people with a very grave radiation exposure, 2-grave, 3-medium, 34-light, 64 people had radiation reaction and 39 had a subclinical form of affection 4 people of the above-mentioned 5 have died

The accident of 1989 (Northern Fleet)-did not have radiological consequences Local radioactive pollution of the water area for the period of 2 months

The accident of 1979 (Pacific Fleet)- 4 people-radiation exposure of a light and medium degree, 12-radiation reaction, 22-potentially hazardous radiation exposure

radioactive pollution of the water area for the period of 2 months

The accident of 1985 (Pacific Fleet)-10 people died on site as a result of the explosion, 7-light radiation exposure, 39- radiation reaction Total of the people exposed to a higher radiation-290

The experience of the medical treatment of the personnel who suffered from the accidents at nuclear units shows that at the time of the accident the personnel is exposed to the gamma-radiation on the whole body in doses leading to the development of light, medium and grave degree of marrowy form of radiation sickness Besides all these, beta-radiation leads to skin radiation affection of all levels of gravity Gamma radiation of the whole body is considered to be the determinant one in the field of radiation affection The differences in the individual radioresistance of the personnel stipulated the appearance of different gravity levels of radiation sickness at equal radiation doses and vice versa At the process of accident development there was observed a penetration of radioactive substances into the organism via breathing organs,for example, summation of iodine

The population dose of gamma-radiation received by the crews of the damaged nuclear submarines at direct radiation exposure amounted to 17-74 human Gy. and average individual dose- 0 57 0 22 Gy.

6.3. Risk assessment methodology

At present Russia (as many other highly-developed countries) consider risk assessment methodology to be the priority-driven and effective instrument of scientific substantiation of the administrative decisions in human health protection as well as in environment protection

Among many other problems the problem of the improvement of the quality management over environment seems to be the most significant one Only the scientific definition of the priorities will allow a correct direction and distribution of the financial funds for the nature-protection activities during the process of the Russian submarine dismantlement

The World Scientific Society with The International Commission on Radiological Protection (ICRP) developed (in early 70s) a fundamental philosophy of population protection from the harmful affection of ionizing radiation It was recognized in many countries (except the USSR) and it is based on 3 main regulations /1,2/

- it is expected that a nonthreshold linear hypothesis of radiation affects on a human being is grounded,
- The conditions of applying the ALARA (As Low As Reasonably Achievable) principle are kept,
- It is essential to take into consideration only the anthropological radiation excluding natural background

Non-recognition of the several regulations of the given philosophy in the USSR was defined by the fact that not all of these regulations were indisputable and sufficiently grounded

Many facts are known, for example, which prove the stimulating affection of small doses on

Non-recognition of the several regulations of the given philosophy in the USSR was

human beings and surrounding nature environment which questions the possibility of the unlimited application of its first principles Nevertheless, in 2000 will become a legal basis in the field of radiation protection in Russia

This decision has its merits and demerits. On one hand, the linear hypothesis simplifies the interpretation of the after-affects of ionizing radiation on a human being, on the other hand- leads to the exaggeration of the danger in using the small doses of radiation (up to 0 2 Gr)

At the basis of the ALARA principle there is an approach of setting the radiation at the lowest level after taking into consideration economic and social factors, i e analysis of "benefit-harm" correlation In the Atomic Industry of the USSR there was accepted another approach which used an ALAPA (As Low As Practically Achievable) principle

The usage of the ALAPA principle in the USSR is explained by the fact that it is difficult to make a quantitative evaluation of the thesis of maintaining radiation doses at low levels which can be reasonably achieved upon the consideration of the economic and social factors The experience of the operation of the Nuclear Power Stations in our country has shown that ALAPA principle and protection system developed on its basis satisfactorily solve the problems of radiation protection This principle is considered to be the basis in organization of the radiation protection of the special units of the Navy The consequences of these units operation will be evaluated in the given research

Several authors recognizing in general the positive sides of the ALAPA principle, pointed out that it was not sufficiently grounded for providing the safety of surrounding nature environment In their opinion, there is a need for the new concept which will spare a human being the necessity of being separated from natural environment The ALAPA principle is in line with this new concept

At the transitional stage which is connected with the society reconsideration of the essence of the ecological problems, there appears one regulation which unites both opinions. the observation of the principle of health protection of a human and ecological rationing This stands in line with the main approaches of the military ecology and allows for the quantitative evaluation of the degree of radio ecological danger of the operation of Nuclear Units

The exclusion of background radiation from the analysis of radiation affection on a human being and biocenosis increases the quality of the evaluations made However, this procedure is not a trivial one due to its inconstancy in time and space Earlier this task was not considered to be an essential element of radiation protection and naturally was not studied properly That is why in the given research this task will be studied regarding the conditions of dismantlement of the special units

properly That is why in the given research this task will be studied regarding the conditions of

Due to the incompleteness of the substantiation of the first regulation of ICRP's ideology, the optimal variant of evaluation of the degree of radio ecological danger of operation of the Nuclear Units is the consideration of this problem from the view of risk theories (harmful affection of radiation in the whole radiation range) and radiation hormethesis (the stimulating affect of the small doses and harmful of the big ones) as well as the substantiation of the optimum of these theories application in the researched area

The quantitative criterion of danger is risk. In accordance with the wording of ICRP it means a threat of an undesired event including the probability of its happening and the degree of its gravity In such form risk becomes synonymous with the definition of danger

When applied to the specificity of the military activity which includes the provision system of the population, it is more appropriate to talk about a “dictated” rather than “free-will” risk Apart from this, atomic energy has been used in the Navy for the last 4 decades which means that radio ecological consequences are not to be considered a new type of danger but rather an ordinary one. Under such circumstances the influence of radiation factors on the population, employees and military men is to be treated as a long process of exposure to radiation of small doses (less than 5 mSv/year) or to radiation commensurable with background (very small doses – 0 5 mSv/year)

In the multifactor risk concept the probable death outcome is considered to be a deciding indicator. The consideration of other negative effects in the form of illnesses, heritable diseases, anxieties is expressed via risk coefficient from the fatal cancer in the form of correction to its factual meaning or in money equivalent In those cases when an acceptable model exists , the estimation of damage is made on individual factors

The conceptual basis of the risk theory is considered to be the notion that the society cannot exist without risks. From this notion and from the agreement about the expediency of summation of all kinds of risks which accompany human's life Commission ICRP in its publication 26 recommends to take the quantity of the acceptable risk at 10 –3 deaths a year (1 human/year) for professional workers and additional annual death probability for population individuals -10-5 (annual dose limit is 1 mSv)

According to the specialists from our country there exists a minimal regulated level which is equal to 0 1 mSv/year-the doses below this level are not taken into consideration and thus there is no necessity of risk determination This level is considered to be a negligible one (as it is equal to 10-6 1/human-year) and it separates the sphere of risk optimization from that of unconditionally acceptable risk.

The question of relevancy of the calculation of quantity of the radiation risk in case of small doses is still now open as practically all the radio ecological consequences of operation of

unconditionally acceptable risk.

the Navy Nuclear Units can be considered relevant This is connected (as it was stated above) with a lot of data received by Russian and foreign researchers which disprove the regulation (the working hypothesis of ICRP) that accidental effects have linear and nonthreshold dependence on the dose quantity and that is feasible the evaluation of risk and quantities of the dose limits on the basis of data received at evaluation of big doses Under real conditions there are no grounds to deny the presence of practical threshold of the accidental effects at doses less than 3 5 mSv/year. That's why it is worth heeding the opinion of the author /13/ that the attempts of the Commission ICRP in the publications 26 and 60 to define the standards on this basis are a little bit too premature

It is worth reminding that when substantiating the dose limit for the population at 1 m Sv/year The Commission used the approach based on the comparison with radiation from natural background without considering the influence of radon and it led to the fact that the natural background has turned out to be 2.4 times lower than the world average. 2 4(0 5,+10 0) mSv/year/13/ This approach questions the relevancy of determination of the radiation risk at doses equal to average quantity and further more to its low limit as it contradicts the data about the satisfactory health state of the people living in these conditions for centuries

The last regulation is considered a conceptual basis of the theory of radiation hormethesis /14/ in accordance with which at constant radiation equal to the doses 5-10 times exceeding the background and the absence of other negative factors on surrounding nature environment there is no basis for saying that radiation is harmful to a human's health On the contrary, radiation proves itself as stimulator which improves the conditions for the development of the plant and animal world Accordingly, the practice of the calculation of the radiation danger (risk) at doses lower than 12-24 mSv/year becomes unreasonable Such approach is more useful from moral-psychological point of view than information about negligible but harm all the same

It should be noted that the Commission ICRP confirms that at all the ages the additional death-rate of radiation cancer at doses 5 and even 50 mSv/year is less than the difference in natural death-rate of women and men and much less than the difference in natural death-rate of populations of the countries in which living standard is high enough as well as in the countries where the atomic energy is used and not /9/

The analysis of the problem of the harmful affection of very small doses on a human being has shown that the interval of 1-3 mSv/year is considered an area of uncertainty in which from the risk theory it is impossible to take an unambiguous decision on the presence of harm. Accordingly the data given in tables 7 1,7 2 should be treated carefully and only for the determination of the consequences for individual cases The conservatism of the given

Accordingly the data given in tables 7 1,7 2 should be treated carefully and only for the

estimations (which are set several times higher as a result of using unequal models for the estimations) should be always kept in mind

The evaluations of the potential risks for the human's health connected with nuclear submarine dismantlement do not have normative-methodological basis The dose limits of the normative documents and the levels derived from them originate from the definition and normative meaning of the effective dose which is recommended by ICRP Commission with the aim of characterization of the radiation harm in the risk definitions Risk methodology is recommended by the U.S Environment Protection Agency and at present undergoes a trial on the basis of the joint corresponding resolution of the Committee on Ecology of Russia and State Sanitary Committee of the Russian Ministry of Health It is suggested to use the simplified approximations-averaged risk coefficients on sex, age and so on The emergency situations do not cover the given coefficients.

The consecutive risk assessment methodology must use the definitions and corresponding quantities of the pollution event probability, dose difference probability

The negative influence of radiation on human being is now evaluated not only as a fact of deterioration of his health but in the form of the social consequences economic, moral, violation of human's rights and so on. In that case in the form of generalized criterion of the harm we understand the price form of the harm evaluation/

$$Y= \alpha R,$$

Where Y-damage, α- risk price, R-risk

Damage (risk price) , as a rule, is on allocation to some single risk, for example, 2 10-4 1/person-year and is 10-1000 $ per risk unit for the highly developed countries in different industrial sectors For the poor countries the price is lower For example, in Russia at the plutonium dismantlement the damage from radiation of 10per-mSv or risk unit of 5 6 10-4 1/per/year is equal to 170 $ Risk price α may depend on R In this case it is admissible to use any of the dependencies depicted on the picture however, the multigraded one with a different risk price is considered optimal

The above-mentioned approach should not be treated as the final stage because in the future there will be considered a factor of social consequence so that the quantity of the individual risk does not exceed the quantity of the public benefit, which the state gets from application of the hazardous technology in exchange for admissible social harm This is the essence of the conflict between the state and the population in the areas of the location of the special units of the Navy

special units of the Navy

The given risk assessment methodology (intended for perfection and further usage in the project of Russian nuclear submarine dismantlement) is based on modern international approaches to this problem and includes 4 main stages which are realized in series:

- hazard (harmfulness) identification,
- exposure evaluation,
- determination of the "dose-reply" dependence,
- risk characterization

At the initial stage of the works fulfillment a conceptual model of the researched area will be formed This model will reflect all correlations of the main sources of environment pollution in the process of the nuclear submarine dismantlement. The given model will be corrected at every stage of risk assessment

Works on hazard (harmfulness) identification must show which factors and how can cause adverse consequences for the human's health

At this stage the inventory of the sources of different environmental objects pollution as well as the inventory of all the components of the industrial wastes at all stages of submarine dismantlement will be made All the pollutants will be ranked in accordance with their penetration volume into the atmosphere, degree of biological activity

Along with the data on the radioactive and chemical substances which penetrate into the atmosphere there will be gathered and analyzed the information on the pollution level of the researched region The question about the adequacy and reliability of the data at hand will be decided on the basis of this analysis and the characteristic of the possible mechanism of pollutants formation and transfer

Besides, at this stage priority-driven agents will be chosen out of the list of all factors influencing the human's health at the researched area These agents will be characterized at later stages of risk assessment The given choice will be made according to the system of special criteria which reflect substance prevalence, its hazardous properties, the possibility of analytical definition The number of priority-driven factors will be defined upon the consideration of the existing resources (financial, instrumental, human) of the given project on nuclear submarine of the Russian submarine dismantlement

At the next stage of the research- exposure evaluation- the characteristic of possible pollution sources will be given along with the route of pollutants movement from these sources to a human being, the ways and points of affection and exposure levels The goal of this stage is the definition of the possible radiation and chemical loads for the personnel, population and environment at different stages of nuclear submarine dismantlement process as well as to

the definition of the possible radiation and chemical loads for the personnel, population and

determination of the exposure levels for the population on the whole and for separate subpopulations. A special attention will be paid to the most sensitive "critical" groups.

Exposure evaluation will be based on the data of dynamic monitoring or on the results of prevalence process modeling, inter-environmental transportation and fate of the radioactive and/or chemical substances in the environment The choice of exposure evaluation methodology is defined by the research goals, the degree of completeness and reliability of benchmark data. For these particular purposes we plan to use the software products "Trace" and "Nostradamus" developed by IBRAE, although it should be noted that a practical use of similar models requires the information on many hard-to-get characteristics of a substance, environmental objects and the population exposed The possibility of finding the group of the benchmark data for the accurate calculations may significantly influence the efficiency of these models usage for risk assessment

At the stage of evaluation of the "dose-reply" dependence there will be carried out an analysis of the existing models according to the quantitative correlations between doses of the researched agents and frequency as well as to the hazard degree of the possible harmful effects in the researched population If at the previous stage of the exposure evaluation the association between the agent and a harmful effect was analyzed only at qualitative level , at the stage of evaluation of the "dose-reply" dependence this correlation is expected to be led to the quantitative indicators Risk assessment will be carried out separately for the agents which do not have affection threshold (carcinogens) and for the factors which cause harmful effects after reaching a certain dose (non- carcinogens)

Should there be any necessity and financial resources , additional epidemiological researches can be carried out At present qualitative models are developed which reflect the dependence of various harmful effects of the population exposed (additional early mortality, hospitalization frequency, aggravation of the morbidity symptoms) on the affection levels of "classical" atmosphere pollution (lead, ozone, nitrogen dioxide, sulfur dioxide and so on) The similar criteria are used abroad for the economical evaluation of the efficiency of the measures on environment protection EU Commission recommends to apply these criteria of risk assessment for the characterization of the atmosphere pollution affection (for example, suspended substance) on the human's health For many of these models it is very important to have background data on the health and mortality of the population as ,according to some scholars, the influence of the pollution factor over the human's health is limited to the multiplicative change of the background medical-statistical indicators of the population

At the final stage of the risk assessment process-risk characterization- the analysis of all the received data will be given The goal of this particular stage is determination of the medical

multiplicative change of the background medical-statistical indicators of the population

and ecological priorities as well as revelation of the risks which should be prevented or reduced up to the admissible level At this stage we plan to carry out an aggregate analysis of the uncertainties and their influence on the final conclusions

Thus in the process of risk assessment we will determine

- risk quantities for separate factors at different ways of affection from certain environments,
- total risks for affection routes, ways of penetration, total risks for substances with similar type of harmful affection;
- integrated hazard indices for the factors with different type of harmful affection, for example, carcinogens and non- carcinogens,
- analysis of risk distribution in the population, in very sensitive subgroups

The task (which is not part of the risk assessment for the human's health but closely connected with it) and decided through the "risk" definition is the application of the insurance system to the nuclear submarine liquidation

Upon the completion of the process of the risk assessment all the received data should be handed over to a group of specialists who are responsible for the concrete project decisions on the problems of submarine's dismantlement

The materials presented here should be considered as fragment illustration to a so complicated problem as risk assessment

As far as the unanswered questions are concerned, they are the following.

- choice of the affection subject (administrative unit for which risk assessment is carried out)
- geographical, economic, social and other characteristics of the affection subject,
- radiation and radio-ecological situation on the territory of the affection subject,
- description of the radiation and radio-ecological monitoring systems on the territory of the affection subject,
- data on the level of the total, man-caused risk on the territory of the affection subject,
- structure of man-caused risk on the territory of the affection subject and main risk-building factors,
- morbidity structure on the territory of the affection subject,
- structure and number of critical population groups on the territory of the affection subject for which an individual, social and joint risk will be assessed,
- density and living conditions of the population,
- technical characteristic of the risk sources for the researched population groups (the presence of the hazardous enterprises)
- technical characteristic of the hazard sources at the dismantlement process
- probability of the accident initiation at utilization process as a result of the accidents at other objects of man-caused risk on the researched territory,
- method of evaluation of the accident technical probability (the formation of the hazard source),

objects of man-caused risk on the researched territory,

- method of evaluation of the probable formation of the concentration fields,
- method of evaluation of the formation of effective doses at the accidents,
- method of evaluation of efficiency of the protective measures (quantitative and qualitative),
- social-psychological risk perception by different population groups on the researched territory;
- proposals on the risk limits and quotas for the population researched territory,
- proposals on the usage of the economic equivalents of the ecological satety criteria during the dismantlement process,
- proposals on the organization of the risk insurance during the dismantlement process,

All the above-mentioned unanswered questions may be divided into 3 groups

- The questions defined by the necessity of getting the information from the executive authorities.
- The questions (methodological) defined by the position of the ATRP-R team.
- The questions which arise in the research process and presuppose further realization in the legal and normative documents

It is obvious that the decision of the 2 first groups of question should precede the study at the next stages of ATRP-R research

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7. MODEL WORK PLAN

The final stage of the nuclear submarine life span begins with the decommissioning order and finishes with the completion of dismantlement (complete liquidation) of the reactor compartment Following the Utilization Concept as developed by Ministry for Nuclear Energy earlier this year this period extends for at least 70 years During 95% of this time no actual dismantlement operations are performed on the nuclear submarine This time is given to the waiting and storage procedure first for the submarine with the spent nuclear fuel, then without it, followed by cutting the hull into three compartment blocks and their separate storage

After the reactor compartment has been cut out, it is stored at the coastal facilities It is therefore more accurate to define the environmental security implications of not only the actual dismantlement operations, but rather the lengthy storage of the decommissioned nuclear submarine and it elements, which contain the radioactive materials

In the sections above there has been presented the overview of the datasets and information on some basic considerations, which need to be taken into account for future reference at the future stages of the research

In the Tab 7 1, 7 2 and 7 3 below there are suggested the the dataset availability for the immediate environmental security assessment of the final life span of the decommissioned nuclear submarines

Sufficient declassified dataset availability

Datasets	Theoretical Data Availability
Nuclear submarine dismantlement procedures	Yes
Dismantlement emergencies and accidents scenarios	Yes
Spent fuel radio nuclide composition	No
Metal structures radio nuclide composition	No
Environmental migration of the radio nuclides	Yes
Environmental and geographic location points of the nuclear submarines	No
Medical and biological exponents for various human groups	No

Tab 7 1.

Tab 7 1

board Impact analysis

4 2 Potential emergencies during spent fuel unloading and storage operations Impact analysis

4 3 Potential emergencies during nuclear submarine sediment, 3 compartment (block) cutting and storage operations Impact analysis

4 4 Potential emergencies during radioactive waste unloading and lengthy storage operations in the open areas Impact analysis

4 5 Potential emergencies during lay-up operations, radioactive waste unloading and dismantlement of the emergency service ships Impact analysis.

Section 5 "Risk analysis of the nuclear submarine dismantlement operations"

5 1 Description of the grounds for the risk assessment methods for both natural environment and local population Revision and processing of the existing methods, if required

5 2 Risk assessment for the normal regime situations of the nuclear submarine dismantlement operations

5.3 Risk assessment for the emergency situations of the nuclear submarine dismantlement operations

Section 6 "Development of the integral monitoring system guidelines, securing the appropriate level of protection for the nuclear submarine dismantlement operations".

6 1 Analysis of the control devices for the radioactive and chemical wastes, resultant from the nuclear submarine dismantlement operations

6 2 Analysis and evaluation of the existing local monitoring systems

6 3 Development of the technical suggestions for the integral monitoring system

8. CONCLUSIONS AND RECOMMENDATIONS

1. In the course of preparing for the ATRP-R effort the Russian side of the project has set up the administrative and executive structures (Supervisory Board, Expert Council, groups of experts) As a result over 40 highly qualified leading professionals and scientists of Russia have made up the skilled team of specialists in nuclear energy, environmental protection, shipbuilding, as well as naval experts and analysts All principals of the ATRP-R operations have been supported by the leading authorities of the Russian Ministry of Defense, Ministry for Nuclear Energy and the Academy of Science of the Russian Federation

2. In the course of the material preparations the current state of the works on nuclear submarine dismantlement has been analyzed The data on the number of the decommissioned submarines as of 2000 as well as the information on the dismantlement infrastructure in Northern and Far Eastern regions have been presented

3 In the given report there is a description of all the stages of the applied technologies used at submarine utilization and Russian concept of the complex dismantlement of the nuclear submarines till 2010

4 Following the tasks of the Statement of Works , the final report represents is called to describe various aspects, which enable the definition of the environmental security implications for the decommissioned Russian nuclear submarines The essential part of the final report is presented in 7 sections, with the primary objective of each being the definition of the availability and sufficiency of the existing data as may be required for assessing the environmental security implications of the decommissioned Russian nuclear submarines at a later stage

5 The foundation for further works on the issue of the decommissioned Russian nuclear submarine dismantlement operations rests on the raw (initial) data sets Section 2 of this report represents the meta-database specifications and describes the content of the informational field Primary information on the initial data and evaluation of its sufficiency is distributed per each particular section of this report in accordance with the table of contents as shown above.

6 As a result of the meta-database analysis there has been established that for the most part the available declassified data is indeed sufficient for conducting a research and analysis of the environmental security implications of the decommissioned Russian nuclear submarines Additional work is required in the area of means and methods of control over some particular types of pollutants, their exposure dynamics and legal framework for the dismantlement operations A substantial amount of the initial data on the project requires additional systematization

7 The primary danger in operations with the decommissioned Russian nuclear submarines roots from the potential nuclear and radiation accidents and other emergency occurrences, especially of the spent nuclear fuel-aided nature The priority for the further work on this project should be given to meticulous development of the emergency scenarios for every stage of the dismantlement operations and elaboration of the sets of actions to avoid or localize such occurrences

8 In the course of the work all the sources of pollution and all potential hazards have been analyzed It has been pointed out that the priority ranking of the works on the increase of the ecological security must be defined by the risk degree for nature and population.

9 Priorities on the works of increasing the environmental protection in dismantlement and sediment operations should be defined following the particular hazards associated with the ecological habitats and human health Evaluation of risks per each

the ecological security must be defined by the risk degree for nature and population.

the ecological habitats and human health Evaluation of risks per each pollutant/contaminant for particular areas/territories should represent another essential objective of further work on this project

10 The first step for the beginning of the second stage of works on the environmental security analysis of the decommissioned nuclear submarines should constitute the development and agreeing of the next appropriate Statement of Works (technical order)

11. Such a SOW for the year 2001 can be based on the first two divisions of the suggestions as put forth in the Model Work Plan hereto

12 As a particular priority should be emphasized not merely the definition of risks for all procedures associated with the nuclear submarine dismantlement operations, but rather the feasibility of the efforts and particular actions which need to be taken in order to decrease such risks

13 In the final report the scales and the character of the possible impact of the utilization of the Russian nuclear submarines on environment and human's health have been shown. A special emphasis has been placed on the actuality of the ecological problems , the importance of which is not limited by only Russian interests The necessity of the complex research of the ecological consequences connected with all the stages of the nuclear submarine dismantlement has been especially emphasized. As it follows form the analysis of both completed and in-progress international and Russian programs, the proposed Project will be a first attempt of the fundamental systematic research of this important problem of international significance

LIST OF FINAL REPORT EXECUTORS

Sarkisov Ashot Arakelovitch	(Russian Academy of Science IBRAE)- Academician, The Head of the Expert Council
Alexandrov Alexei Ivanovitch	(State Duma of the Russian Federation)- State Duma Deputy, the Member of the Supervisory and Expert Council
Alexeev Sergey Pertrovitch	(Navy of the Russian Federation)- Doctor of Science, the Member of the Supervisory and Expert Council
Aroutunian Rafael Varnazovitch	(Russian Academy of Science IBRAE)- Doctor of Science, the Member of the Supervisory and Expert Council
Akhounov Victor Davletovitch	(Minatom of Russia)- Doctor of Science, the Member of the Supervisory and Expert Council
Bolshov Leonid Alexandrovitch	(Russian Academy of Science IBRAE)- Member of Russian Academy of Science
Vasiliev Albert Petrovitch	(Minatom of Russia)- an expert
Vysotskiy Leonid Leonidytch	(Navy of Russia)- Doctor of Science, expert
Gousev Leonid Borisovitch	(Navy of Russia)- Doctor of Science, expert
Danilyan Valery Arshakovitch	(Russian Academy of Science IBRAE)- expert
Denisov Alexander Michalovitch	(State Technical Commission at President of Russia)- a member of the Expert Council
Dobrotvorskiy Alexander Nikolaevitch	(Navy of the Russian Federation)- Doctor of Science, expert
Dovgousha Vitaly Vasilievitch	(Rusvessel building)- Doctor of Science, expert
Zhaharov Victor Michailovitch	(Navy of Russia)- Member of the Expert Council
Kalinin Remos Ivanovitch	(Russian Academy of Science IBRAE)- Doctor of Science, expert
Kalantarov Valentin Evgraphovitch	(Russian Academy of Science IBRAE)- Doctor of Science, expert
Kisilyov Vladimir Pavlovitch	(Russian Academy of Science IBRAE)- Doctor of Science, expert
Kovalenko Victor Nikolaevitch	(Min Atom of Russia)- expert
Kozlovskiy Artem Vladimirovitch	(ATRP-R)- an expert
Koulik Anatoliy Victorovitch	(Ministry of Defense of Russia)- an expert
Lavrenouk Oleg Nikolaevitch	(Ministry of Defense of Russia)- an expert
Lisovskiy Igor Valentinovitch	(Saint Petersburg Technical University)- Doctor of Science, Expert
Lountsevitch Valentin Vasilievitch	(State Duma of the Russian Federation)- State Duma Deputy, the Member of the Expert Council

Lountsevitch Valentin Vasilievitch (State Duma of the Russian Federation)- State Duma

Lyscsov Vitaly Nikolaevitch	(Russian Scientific Center of Kourchatov)- Doctor of Science, expert
Mazokin Vasily Alexandrovitch	(MinAtom of Russia)- expert
Makeev Vechiaslav Michailovitch	(Russian Academy of Science)- Doctor of Science, expert
Pologich Boris Georgievitch	(Russian Scientific Center of Kourchatov)- Doctor of Science, expert
Pavlovskiy Oleg Anatolievitch	(Russian Academy of Science IBRAE)- Doctor of Science, expert
Nikitin Vladimir Semenovitch	(Rusvessel building)-Candidate of Science, The Member of the Expert Council
Ronzhin Igor Victorovitch	(Ministry of Defense of Russia)- an expert
Smirnov Pavel Leonidovitch	(Russian Academy of Science IBRAE)-expert
Testov Stanislav Geraldovitch	(Ministry of Defense of Russia)- expert
Titov Juri Vasilievitch	(Ministry of Defense of Russia)- expert
Shelest Vitaly Petrovitch	(ATRP-R)- Doctor of Science, Member of the Supervisory Council
Sheremetiev Victor Michailovitch	(Ministry of Defense of Russia)-Doctor of Science ,Member of the Expert Council
Shishkin Vladimir Alexandrovitch	(MinAtom Russia)- Member of the Expert Council
Shvedov Pavel Alexeevitch	(Russian Academy of Science IBRAE)-expert
Filin Boris Nikolaevitch	(Russian Academy of Science IBRAE)-expert
Khlopkin Nikolai Sidorovitch	(Russian Scientific Center of Kourchatov)- academician, Member of the Expert Council

APPENDIX 1

THE LIST OF PARTICIPANTS OF THE PROJECT

The line-up of the executive organs of ATRP-R.

Supervisory Council

Goman Vladimir Vladimirovitch	ATRP R Chairman of the Supervisory Council
Sarkisov Ashot Arakelovitch	IBRAE RAS,Academician, Chairman of Expert Council
Alexandrov Alexei Ivanovitch	State Duma of the Russian Federation, Member of Security Committee of the State Duma
Alexeev Boris Nikolaevitch	Ministry of Defense, Head of the Ecological Security of Defense Ministry
Evdokimov Juri Alexeevitch	Governor of the Murmansk Region
Kasatonov Igor Vladimirovitch	Navy Admiral of the Russian Federation
Laverov Nikolai Pavlovitch	Russian Academy of Science, Academician, Vice-President of Russian Academy of Sciences
Lebedev Valery Alexandrovitch	Ministry of Nuclear Energy, Deputy Minister of Russian Min Atom
Shelest Vitaly Petrovitch	ATRP-R, Executive Director

Expert Council

Sarkisov Ashot Arakelovitch	IBRAE RAS.Academician, Chairman
Alexandrov Alexei Ivanovitch	State Duma of the Russian Federation- Member of
Alexeev Sergey Pertrovitch	Navy of Russia, The Head of State Scientific-Research Navigation Hydrographic Institute
Arutyunyan Rafael Varnazovitch	Russian Academy of Science IBRAE – Director First Deputy
Akhounov Victor Davletovitch	Minatom of Russi)- Head of Department
Birillo Nikolai Nikolaevitch	Navy of Russia , The Head of the technical department
Bolshov Leonid Alexandrovitch	Russian Academy of Science IBRAE-
Denisov Alexander Michalovitch	State Technical Commission at the President of the Russian Federation
Zhaharov Victor Michailovitch	Navy of Russia, The Head of radiation chemical and biological protection of the Navy of Russia
Karachoun Nikolai Dmitrievitch	Navy of Russia Deputy Head of the Technical Department,
Lounchevitch Valentin Vasilievitch	State Duma of the Russian Federation, State Duma
Karachoun Nikolai Dmitrievitch	Navy of Russia Deputy Head of the Technical Deputy

Maslakov Valery Alexandrovitch	Russia Ship building Agency, Director of "Zvezda" plant
Nikitin Vladimir Semenovitch	Rusvessel building, Director of SRI "Onega "
Ponomarev Vladimir Nikolaevitch	Ministry of Construction of Russia, First Deputy to the Russian Minister of Construction
Roubanov Vladimir Arsentievitch	RAS, Member of the Russian Academy of Science
Rouksha Viacheslav Vladimirovitch	Murmansk Sea Steam Navigation, General Director
Soloviynov Alexander Alexandrovitch	Environment Committee , Deputy to the Head
Shelest Vitaly Petrovitch	ATRP-R
Sheremetiev Victor Michailovitch	Ministry of Defense of Russia, Leading specialist
Shishkin Vladimir Alexandrovitch	MinAtom Russia- General Engineer, Head of the Department "NIKIED"
Csatourov Juri Sarkisovitch	Federal Hydromed Center, First Deputy to the Head
Khlopkin Nikolai Sidorovitch	Russian Scientific Center, Academician, Director of the Department of the nuclear reactor transportation

Program experts

Babayansc Gennadiy Ivanovitch	Director of the Experimental Plant "Loutch"(Ray)
Belikov Alexander Dmitrievitch	Russian Navy ,Leading radiologist
Danilyan Valery Arshakovitch	Russian Academy of Science IBRAE
Dobrotvorskiy Alexander Nikolaevitch	Navy of Russia, The Deputy Head of State Scientific-Research Navigation Hydrographic Institute
Dovgousha Vitaly Vasilievitch	Rusvessel building, Director of Industrial and Naval Medicine
Vasiliev Albert Petrovitch	Ministry of Nuclear Energy of Russia, Director of the Center,
Vysotskiy Leonid Leonidytch	Navy of Russia
Golovinskiy Stanislav Akimovitch	Murmansk Sea Navigation, Technical Director of the Atomic Fleet
Gousev Leonid Borisovitch	Navy of Russia
Kalinin Remos Ivanovitch	Russian Academy of Science IBRAE- Director of laboratory
Kalantarov Valentin Evgraphovitch	Russian Academy of Science IBRAE
Kovalenko Victor Nikolaevitch	Min Atom of Russia- Deputy to the Head of Department
Kalantarov Valentin Evgraphovitch	Russian Academy of Science IBRAE

Kiselev Vladimir Pavlovitch	Russian Academy of Science IBRAE, Head of the Department
Kozlovskiy Artem Vladimirovitch	ATRP-R
Koulik Anatoliy Victorovitch	Defense Ministry - a leading specialist
Lavrenouk Oleg Nikolaevitch	Defense Ministry - a leading specialist
Linge Igor Innokentievitch	Russian Academy of Science IBRAE
Lisovskiy Igor Valentinovitch	Saint Petersburg Technical University,
Lyscsov Vitaly Nikolaevitch	Russian Scientific Center of Kourchatov, Head of Laboratory
Mazokin Vasily Alexandrovitch	MinAtom of Russia- the Head of laboratory
Makeev Vechiaslav Michailovitch	Russian Academy of Science- Director of the Institute on the environment protection of the Northern Region
Pimenov Sergey Vladimirovitch	General Director of the "Metal Conversion"
Pologich Boris Georgievitch	Russian Scientific Center of Kourchatov, head of laboratory
Pavlovskiy Oleg Anatolievitch	Russian Academy of Science IBRAE-
Ronzhin Igor Victorovitch	Ministry of Defense - Deputy to the Head of Department
Smirnov Pavel Leonidovitch	Russian Academy of Science IBRAE
Testov Stanislav Geraldovitch	Ministry of Defense - Department Head,
Titov Juri Vasilievitch	Ministry of Defense - Deputy to the Head of Department
Filin Boris Nikolaevitch	Russian Academy of Science IBRAE
Shvedov Pavel Alexeevitch	Russian Academy of Science IBRAE
Sherbina Natalia Timofeevna	Ministry of Nuclear Energy , leading specialist
Yanovskay Nina Simonovna	Ministry of Nuclear Energy, Director of "Nuclid" center,

META DATABASE SPECIFICATIONS

Identification Information

1. General Information

1.1. The content of the database

The data identified in this feasibility study will cover three broad classes of information The collected information will be assessed, structured and split into three main information format categories

- Textual (raw data, reports, memos, procedures, organizational structure outline, codes, scientific and technical literature, etc),
- Charts and tables (complete sets of charts and diagrams),
- Graphics (electronic and hard copies of raster graphics, maps, schemes, etc.)

The three aforementioned categories shall also include additional datasets, as generated specifically for this feasibility study, e g concerning the Russian organizational structure of the ATRP-R program

1.2. Textual documents

1 In the final analysis the following textual data shall be provided in the framework of this feasibility study and accordingly described and accounted for in the proposed meta-database

2 List of the information sources used by the Russian side including the list of the normative-legal documents, conferences, seminars, meetings and articles

3 Project documentation, including schedule of the feasibility study related works, delivery timetables, lists and CVs of experts involved, deliverables

4 Scientific reports on the researches conducted

5. Expert reports on the project feasibility in the particular fields of their specialization

6. Description of the utilization stages with taking into the account the peculiarities of the Northern and Far –Eastern Regions including the description of the utilization infrastructure in these regions.

7 Information on the primary contaminant sources and sites, including but not limited to the index of the decommissioned nuclear submarines of the Northern and Pacific Fleets of the Russian Federation, list of the nuclear submarines with the active units yet to be dismantled, overall number of the three-tank sections to be scrapped, etc

8 Description of the contaminant sources resultant from the decommissioning and scrapping procedures, including the full list of radioactive and other hazardous substances thereto

8 Description of the contaminant sources resultant from the decommissioning and

9 Information on the contamination of the Northern and Far Eastern territories of Russia

10 General geographic outline of the lengthy parking spots for the decommissioned and currently dismantled nuclear objects

11 Information on the migration of the pollutants in air, water and soil substances

12 Potential impact of the contaminants as resultant from the nuclear submarine dismantlement operations on the natural environment and human health

13 Description of the possible risk scenarios calculated for all submarine life cycle stages after decommissioning Potential threats and risks for human health and natural habitats

14 Definitions and standards of the Russian risk assessment methodologies, including but not limiting to, the legal regulations and norms adopted in the Russian Federation pertaining risk assessment techniques

15 Complex assessment outline for the utilization of the radioactively hazardous objects

1.3. Electronic Charts

1 General information on potentially hazardous radioactive sites

2 Data on the potential radioactive hazards in the Northern region of Russia

3 Data on the potential radioactive hazards in the Far Eastern region of Russia

4 Solid and liquid radioactive waste data broken down between the Russian regions

5. Gamma-radiation field maps for the decommissioned reactor facilities

6 Information on the detonation, fire and electric security standards for the decommissioned vessels

7 Technical conditions of the nuclear steam production facilities treatment for the decommissioned vessels

8 Nuclear and radioactive security procedures, storage conditions for the decommissioned vessels

9 Treatment of the general naval systems for the decommissioned vessels

10 Treatment and maintenance of the hull and hull structures for the decommissioned vessels

11 Results of the complete radioactive and environmental security researches of the contaminated harborages and other water areas

1.4. Graphic data and electronic maps

12 Survey maps of the radioactively hazardous objects dismantled in the Northern and Far Eastern regions of Russia

13 Location sites of the decommissioned nuclear submarines and surface vessels

14 Location of the sedimentation sites for the nuclear submarines and shipping yards as used for the utilization and dismantlement operations

15 Temporary storage sites for both solid and liquid radioactive wastes, resultant from the dismantlement operations

16 Schemes and layouts of the nuclear submarine scrapping yards

15 Temporary storage sites for both solid and liquid radioactive wastes, resultant from the dismantlement operations

17 Radioactivity assessment and waste stream maps for the lengthy parking sites of the decommissioned nuclear submarines

18. Standard Specialized general geographic maps and charts (e g. currents, wind rose, etc).

19 Information on the seasonal and longstanding watch results of the lengthy parking sites for the decommissioned objects

20 Forecasting contamination maps for the territories and harborages polluted as a result of factual radioactive accidents and occurrences

21 Gamma field maps for the polluted territories and harborages

22 Location maps of the potential environmental contamination sites

23 Forecast maps and modeling charts for various scenarios of the hypothetical radioactive accidents and occurrences at the radioactively hazardous sites, currently utilized

2. Specifications of the project database

2.1. Meta Data Format

The bulk of the aforementioned documentation shall be made available in the text format (Microsoft Word or HTML), electronic tables and charts (Microsoft Excel), database form (Microsoft Access 97), pictures, clips and images (Windows BMP or JPEG) The data storage and usage standards for the current meta-database have to therefore provide for its readability and compatibility with the core database(s), which will embrace the factual feasibility study data

2.2. Meta Database Standards

Following the recommendations of the American participants in the projects for the meta-database ("data about data") ATRP-R experts have envisaged to adhere to the Content Standards for Digital Geospatial Metadata (FGDC-STD-001-1998), as suggested by the Federal Geographic Data Committee of the USA for the description of the identification information Primarily this standard has been developed for the spatial geographic information This standard however presents a considerable amount of rules and recommendations, the full description of which runs into over 90 text pages

Below we have outlined **the major sections of the CSDGM standards.**

Identification Information (data set title, area covered, keywords, purpose, abstract, access and use restrictions)

Data Quality Information (horizontal and vertical accuracy assessment, data set completeness and lineage)

Spatial Data Organization Information (raster, vector, or an indirect (e g address) link to location)

Spatial Reference Information (lat/long, coordinate system, or map projection)

Entity and Attribute Information (definitions of the attributes of the data set)

Spatial Reference Information (lat/long, coordinate system, or map projection)

Distribution Information (distributor, file format of data, off-line media types, on-line link to data)

Metadata Reference Information (who created the metadata and when).

The supplementary **minor sections of the CSDGM** additionally provide for the following specification·

Citation Information (originator, title, publication date, publisher)

Time Period Information (single date, multiple dates, range of dates)

Contact Information (contact person and/or organization, address, phone, email)

The analysis of the existing meta-databases by the ATRP-R experts has proved that these **major and minor CSDGM sections** seem to indeed represent the minimum mandatory elements appropriate for initial data set documentation, which as it is understood by the Russian party fully meets the purpose and scope of the current feasibility study

In the light of the constraints of the current feasibility study and in order to implement the aforementioned CSDGM standards the current feasibility study stage shall be based on the aforementioned documentation types and minimum CSDGM sections

2.3. Hardware and software requirements

Current feasibility study metadata requirements precondition IBM PC compatible computers as the most preferential hardware platform (Celeron-400 processor, 64 Mb RAM, 2 Gb HDD, 800*600 pixels SVGA, CD-ROM, 15" monitor, FDD 3 5")

For the metadata preparation there has been identified a number of specialized software products, widely available in the Internet, i e the following programs could be particularly considered as the most compatible with the MS-Windows operating system

- **NOAA FGDC Metadata Toolkit 1.0 Beta**.
- **Metamaker 2.10**,
- **DataLogr 1.0,**
- **The MDC (Metadata Collector),**
- **KMDD (Klamath Metadata Dictionary),**
- **Corpsmet95,**
- **Dataset Cataloger 4.0,**
- **Metadata Manager Pro**
- **Metadata Management System,**
- **Metagen32.**

At present the analysis of these software products is being carried aiming at the choice of the most suitable one for this product

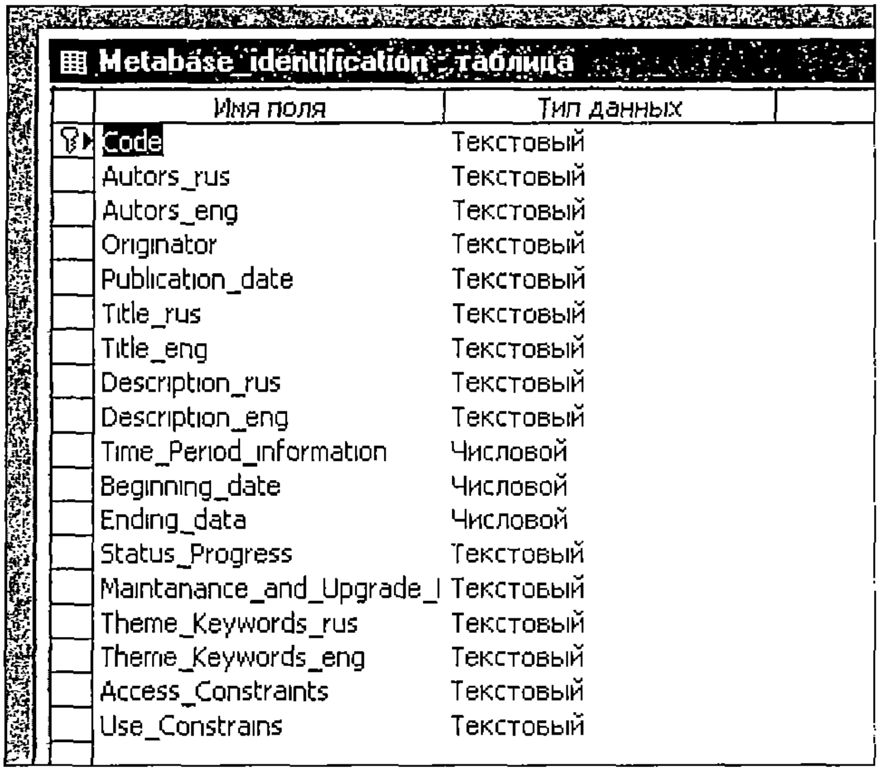
the most suitable one for this product

2.4. Perspectives of computer metadatabase version development

In the course of preparation of the computer metadatabase version's prototype the additional information on leterature sources will be given (about 300 names) and selective additional information on other sections All the information will be entered into MS-ACCESS metainf mb in the form of interconnected tables (for the provision of the effective search on any important parameters), the structure of which is given in fig 1 and 2 In order to simplify the system use by English speakers the names of all the fields in the database are given in English Russian-language information is mainly used but part of the key information (titles, main contents, key words) are translated into English

There is a possibility of continuation of the development and support of the works on the operation and expansion opf the metadatabase at IBRAE RAN In future the metadatabase can be suplemented with the data of all available information associated with the problem of nuclear submarines dismantlement.

Identification_Information

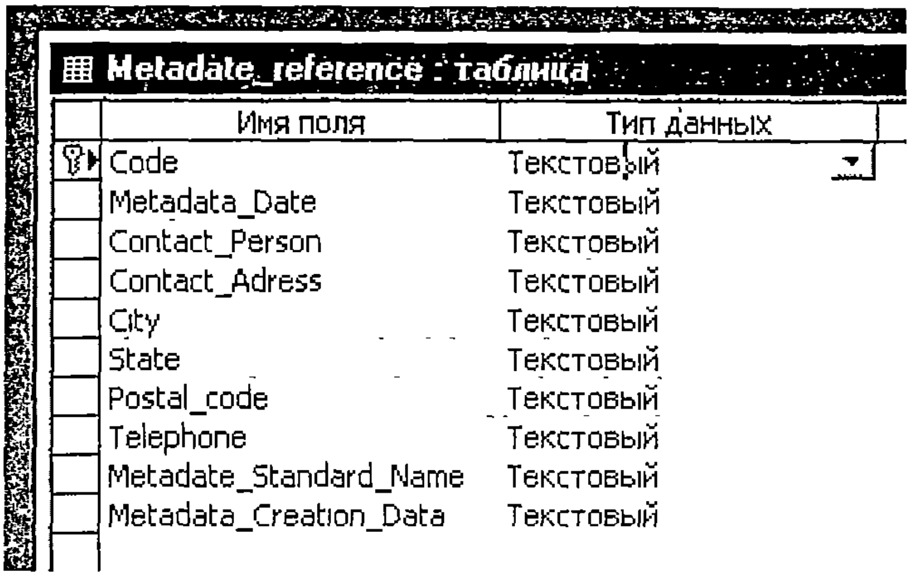


Metabase_identification : таблица

Имя поля	Тип данных
Code	Текстовый
Autors_rus	Текстовый
Autors_eng	Текстовый
Originator	Текстовый
Publication_date	Текстовый
Title_rus	Текстовый
Title_eng	Текстовый
Description_rus	Текстовый
Description_eng	Текстовый
Time_Period_information	Числовой
Beginning_date	Числовой
Ending_data	Числовой
Status_Progress	Текстовый
Maintanance_and_Upgrade_I	Текстовый
Theme_Keywords_rus	Текстовый
Theme_Keywords_eng	Текстовый
Access_Constraints	Текстовый
Use_Constrains	Текстовый

Fig. 1.

Metadata_Reference_Information



Metadate_reference : таблица

Имя поля	Тип данных
Code	Текстовый
Metadata_Date	Текстовый
Contact_Person	Текстовый
Contact_Adress	Текстовый
City	Текстовый
State	Текстовый
Postal_code	Текстовый
Telephone	Текстовый
Metadate_Standard_Name	Текстовый
Metadata_Creation_Data	Текстовый

Fig. 2.

Example of the meta-information data base fragment (about literature sourse) is shown here:

- Identification_Information
- Metadata_Reference_Information

Identification_Information

Citation

Citation_Information

Originator: Saint-Petersburg, "LIO Editor"

Publication_Date: 1998

Title

Navy and radiation Higiene v. 1

Description

Abstract

In the first volume of the Guidlines the main sections of hygiene are given: social hygiene with legal base of population health protection and military men, commune hygiene, feeding hygiene, clothes hygiene, labour of Navy specialists, included are the materials on medical aspects of ecological provision of Armed Forces in Russia. The guidelines contain theoretical thesis of the navy hygiene with a complete set of information of normative, methodological and reference character

reference character

Purpose

The guideline is intended for the listeners of the Navy-Medical Academy, other educational institutions which prepares Navy doctors and may be of use to the specialized state institutions of sanitary epidemic character, Ministry of Emergency Situations, municipal services

Time_Period_of_Content

Time_Period_Information

Range_of_Dates/Times

Beginning_Date 1998

Ending_Date 1998

Currentness_Reference

Status

Progress Complete

Maintenance_and_Update_Frequency Not planned

Keywords

Theme_Keyword_Thesaurus Higiene

Theme_Keyword navy, higiene, medicine

Access _Constraints Book must be received upon request

Use_Constraints Book contents is not available in Internet

Metadata_Reference_Information.

Metadata_Date 2000

Metadata_Contact

Contact_Information

Contact_Person_Primary

Contact_Person Vladimir Kisselev

Contact_Address

Address_Type B Tulskaya 52, Nuclear Safety Institute RAS (ИБРАЭ РАН)

City Moscow

State_or_Province Russia

Postal_Code 113191

Contact_Voice_Telephone 007(095)9552296

Metadata_Standard_Name FGDC Content Standards for Digital Geospatial Metadata

Metadata_Standard_Version 19940608

Metadata_Standard_Version 19940608

3. Composite elements (blocks) of database and sources of their information

№№	Name of the blocks of the information field	Information sources (selectively)	place of information storage
1	Organizational, management and executive structures of the project	In the final report	IBRAE
2	Reports and notes of the experts	3.1, 3.39, 3.46, 3.53	IBRAE
3	General review of the dismantlement process in the North and Far East	3.53, 3.60	IBRAE
4	Information on the main dismantled objects in the North and Far East		IBRAE
5	Information on pollution after dismantlement of nuclear submarines	2.12, 2.25; 2.37, 3.5, 3.20, 3.22	IBRAE
6	Information on current state of the territories participating in submarine dismantlement in the North and Far East	2.2, 3.19; 3.26, 3.49	Navy
7	The main regulations of the technological process of dismantlement for each ground of the North and Far East	2.31, 2.32, 3.60	Navy
8	Information on the health state of population living on the territories which participate in the dismantlement process	2.9, 2.10; 2.14, 3.12, 3.14, 3.66	In the open publication
9	Description of the sediment places, three compartment and reactor blocks and infrastructure of the dismantlement process and places of the spent nuclear fuel storage	2.36, 2.37, 3.5, 3.60	IBRAE
10	Existing risk evaluation methods and ecological consequences of dismantlement	3.13, 3.14, 3.39	IBRAE
11	Information on the existing monitoring system in the regions of the submarine dismantlement	3.1, 3.34, 3.37, 3.40, 3.46, 3.86	Navy
12	Normative-legal basis for the dismantlement and radioactive wastes treatment	[1.1-1.137], 2.10, 3.46	Navy, Ministry of Atomic Energy
13	The concept of complex dismantlement of the Russian nuclear submarines up to 2010		Navy

4. List of information sources used by the experts during the preparation of the materials of the ATRP-R program

1. Normative-legal documents.

1 1 Russian Law "On the protection of the population and territories from emergency situations of natural and man-caused character" 21 12 94 № 68-FL

1 2 Russian Law "On radiation safety of the population» 09 01 1996 г № 3-FL3 defines legal basis for the provision of the radiation safety of the population

1.3 Russian Law "On ecological expert examination" 23 11 95 № 174-FL Stipulates the requirements for the order of the conduction of the ecological expert examination, its main tasks and functions

1 4 Russian Law "On the internal sea-waters, territorial sea and included zone of the Russian Federation" 31 07 98 № 155-FL № 31 Art 3833 Stipulates the order of obtaining permits for research works conduction in internal sea-waters, territorial sea and included zone of the Russian Federation

1 5 Russian Law "On continental shelves of the Russian Federation" 30.11 95 № 187-FL Stipulates the order of obtaining permits for research works conduction on continental shelves of the Russian Federation

1 6 Russian Law "On the exclusive economic zone of the Russian Federation"17 12.98 № 191-FL Stipulates the order of obtaining permits for research works conduction in the exclusive economic zone of the Russian Federation

1.7 Russian Law "Code of the trade navigation of Russian Federation " 30 04 99 № 81-FL.

1 8 Russian Law " On industrial safety of the hazardous production objects 21 07 97 № 116-FL Stipulates legal, economic and social basis of provision of the safe operation of the hazardous objects

1 9 Russian Law " On environment protection " 19 12 91 №2060-1 Changes from 21 02 92 № 2397-1 and 2 06 93 № 5076-1 Defines general ecological requirements for projection, plants operation, constructions in industry and agriculture, pipeline construction and other objects which influence directly or indirectly environment. Defines the system of nature protection legislation of the RF " Water code of the RF" from 23 11 95, 'Land Code of RF" from 25 04 95, The basis for the forest legislation" from 24.04 95, "on the protection of the atmospheric air" form 4 May of 1999, 'On specially protected territories" from 14 03 95

1 10 Russian Law " On compulsory social insurance from accidents at production units" 24 06 98 № 125 FL-3

1 11 Russian Law " On licensing of several activities " 25 09 98 N 158-FL

1 12 Russian Law " On industrial wastes " 24 06 98 № 89-FL

1 13 Russian Law " On sanitary-epidemic safety of the population" 03 03 1999г № 52-FL Stipulates sanitary rules, norms and hygienic normatives during the treatment of radioactive substances and other sources of ionizing radiation

1 14 The resolution of the Russian Federation Government from 23 September № 1094 "On classification of the emergency situations of natural and man-caused character

radioactive substances and other sources of ionizing radiation

"Contains classification of of the emergency situations of natural and man-caused character.

1 15. The resolution of the Russian Federation Government from 31 October № 1310 "On measures providing ecological safety during the activities of the Russian Armed Forces"

1.16 The resolution of the Russian Federation Government from 18 May 1998 N 461 "On approval of the state ecological control conduction in the closed territorial formations and special military objects"

1 17 The resolution of the Russian Federation Government "On unified state automated system of radiation background control", 1992

1 18 The resolution of the Russian Federation Government from 24 12 94 № 1418 (edit from 01 12 97) "On licensing of several activities "

1 19. The resolution of the Russian Federation Government 05 11 95 № 1113 "On unified state system on prevention and liquidation of the emergency situations"

1 20 The resolution of the Russian Federation Government from 01 07 95 № 675 "On declaration of the industrial object of the Russian Federation"

1 21 The resolution of the Russian Federation Government from 17 07 98 № 779 "On the Federal executive body responsible for the provision of the industrial safety"

1.22 The resolution of the Russian Federation Government from 11 08 98 № 928 "On the list of technical equipment to be certified and used at production units "

1 23 The resolution of the Russian Federation Government from 02 02 98 № 1420 "On terms of declaring the industrial safety of the operating hazardous production objects"

1 24 The resolution of the Russian Federation Government from 01 07 96 № 766 "On state regulation and control of transboundary transportation of the hazardous wastes"

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