

ASSESSMENT OF THE RADIATION AND HEALTH PHYSICS SITUATION IN THE AREA OF SHIP REPAIR ENTERPRISES IN KAMCHATKA KRAI

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Abstract. The objectives of the study are to examine the radiation and health physics situation in the area of ship repair enterprises servicing ships with nuclear power installation; to assess its possible impact on the environment and the population.

Materials and research methods. The study of radiation and health physics situation on the territory was conducted by walking gamma survey using portable gamma spectrometric complexes MKS-01A "Multirad-gamma" and MKS-AT6101C. Gamma-spectrometric and radiochemical methods of analysis were used to determine the specific activity of man-made and natural radionuclides in environmental samples.

Results of the study and their analysis. Practical medical and hygienic measures to study the radiation and health physics situation were carried out in 2019. It was found that the ambient equivalent dose rate in the areas of ship repair enterprises is at the level of regional values and does not exceed 0.12 μSv/h. Radionuclide specific activity in the soil of the surveyed areas does not exceed 4.5 Bq/kg – for ⁹⁰Sr and 12 Bq/kg – for ¹³⁷Cs, which does not exceed the established norms for unrestricted use of solid materials. Radionuclide content in the sea water samples taken in the area of closed administrative territorial unit Krashenninikov Bay does not exceed on average: for ¹³⁷Cs – 7 mBq/L, for ⁹⁰Sr – 2.1 mBq/L. When comparing the results obtained with the official data on the radionuclide content in the water of Avacha Bay (⁹⁰Sr up to 2.08 mBq/L at the annual average of 1.14 mBq/L), we may state that they are at the same level as the regional ones. Radionuclide content in bottom sediment samples varies within the following limits: for ¹³⁷Cs – from 0.14 to 3 Bq/kg, for ⁹⁰Sr – from 0.11 to 1.5 Bq/kg and is similar to the general values for soil samples.

Thus, the radiation and health physics characteristics of the study area vary little and remain practically at the level of the results of studies conducted in 2014-2015. The content of man-made radionuclides in the samples of environmental objects is at the level of average values typical for the region.

Potentially radiation-hazardous works carried out in 2019 at enterprises of closed administrative territorial unit Vilyuchinsk had no reliable radiation impact on the environment and population.

Key words: cesium-137, closed administrative territorial unit Vilyuchinsk, dose rate, Kamchatka Krai, nuclear submarines, radiation and hygienic situation, radiation safety, radiochemistry, recycling, ship repair enterprises, spectrometry, strontium-90

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ОЦЕНКА РАДИАЦИОННО-ГИГИЕНИЧЕСКОЙ ОБСТАНОВКИ В РАЙОНЕ РАСПОЛОЖЕНИЯ СУДОРЕМОНТНЫХ ПРЕДПРИЯТИЙ В КАМЧАТСКОМ КРАЕ

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Резюме. Цели исследования – изучить радиационно-гигиеническую обстановку в районе расположения судоремонтных предприятий, обслуживающих корабли с ядерными энергетическими установками (ЯЭУ); оценить её возможное воздействие на окружающую среду и население.

Материалы и методы исследования. Исследование радиационно-гигиенической обстановки непосредственно на территории проводилось методом пешеходной гамма-съемки мощности AMBIENTного эквивалента дозы гамма-излучения (МАЭД ГИ) с использованием портативных гамма-спектрометрических комплексов MKS-01A «Мультирад-гамма» и MKS-AT6101C. Для определения удельной активности техногенных и естественных радионуклидов в пробах объектов окружающей среды применялись гамма-спектрометрические и радиохимические методы анализа.

Результаты исследования и их анализ. Практические медико-гигиенические мероприятия по исследованию радиационной гигиенической обстановки проводились в 2019 г. Было установлено, что МАЭД ГИ в районах

расположения судоремонтных предприятий находится на уровне региональных значений и не превышает 0,12 мкЗв/ч. Удельная активность радионуклидов в почве обследуемых территорий не превышала 4,5 Бк/кг – по ^{90}Sr и 12 Бк/кг – по ^{137}Cs , что не выше установленных нормативов для неограниченного использования твердых материалов. Содержание радионуклидов в пробах морской воды, отобранной в районе закрытого административно-территориального образования – ЗАТО (бухта Крашенинникова), не превышало в среднем: по ^{137}Cs – 7 мБк/л; по ^{90}Sr – 2,1 мБк/л. При сравнении полученных результатов с официальными данными о содержании радионуклидов в воде Авачинской бухты (^{90}Sr – до 2,08 мБк/л при среднегодовом – 1,14 мБк/л) можно было констатировать, что они находились на одном уровне с региональными. Содержание радионуклидов в пробах донных отложений варьировалось в следующих пределах: по ^{137}Cs – от 0,14 до 3 Бк/кг; по ^{90}Sr – от 0,11 до 1,5 Бк/кг и было сходно с общими значениями для проб почвы.

Таким образом, радиационно-гигиенические характеристики исследуемого района слабо варьировались и оставались практически на уровне результатов исследований, проведенных в 2014–2015 гг. Содержание техногенных радионуклидов в пробах объектов окружающей среды находилось на уровне средних значений, характерных для региона. Потенциально радиационно опасные работы, проводившиеся в 2019 г. на предприятиях ЗАТО г. Вилучинск, не оказали достоверного радиационного влияния на окружающую среду и население.

Ключевые слова: атомные подводные лодки, закрытое административно-территориальное образование г.Вилучинск, Камчатский край, мощность дозы, радиационная безопасность, радиационно-гигиеническая обстановка, радиохимия, спектрометрия, стронций-90, судоремонтные предприятия, утилизация, цезий-137

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Introduction

At present the Federal Target Program "Industrial Utilization of Weapons and Military Equipment of the Nuclear Complex in 2011-2015 and until 2020" realisation is coming to an end in Russia. One of its tasks is to ensure public health and environmental safety during the disposal of weapons and military equipment¹. A study of the radiation and hygienic situation in the area of ship repair facilities that dismantled decommissioned submarines with nuclear power units and former onshore technical bases that stored and processed spent nuclear fuel was conducted.

The study area is an area of closed administrative-territorial formation Vilyuchinsk. Two enterprises are located on its territory: Joint Stock Company "North-Eastern Repair Center" and the Center for Radioactive Waste Management – Vilyuchinsk Branch of the Far East Center for Radioactive Waste Management – a branch of Federal State Unitary Enterprise "Federal Environmental Operator".

The Northeast Repair Center is located in Seldevaya Bay. The center repairs nuclear and diesel submarines, surface ships, auxiliary vessels, and dismantles nuclear submarines². Nearby is one of the districts of the closed administrative territorial entity of Vilyuchinsk – the settlement of Seldevaya. As part of the state contract with the Federal State Unitary Enterprise Enterprise for Radioactive Waste Management, work was performed at the end of 2019 to lift and subsequently transport the afloat reactor units to a disposal site in Primorsky Krai³.

Vilyuchinsk Branch of DalRAO Far East Center – Branch of Federal State Unitary Enterprise "Federal Environmental Operator" was established on the territory and on the basis

of the property of the Pacific Fleet coastal technical bases in Krashennnikov Bay.

The coastal technical base provided:

- Recharging of nuclear submarine reactors using floating technical bases at nuclear submarine repair sites;
- Recharging of activity filters of the 1st and 3rd circuits of nuclear power plants of nuclear submarines;
- Reception and storage of solid radioactive waste in onshore storage facilities;
- Short-term mooring at the floating berth of nuclear service ships (Project 326M floating maintenance base) and technical liquid tankers (Project 1783 and 1783A) and temporary storage of spent fuel assemblies, liquid radioactive waste, substandard fuel assemblies in them;
- Storage and transfer of special technological (reloading) equipment to the floating technical base⁴.

At present, the enterprise is solving tasks related to temporary storage of radioactive waste. Since 2016, work has been underway at the Vilyuchinsk branch to remove waste from storage facilities, to place it in shipping containers that will be transported by sea to the Regional Center for Conditioning and Long-Term Storage of the DalRAO Far East Center for subsequent immobilization and placement in long-term storage. After complete withdrawal of radioactive waste, the facilities will be decontaminated, and the area will be "rehabilitated". At present, all solid radioactive waste has been completely removed from the Vilyuchinsk Branch to the pier of the Severo-Vostochny Repair Center.

Vilyuchinsk, located on the coast of Tarja Bay (Krashennnikov Bay) of Avacha Bay, 25 km from the regional center, was created in accordance with the Decree of the Presidium of the RSFSR Supreme Soviet of October 16, 1968 by

¹ URL: <http://stat.mil.ru/pubart.htm?id=11845577@cmsArticle> (10/19-2020)

² URL: <https://свпу.рф/> (10/1920)

³ URL: <http://nuclear-submarine-decommissioning.ru/node/1246> (10/1920)

⁴ Progress Research Report / State Research Center – Burnazyan Medical Biophysical Center of FMBA of Russia. Moscow, 2014.



Рис. 1. Схема расположения исследуемых территорий в ЗАТО Вилочинск Камчатского края⁶
 Fig. 1. Scheme of the location of the study areas in the closed administrative territorial unit Vilyuchinsk, Kamchatka Krai⁶

merging the settlements Primorsky, Sovetskiy, Seldevaya, Rybachiy, Yagodny, Lakhtazhny and Bogatyrevka⁵. The location of the studied territories is shown in Fig. 1.

The objectives of the study are to examine the radiation and health physics situation in the area of ship repair facilities servicing ships with nuclear power installations; to assess its possible impact on the environment and the population.

Materials and methods of research.

The following parameters were measured within the research:

- gamma equivalent dose rate of ambient gamma radiation;
- specific activity of man-made radionuclides in soil;
- specific activity of man-made radionuclides in marine bottom sediments and seawater.

Environmental sampling was conducted in accordance with regulatory documents and methodological guidelines⁷⁻¹⁰.

Soil sampling points were located evenly over the area of the study in areas with undisturbed soil cover. Samples of 1 kg were taken from the surface layer of five centimeters.

An average seawater sample was taken by excavating equal volume (5.0 l) water samples at a distance of 1-2 m from the shore for a set time (10-20 min) up to the required total volume (20 l) of the sample. Seawater sampling points were selected in the coastal water areas free from aquatic vegetation and other objects.

The activity of gamma-emitting radionuclides in the selected samples was measured by gamma-spectrometric method on a CANBERRA gamma-spectrometer with a germanium detection unit in accordance with the measurement procedure [1].

Determination of ⁹⁰Sr specific activity in selected samples was performed on radiometric units UMF-2000 after radiochemical separation of radionuclides in accordance with the methodical instructions [2].

The ambient equivalent dose rate of gamma-radiation on the territory was studied in accordance with the methodological recommendations by the method of continuous

walking gamma survey [3]. Portable spectrometric units MKS-01A "Multirad-M" and MKS-AT6101C were used for measurements of ambient equivalent dose rate of gamma radiation throughout the territory. Range of recorded gamma radiation energy MKS-01A "Multirad-M" with a detector unit BDKS-63-01A ranges from 0.04 to 3 MeV; measurement range of photon radiation dose equivalent ambient dose rate is from 0.03 to 60 μ Sv/h. Maximum permissible basic relative error of gamma radiation dose rate ambient equivalent measurements ranges from

0.03 to 0.05 μ Sv/h and is 25%; in the range from 0.5 to 60 μ Sv/h — (25% — 0.167 MAED). The range of registered energy of gamma radiation of spectrometer MKS-AT6101S with detector unit BDKG-11M is 0.02 to 3 MeV, the measurement range of photon radiation ambient dose equivalent power is 0.03 to 150 μ Sv/h. Maximum permissible basic relative error of measurements in the range from 0.01 to 150 μ Sv/h is 20%. These devices allow to conduct gamma survey of the area with the possibility of radionuclide identification and referencing to geographical coordinates using global navigation system (GPS). The appearance of the devices in use is shown in Fig. 2.

Results of the study and their analysis.

Comparison of the measurement results of the ambient equivalent dose rate of gamma radiation in 2019 with the results of earlier measurements are shown in Table 1.

The values of ambient equivalent dose rate of gamma radiation obtained in 2019 were at the same level throughout the territory and within the variation of natural radiation background for Kamchatka Krai (0.10-0.12 Sv/h), and at the same level as the results of previous studies conducted in 2014-2015. [6]. The scheme of the course of the survey of the ambient equivalent dose rate of gamma-radiation in 2019 is shown in Fig. 3.

In the course of works on the territory of closed administrative territorial unit of Vilyuchinsk we took and analyzed samples of environmental objects on the content of man-made and natural radionuclides. Table 2 shows the results of the analysis of soil samples for radionuclide content in the studied area.

Levels of ¹³⁷Cs and ⁹⁰Sr technogenic radionuclides content in soil in the territory of Vilyuchinsk Closed Administrative Territorial Unit are generally uniform. The maximum values of ⁹⁰Sr and ¹³⁷Cs content in the soil of the area of the location of JSC "Northeastern Repair Center" and Primorsky area are 4.5 and 12 Bq/kg respectively, which does not exceed the established norms for unrestricted use of solid materials¹¹.

⁹ Nature Protection. Soils. Methods for Sampling and Preparation of Soil for Chemical, Bacteriological, Helminthological Analysis. GOST 17.4.4.02-84. 2008. 7 p. (In Russ.).

¹⁰ Soil Quality. Sampling. Part 5: Guidance on the Procedure for the Investigation of Urban and Industrial Sites with Regard to Soil Contamination (MOD). ISO 10381-5:2005. 2009. 27 p. (In Russ.).

¹¹ Federal Center for Hygiene and Epidemiology of Rosпотребнадзор. Basic Sanitary Rules for Radiation Safety (OSPORB-99/2010). Sanitary Rules and Regulations. 2010. 83 p. (In Russ.).

⁵ URL: <http://www.viluchinsk-city.ru/city/history.php> (09.10.2019)

⁶ URL: <http://www.google.ru/maps> (10/26/2020).

⁷ Water. General Requirements for Sampling. GOST 31861-2012. 2013. 31 p. (In Russ.).

⁸ Nature Protection. Soils. General Requirements for Sampling. GOST 17.4.3.01-83. 2004. 3 p. (In Russ.).



Рис. 2. Спектрометрические комплексы MKS-01A «Мультирад-М» и MKS-AT6101C [4, 5]

Fig. 2. Spectrometric complexes MKS-01A "Multirad-M" and MKS-AT6101S [4, 5]

The data in Table 2 show that activity values of natural radionuclides in soil in the territories of closed administrative territorial unit Vilyuchinsk obtained in 2019 were almost at the same level as average activity values in the territory of Vilyuchinsk Far East Center "DalRAO" in 2014-2015.

Radionuclide content in the seawater samples (3 samples) taken in the area of Vilyuchinsk Branch of DalRAO Far East Center did not exceed on average: for ^{137}Cs — 7 mBq/L; for ^{90}Sr — 2.1 mBq/L. When comparing the obtained results with reference data on radionuclide content in the water of Avacha Bay (^{90}Sr — up to 2.08 mBq/L with annual average value of 1.14 mBq/L), one could state that they were at the same level as the regional ones [6].

Radionuclide content in bottom sediment samples (3 samples) varies within the following limits: for ^{137}Cs — from 0.14 to 3 Bq/kg; for ^{90}Sr — from 0.11 to 1.5 Bq/kg.

According to the Federal State Budgetary Institution "Typhoon", in 2019 in the observation points of the 100-km zone of radiation hazardous objects in Kamchatka Region, the average monthly values of atmospheric deposition varied from 0.3 to 0.85 Bq/m²×day. They averaged 0.5 Bq/m²×day and did not exceed 183 Bq/m² year in total for the year [6]. These values do not differ from the average values typical for the whole Kamchatka Krai in 2019.

Conclusion

A study of the radiation situation in the area of the closed administrative territorial unit Vilyuchinsk in 2019 showed:

1. In all investigated areas of closed administrative territorial unit Vilyuchinsk the values of ambient equivalent dose rate of gamma-radiation are at the level of regional values and correspond to the average values of ambient equivalent dose rate of gamma-radiation obtained in the course of previous studies (2014-2016). It can be confidently stated that during all the years of research the gamma-radiation ambient dose equivalent rate in the area of closed administrative territorial unit Vilyuchinsk has not changed.

2. Obtained in 2019 values of man-made and natural radionuclides in soil, bottom sediments and sea water — both in the area where the enterprises are located and in nearby settlements (Primorsky, Rybachiy and Seldevaya

Таблица 1 / Table No. 1
Распределение значений МАЭД ГИ на территории ЗАТО г. Вилучинск в 2019 г.

Distribution of the ambient equivalent dose rate of gamma radiation values in the territory of the closed administrative territorial unit Vilyuchinsk in 2019

Место измерения Place of measurement	Количество измерений, абс. Number of measurements, abs.	Значения МАЭД ГИ, мкЗв/ч* Ambient equivalent dose rate of gamma radiation values, μSv/h*	
		max	медиана median
Р-н Приморский Primorskiy district	2327	0,12	0,08 (0,05–0,10)
Пос. Сельдевая Seldevaya village	558	0,11	0,07 (0,05–0,09)
Р-н АО СВРЦ JSC Northeast Repair Center District	194	0,12	0,07 (0,05–0,10)
Дорога отделение Вилучинск – АО СВРЦ Vilyuchinsk Branch –JSC Northeast Repair Center Road	1245	0,09	0,04 (0,03–0,05)
Р-н отделения Вилучинск Vilyuchinsk Branch District	272	0,09	0,04 (0,03–0,05)
Дорога отделение Вилучинск – р-н Рыбачий Vilyuchinsk Branch –Rybachiy District Road	698	0,09	0,04 (0,03–0,06)
Р-н Рыбачий Rybachiy District	3723	0,12	0,05 (0,03–0,06)
Прочие территории Other territories	923	0,11	0,04 (0,03–0,06)
По результатам работ в 2014–2015 гг. ⁴ According to the results of work in 2014-2015 ⁴		0,10	0,08
Общие значения для Камчатского края [6] / Total values for Kamchatka Krai [6]		0,13	0,09

Примечание: * максимальные значения, а также границы средних (указаны в скобках) приведены с запасом на расширенную неопределённость измерений
Note. * maximum values, as well as the boundaries of the averages (in parentheses) are given with a reserve for the expanded uncertainty of measurements

districts) — are at the same level as the average values across the region and correspond to the values obtained in the course of studies conducted in 2014-2015.



Рис. 3. Схема хода съемки МАЭД ГИ на территориях ЗАТО г. Вилучинск в 2019 г.⁶

Fig. 3. Diagram of the survey progress of the ambient equivalent dose rate of gamma radiation in the territories of the closed administrative territorial unit Vilyuchinsk in 2019⁶

Статистические характеристики распределения величин удельной активности радионуклидов в почве, полученных в ходе работ в 2019 г., в сравнении с результатами исследований, проводившихся в 2014-2015 гг.⁴
 Statistical characteristics of the distributions of specific activity values of radionuclides in soil obtained during the work in 2019, compared with the results of studies conducted in 2014-2015⁴

Территория Territory	Год Year	Кол-во изм., абс. Number of meas- urements,	Диапазон значений удельной активности, Бк/кг* / Specific activity value range, Bq/kg*					
			⁹⁰ Sr	¹³⁷ Cs	²³² Th	²²⁶ Ra	⁴⁰ K	²³⁵ U
Р-н отделения Вилючинск – ДВЦ «ДальРАО» Vilyuchinsk Far Eastern Center "DalRAO" district	2019	6	<0,2-1,3	0,17-5	1-14	3,1-8,0	70-230	-
	2014- 2015 – пром. площадка Industrial territory in	-	1,5** (<0,2-7,0)	9,2** (0,13-116,0)	-	-	-	-
Р-н Приморский Primorskiy District	2019	8	<0,2-1,3	0,18-12,0	2,8-6,8	4,1-9,2	180-290	0,67-2,0
Р-н Рыбачий Rybachiy District	2019	16	<0,2-1,1	0,16-5,4	3,2-7,5	5,3-13,0	147-240	0,64-3,0
Пос. Сельдевая АО СВРЦ Seldevaya Village — JSC Northeast Repair Center	2019	5	<0,2-4,5	<0,44-0,8	4,4-10,0	3,8-7,5	145-250	0,61-2,0
Проч. террито- рии /Other terr.	2019	7	<0,2-0,77	0,33-8,3	3,8-8,6	3-5	43-300	0,5-1,3

Примечание: * значения вычислены с учётом расширенной неопределённости измерений, ** приведены средние значения
 Note: * values are calculated taking into account the expanded uncertainty of measurements, ** average values are given

3. The content of man-made and natural radionuclides in samples of bottom sediments generally corresponds to the content of radionuclides in soil samples of the region.

4. According to the Federal State Budgetary Institution "Typhoon", monthly average atmospheric precipitation in 2019 did not differ from the average values typical for the whole Kamchatka Territory.

In conclusion, we can state that the radiation and hygienic situation in the area of Vilyuchinsk Closed Administrative Territorial Unit is generally satisfactory. The operation of ship repair facilities and enterprises servicing ships with nuclear power installations had no significant radiation impact on the environment and the population.

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