ISSN 1070-3632, Russian Journal of General Chemistry, 2012, Vol. 82, No. 13, pp. 2189–2193. © Pleiades Publishing, Ltd., 2012.
Original Russian Text © T.N. Tairov, 2012, published in Ekologicheskaya Khimiya, 2012, Vol. 21, No. 1, pp. 63–68.

Problems of Informational Support of Chemical and Radiation Ecological Monitoring of Long-Term Technological Storage of Reactor Blocks of Utilized Submarines Afloat in the Northwestern Region

T. N. Tairov

Private Educational Institute, "Atomprof" Institute of Continuing Professional Education, ul. Aerodromnaya 4A, St. Petersburg, 198261 Russia
e-mail: tair.tairov@groc.ru

Received January 23, 2012

Abstract—Complexity of the problems related to utilization of nuclear submarines (NSM) is determined not only by their huge scale but also by the necessity of systemic consideration of diverse factors, including political, economic, ecological, social, technological, and informational. Afloat storage of reactor compartment units is a complex chemical, technological and ecological problem, for sea water induces their extensive corrosion which creates a risk of leakage of radioactive heavy metal isotopes, fission products, and transuranium elements to the environment. While searching for and testing of technological solutions for utilization of NSM, the most important problems are chemical and radiation ecological monitoring of water areas and its informational support. The article contains systemic analysis of problems related to long-term technological storage of reactor compartment units afloat, and an optimal procedure for ecological radionuclide monitoring is proposed. The proposed procedure requires minimal equipment and radiation control range but ensures a sufficient confidence level.

DOI: 10.1134/S1070363212130038

IMPORTANCE OF THE PROBLEM

Among the set of chemical engineering problems related to management of radioactive wastes with a complex chemical composition produced by nuclear power engineering, industry, and nuclear navy, an important problem is decommissioning and disposal of nuclear submarines, especially its radiation ecological aspect [1, 2]. More than 450 naval nuclear reactors have been built in Russia, and their total capacity is comparable to the capacity of Russian nuclear power plants (NPP). Approximately two thirds of these reactors are located in the North-West of Russia, which is about 20% of the total number of nuclear reactors in the world. One hundred forty nuclear submarines and all surface ships are usually located at the naval bases of the Northern Fleet and Atomflot in Murmansk oblast.

The difficulty of solving nuclear submarine disposal problems is determined not only by their enormous volume but also by the need to account for different relevant factors, such as political, economic, environmental, social, and technological.

The lack of a consistent concept for disposal of nuclear ships in their life cycle after large-scale decommissioning in accordance to both international agreements on the reduction of strategic offensive arms and their moral and physical wear and tear, has put forward a number of tasks that require rapid decisions.

Long-term stay of decommissioned nuclear submarines afloat is inevitable. Therefore, real funding of the disposal process must be aimed primarily at developing security measures for long-term (15–20 years) technological storage afloat of nuclear submarines to be decommissioned. Currently, more than 90 nuclear-powered submarines (NPS) in the Northern Fleet are out of service. These submarines are disposed afloat at continuous deployment and temporary storage points, as well as in industrial and Russian Navy water areas.

It is important to emphasize that afloat storage of reactor compartment units (Fig. 1) is a complex chemical, engineering, and ecological problem, taking into account that sea water induces extensive corrosion of body compartments which may lead to discharge of radioactive isotopes of heavy metals, fission products, and transuranium elements to the environment [3, 4, 8, 9].

While developing and testing technological solutions on NPS disposal, the most challenging issue is chemical and radiological environmental monitoring of water areas for reactor compartment storage in view of strict environmental safety requirements and uneasy neighborhood to Norway [5].

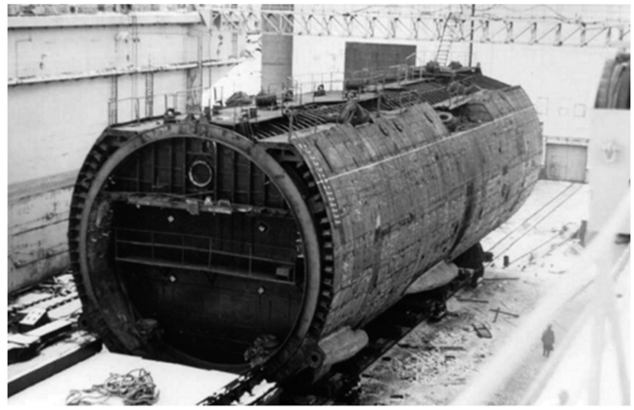

Fig. 1. Reactor compartment of a cruiser submarine.

KNOWN SOLUTIONS

Examinations of decommissioned NPS showed that, after unloading of spent nuclear fuel (SNF) from the reactor and removal of all radioactive materials, the radioactivity distributed over reactor compartment systems of NPS of 1st and 2nd generations may exceed 10000 Ci or 3.7×10^{14} Bq. About 98% of radioactivity originating from long-lived radionuclides is localized in the first loop. The overall radionuclide discharge to water is different for submarines with large and small displacements (Table 1). The yield of radionuclides from low-displacement submarines can be calculated by multiplying the corresponding values for high-displacement submarines by a factor of 0.58.

The time constant of water treatment in the bay was determined with account taken of the regular semidiurnal pattern of the tides in the bays of the Kola Peninsula with a frequency of 705 per year. The average amplitude of the tide is about 250 cm, and it changes only slightly throughout a year. The total volume of water in the bay is assumed to be approximately 108 m^3. Under these conditions, the time constant is about 10^{-2} h^{-1}. Leakage of the pressure hull and the reactor may cause water to get inside and induce rapid leaching of fission products and transuranium elements from spent fuel (Table 2). The content of fission products and transuranium elements was calculated for normal operation mode of submarines of the second generation after fuel exhaustion.

A block diagram of a systemic analysis of the problem under study (Fig. 2) shows that a large set environmental issues exists in addition to technological, political, and legal issues [6, 7]. Among these, the most difficult is development of an optimal general procedure for chemical and radiological environmental monitoring.

The developed procedure is based on systemic analysis of methods and techniques for radiochemical treatment of environmental samples (water, soil, sludge), as well as of techniques for measuring alpha-, gamma-, beta-active nuclides. Figure 3 shows the

Table 1. Yields of particular radionuclides from the pressure hull of a large submarine, Bq/l

Storage duration after disposal (years)	Stay duration before disposal								
	2 years			5 years			10 years		
	^{55}Fe	^{60}Co	^{63}Ni	^{55}Fe	^{60}Co	^{63}Ni	^{55}Fe	^{60}Co	^{63}Ni
0	8.4×10^5	9.6×10^4	2.4×10^4	3.2×10^5	6.7×10^4	2.4×10^4	1.0×10^5	3.4×10^4	2.4×10^4
2	5.0×10^5	7.4×10^4	2.4×10^4	2.3×10^5	5.1×10^4	2.4×10^4	6.2×10^4	2.7×10^4	2.4×10^4
5	2.4×10^5	5.0×10^4	2.3×10^4	1.1×10^5	3.4×10^4	2.3×10^4	2.9×10^4	1.8×10^4	2.3×10^4
10	6.4×10^4	2.6×10^4	2.2×10^4	3.0×10^4	1.8×10	2.2×10^4	7.9×10^3	9.4×10^3	2.2×10^4
20	4.8×10^3	6.8×10^3	2.1×10^4	2.3×10^3	4.8×10^3	2.1×10^4	6.1×10^2	2.5×10^2	2.1×10^4

Table 2. Yields of fission products (^{90}Sr, ^{137}Cs) and transuranium elements (^{239}Pu, ^{241}Am) from leakage of the pressure hull and reactor plant, Bq/l

Storage duration after disposal (years)	Stay duration before disposal					
	5 years		10 years		15 years	
	^{90}Sr, ^{137}Cs	^{239}Pu, ^{241}Am	^{90}Sr, ^{137}Cs	^{239}Pu, ^{241}Am	^{90}Sr, ^{137}Cs	^{239}Pu, ^{241}Am
0	8.8×10^9	7.5×10^8	6.4×10^9	6.0×10^8	5.6×10^9	4.9×10^8
5	6.4×10^9	6.0×10^8	5.6×10^9	4.9×10^8	4.9×10^9	4.0×10^8
10	5.6×10^9	4.9×10^8	4.9×10^9	4.0×10^8	4.3×10^9	3.2×10^8
15	4.9×10^9	4.0×10^8	4.3×10^9	3.2×10^8	3.9×10^9	2.7×10^8

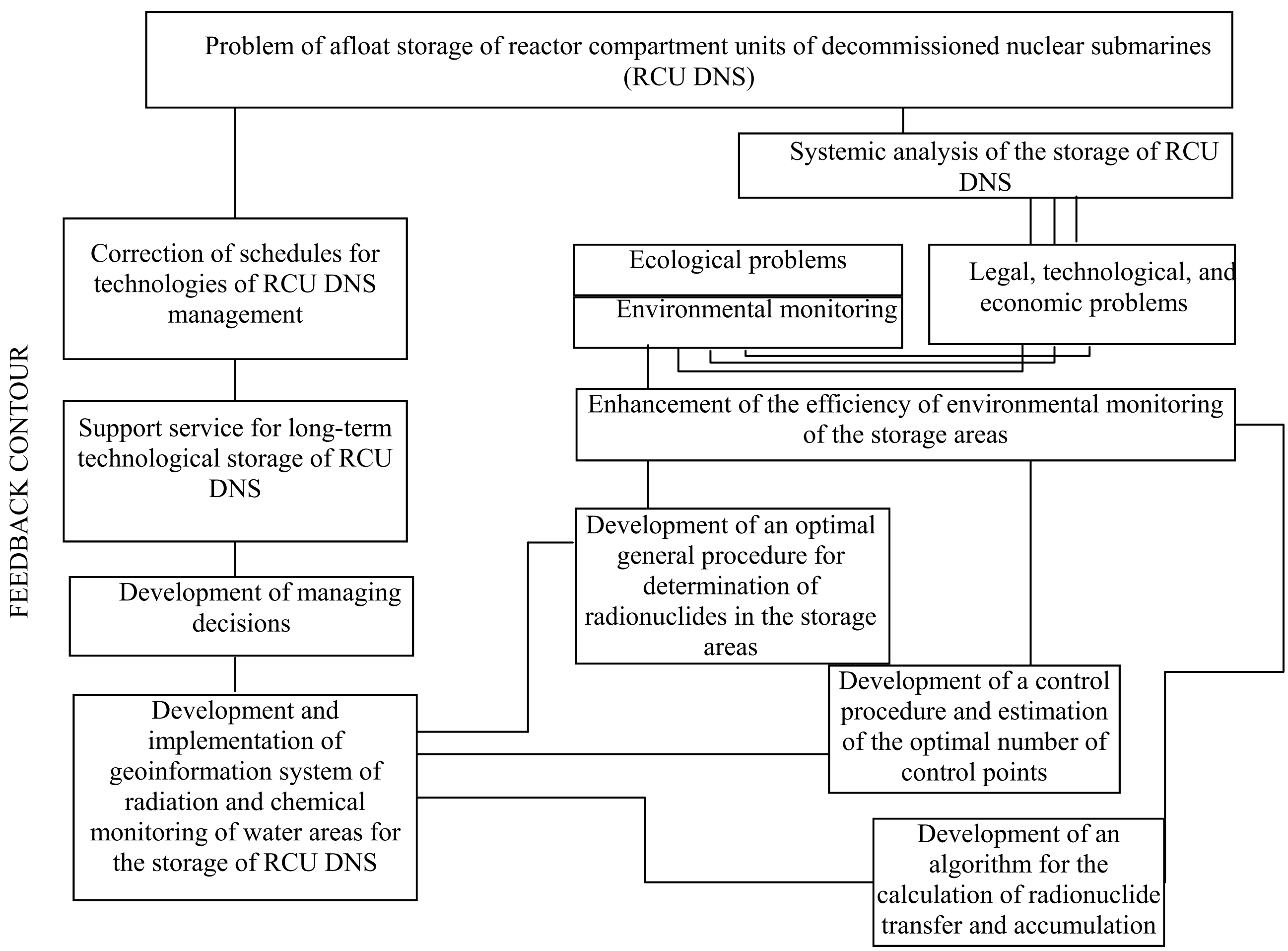

Fig. 2. Block diagram of systemic analysis of ecological problems related to storage of reactor compartment units of decommissioned nuclear submarines (RCU DNS).

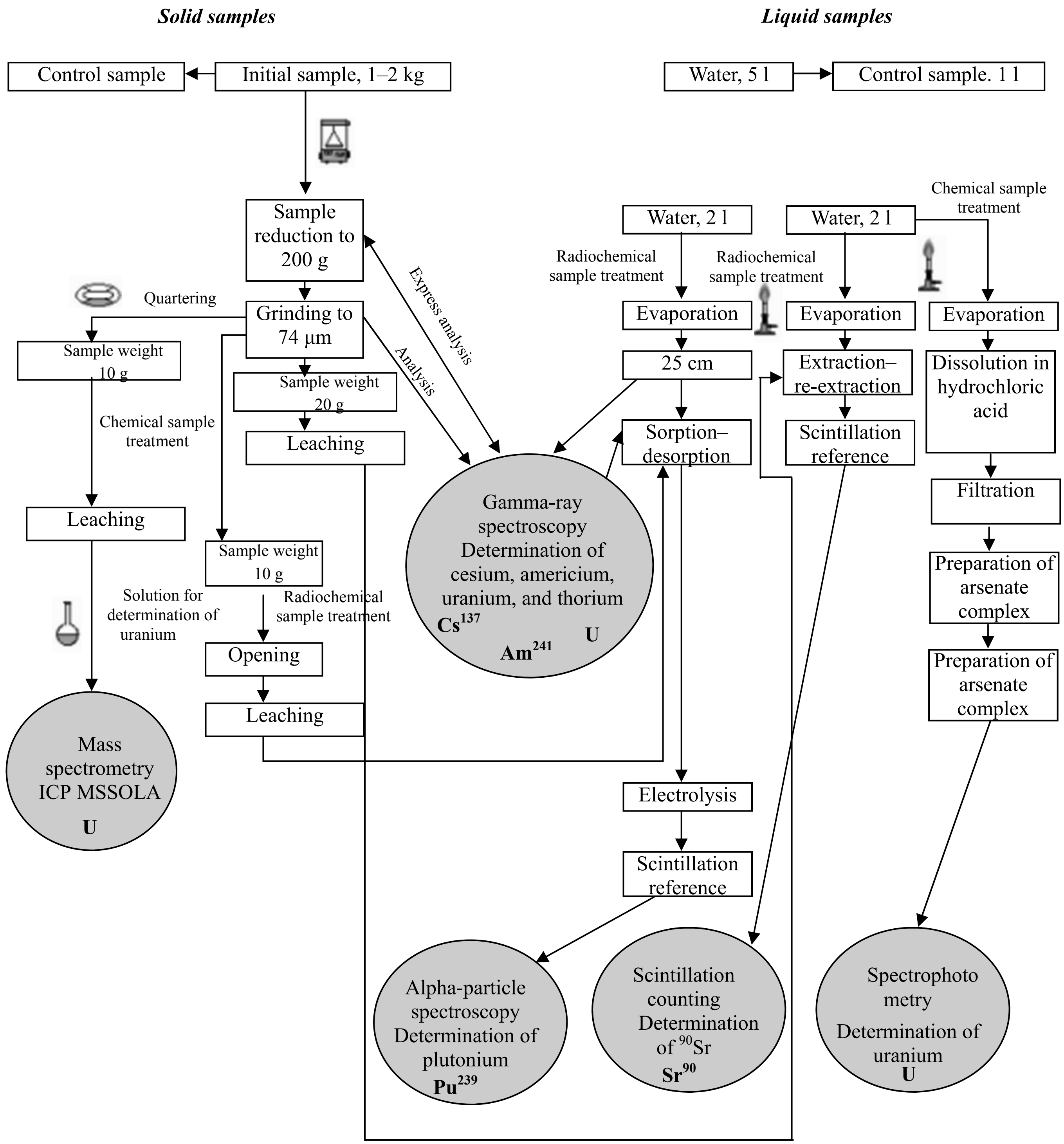

Fig. 3. Optimal general procedure for determination of radionuclides.

scheme of a comprehensive methodology for the isolation, concentration, and determination of radionuclides. The proposed procedure is advantageous due to minimal number of required equipment units and the amount of work on radiation monitoring.

Nitric acid was used for leaching, VP1-P ion exchanger was used for sorption, and diethyl ether was used for extraction.

REFERENCES

1. Agapov, A.M., Makukhin, D.V., Novikov, G.A., and Radaev, N.N., *Aktual'nye voprosy ekologicheskoi bezopasnosti Minatoma Rossii* (Actual Environmental Safety Problems of the Ministry of Nuclear Energy of the Russian Federation), Moscow: Minatom, 2003.
2. Kryshev, I.I. and Ryazantsev, E.P., *Ekologicheskaya bezopasnost' yaderno-energeticheskogo kompleksa Rossii* (Environmental Safety of the Nuclear Power Complex of Russia), Moscow: IzdAT, 2010.
3. Tairov,T.N., *Materialy 32-i mezhvuzovskoi nauchno-teoreticheskoi konferentsii* (Proc. 32nd Interinstitution Scientific–Theoretical Conf.), St. Petersburg: VVMIU, 1996.
4. *Tyazhelye estestvennye radionuklidy v biosfere* (Natural Heavy Radionuclides in the Biosphere), Aleksakhin, R.M., Ed., Moscow: Nauka, 1990.
5. *Rosgidromet. GU "NPO Taifun." Radiatsionnaya obstanovka na territorii Rossii i sopredel'nykh gosudarstv v 2008 godu* (*Rosgidromet*. State Enterprise *NPO Taifun*. Radiological Conditions in Russia and Neighboring Countries in 2008), Obninsk, GU VNIIGMI-MTsD, 2009.
6. Tairov,T.N., *Sozdanie avtomatizirovannoi sistemy radiatsionnogo ekologicheskogo monitoringa (ASREM) v VMF. Polyarnoe siyanie 99* (Development of an Automated Radiological Environmental Monitoring System in Russian Navy. Aurora 99), Moscow: Mosk. Inzh.-Fiz. Inst.
7. Tairov,T.N., *Sovremennye trebovaniya po obespecheniyu bezopasnosti v oblasti ispol'zovaniya atomnoi energii* (Modern Safety Requirements in Uses of Atomic Energy), St. Petersburg, 2005.
8. Brykin, S.N., Serebryakov, I.S., and Tairov, T.N., *Trudy 7 mezhdunarodnoi konferentsii "Bezopasnost' yadernykh tekhnologii. Obrashchenie s radioaktivnymi otkhodami"* (Proc. 7th Int. Conf. "Safety of Nuclear Technologies. Radioactive Waste Management"), St. Petersburg, 2004, p. 107.
9. *Vtoroi natsional'nyi doklad Rossiiskoi Federatsii o vypolnenii obyazatel'stv, vytekayushchikh iz Ob"edinennoi konventsii o bezopasnosti obrashcheniya s otrabotavshim toplivom i bezopasnosti obrashcheniya s radioaktivnymi otkhodami* (Second National Report of the Russian Federation on the Implementation of the Obligations Imposed by the "Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management"), Moscow: IzdAT, 2009.