Current trends of the provision for radiation safety of the population of the Russian Federation

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The article is devoted to the actual issues of Russian Federation population radiation safety providing at the present stage. The important role of radiation-hygienic passportization is underlined in the process of the obtaining of objective information of radiation situation in the country, of population exposure doses from the all sources: artificial and natural, from the use of ionizing irradiation sources in medicine. The leading role is shown of the natural ionizing irradiation sources in the level of the country population exposure. The main directions of activities are stated aimed on the decreasing of population exposure doses from the natural sources. The brief characteristics is given of the radiation situation on the territories radioactively contaminated after the accident on the Chernobyl NPP, in the Pacific Ocean basin after the accident on the "Fukushima-1" NPP, of the main measures for radiation protection providing and for counteraction to radiation terrorism during the period of international sports and mass actions which were carried out in Russia in the last years (XXVII World Summer Universiade in 2013 in Kazan, XXII Olympic and XI Winter Paralympics Games in 2014 in Sochi). The most important tasks are defined for the improvement of Russian Federation population radiation safety at the present stage.

Key words: *radiation protection, radiation safety, radiation hygiene, exposure doses, regulation, permissiable levels, radon, radiation accidents, counteraction to radiation terrorism.*

Our country has achieved frontline positions in the development of nuclear technologies. Radiation hygiene has evolved in parallel with the development of technologies, accumulating our knowledge of the effects of ionizing radiation on human health.

Fundamental scientific achievements of our scientists in the field of nuclear and radiation technologies development and methodology to ensure radiation safety are recognized worldwide. Russian scientists and experts, working as members and experts of the International Commission on Radiological Protection (ICRP), the International Atomic Energy Agency (IAEA), the Scientific Committee on the Effects of Atomic Radiation to the United Nations (UNSCEAR), the WHO, the Global Initiative to Combat Nuclear Terrorism (GICNT) participate in all important international projects providing radiation safety of the population of the planet, including mitigation of consequences of the Chernobyl and Fukushima nuclear power plant accidents. They are also instrumental in the development of almost all international documents on radiation safety relevant to the use of nuclear technology and radioactive substances.

Our scientists have developed and implemented a unique system of hygienic standards, ensuring a high level of radiation safety of the personnel and population. The system of radiation safety of the population in our country has always been the foremost, outrunning many nuclear countries in the operative implementation of the innovative science into the radiation protection of the population. This is well illustrated by the establishment of dose limits for the personnel working with sources of ionizing radiation (SIR). In 1948, in the first Soviet standard (standard T-1031) the dose limit for the annual radiation exposure of radiologists was established, equivalent to the current 300 mSv, while the ICRP recommended a 500 mSv limit. With the development of radiobiology and the accumulation of new data on the effects of ionizing radiation on the human body, dose limits were lowered, reaching 20 mSv per year (table. 1).

Scientifically based system of hygienic standards for radiation exposure, enshrined in the Radiation Safety Standards (NRB) and basic sanitary rules of radiation safety (OSPORB), combined with an effective system of the supervision of compliance with established standards, allowed to adopt the Federal Law "On Radiation Safety of the Population" in 1996 [2], which established the legal basis for the implementation of modern concepts of radiation safety. It allowed to authorize acceptable levels of radiation risk as the radiation safety criteria and introduced the effective dose as the measure of the radiation risk as a standard quantity. The law created a legal basis for a real publicity in the field of radiation safety and defined the criteria for assessing the radiation safety of the personnel of the radiation facilities and the public. According to this Law. the radiation-hygienic certification became the basis for the system of information support of the state regulation in the field of radiation safety of the population. The law defined that "... the public authorities, local governments, and institutions working with sources of ionizing radiation, should evaluate the radiation safety ... The evaluation results are recorded annually in the radiation-hygienic passport of the organizations or territories." Article 6 of the Law states that "Authorities of subjects of the Russian Federation ... develop and implement regional (territorial) programs in the field of radiation safety assurance, organize monitoring of the radiation conditions in the respective territory ..., provide conditions for the realization and protection of human rights considering the interests of state in the field of radiation safety ... ".

Table 1

Dynamics of primary dose limit for the professionals [1]

Year	ICRP, mSv/ year (B. Lindell, Bulletin on radiological protection, 1999)	USSR–The Russian Federation	
		mSv/year	Reference
1934	500		
1948		300	Norms, T- 1031
1950	150	300	Norms, 2413
1953		150	Norms, 129-53
1957		150	Norms, 233-57
1958	50		
1960		50	Sanitary Rules, 333-60
1969		50	NRB-69
1976		50	
1977	50		
1987		50	NRB-76/87
1990	100 mSv over 5 years (an average of 20 mSv / year, but not more than 50 mSv / year)		
1996		100 mSv over 5 years (an average of 20 mSv / year, but not more than 50 mSv / year)	Law, NRB-96
1999		100 mSv over 5 years (an average of 20 mSv / year, but not more than 50 mSv / year)	NRB-99
2009		100 mSv over 5 years (an average of 20 mSv / year, but not more than 50 mSv / year)	NRB-99/2009

To create the national system of the radiation-hygienic certification in 1997 the State Sanitary and Epidemiological Surveillance Service created "The order of development of the radiation-hygienic passports of organizations and territories", approved by the RF Government Enactment № 93, 28.01.1997. It defines that the "radiation-hygienic certification of the organizations and territories is the state system of the evaluation of influence of the major radiation sources (anthropogenic and natural) and is aimed at ensuring of the radiation safety of the population."

To implement the Government Enactment № 93 standard forms of radiation hygienic passports of the organizations and territories in the form of the Guidelines MU-177-112 "The order of completion and recording of the radiation-hygienic passports of the organizations and territories." were developed and approved by the Enactment of the Chief State Sanitary Inspector of the Russian Federation № 22, of 25.09.1997.Thus, to the beginning of 1998 by the efforts of the State Sanitary and Epidemiological Surveillance services organizational and methodological basis for radiation-hygienic certification was established and thus the conditions for the completion of the radiation-hygienic passports by all radiation facilities and territories were created.That was the first report on radiation safety in accordance with the requirements of the Law.

RF Government Enactment № 93 specified a particular procedure for the development of radiation-hygienic passports:

-Administration of the territories of the Russian Federation is responsible for the organization of radiation-hygienic certification;

- Administration of the radiation facility is responsible for the organization of radiation-hygienic certification in the radiation facilities..

Administration of the constituent territories of the Russian Federation assigns the organization responsible for data collection and compilation of radiation hygienic passport of the constituent territory. In the majority of the regions of the Russian Federation, local State Sanitary and Epidemiological Surveillance Service authorities are responsible for data collection and compilation of radiation hygienic passport of the region.

- FBUZ "Center of Hygiene and Epidemiology" – in 29 constituent territories;

- State Sanitary and Epidemiological Surveillance Service – in 16 constituent territories;

- Local departments of natural resources, protection of the environment and ecology – in 21 constituent territories;

- Local departments of the population protection – in 6 constituent territories;

- Local health authorities – in 4 constituent territories.

Currently radiation-hygienic passport of the Russian Federation includes the results of radiation-hygienic certification of all the organizations and territories under the surveillance of the executive authorities, which have the State Sanitary and Epidemiological Surveillance authorities:

- Rospotrebnadzor;
- FMBA of Russia;
- Ministry of Defense of Russia;
- Ministry of Internal Affairs of Russia;
- FSIN of Russia;
- Office of the President of the Russian Federation;
- Federal Security Agency of the Russian Federation.

The amount and quality of data obtained in the framework of radiation-hygienic certification is sufficient for use as an information base for the regulation of the radiation safety in the territories, including the optimization of state sanitary and epidemiological supervision of the radiation safety of the population. It is an objective tool with the help of which the administration of the territory or radiation facility should plan and implement the necessary measures for the optimization of the radiation protection of the population.

According to the Radiation-hygienic passports [3] and a Joint system of the control of the individual doses to the population (ESKID) [4], the average effective dose of the residents of the Russian Federation from all radiation sources in 2012 equaled to 3.95 mSv, which is 1,15 mSv higher than the average value of the total population dose from the all sources of radiation (2.8 mSv), presented in the reports of UNSCEAR (Figure 1) [5]. The higher dose for the Russian

citizen is mainly explained with the implementation of the dose monitoring of the population. In the system of radiation-hygienic certification and ESKID instrumental measurements for all the components of the radiation dose are implemented. Since 1999, with the first radiation-hygienic passports of the Russian Federation, there was a jump in the mean total annual dose of inhabitants of the Russian Federation from 2.2 mSv to 3.8 mSv.

Secondly, a significant part of the territory of the Russian Federation is located in the Northern latitudes, where the levels of exposure from natural sources are significantly higher than in countries with a warm climate. According to the literature higher doses of radiation compared with the global average levels, are confirmed in other Nordic countries – Finland, Sweden, Norway, Canada. In addition, the radiation dose of the public depends on the availability of areas with radiation anomalies [6-9].

In the structure of the average dose of the population of the Russian Federation natural exposure makes the largest contribution – almost 86% or 3.38 mSv/year (Fig. 2). Second place goes to medical exposure – about 14%, or 0.56 mSv/year. Radiation accidents, fallout from nuclear weapons testing, and occupational exposure contributes only 0.18%, or 0.007 mSv/year.

μSv), the contribution of natural sources in total dose is 84.5% with a dose of 2.76 mSv/year.

Such a significant contribution from natural radiation sources to the dose of the population of Russia determines the importance of limiting the public exposure from these sources. We have conducted a detailed analysis of the structure and levels of the exposure of the population of the Russian Federation from natural sources of ionizing radiation.

The average annual dose per caput in the Russian Federation from only the natural sources is 3,38 mSv/year.

Its structure is provided on Fig. 5:

- Internal dose due to inhalation of radon and its short-lived progeny is 1.97 mSv/year (more than 58% of the dose due to natural sources);
- External dose equals to 0.66 mSv/year, or 19% of the total dose,
- The dose due to ingestion of natural radionuclides with food is 0.14 mSv/year, or about 4%;
- Dose from drinking water is 0.03 mSv/year, or about 1% of the total dose.

As we can see from the Figure 5, the highest (over 58%) contribution to the dose of the citizens of the Russian Federation from natural sources is from inhalation of radon and short-lived radon progeny.

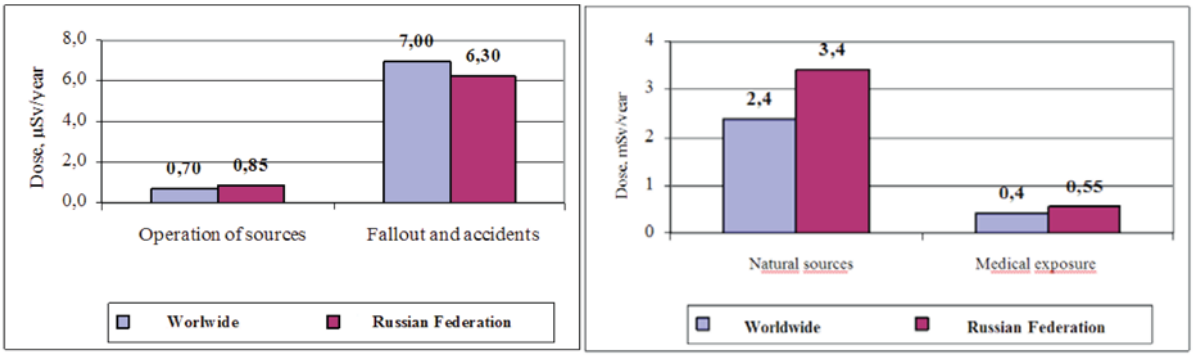

Fig. 1. Comparative characteristics of the average doses of the public from different sources of ionizing radiation (Worldwide and the Russian Federation data)

For different constituent territories of the Russian Federation, the ratio of the components of the total dose from all sources of ionizing radiation is different (Fig. 3). Although the contribution of natural exposure in the total dose for the entire Russian Federation is 86%, for the Astrakhan region, where the level of natural exposure is low (just 2,12 mSv) this contribution is 74,62%, and in the Republic of Altai region with the highest levels of exposure from natural sources (9,89 mSv) relative contribution of natural exposure is 91.5%. However, for some regions, for example, in the Republic of Ingushetia, the share of natural exposure in the total dose is more than 98%, which is associated with the very low levels of medical exposure (0.07 mSv), while Russian average medical exposure dose is 0.55 mSv.

Even for the most affected by the Chernobyl accident Bryansk region (Fig. 4), where the annual dose of the inhabitants due to elevated radiation level is 13 times as high as the national average dose (84.3 μSv for the inhabitants of the Bryansk region versus the average dose in Russia of 6,3

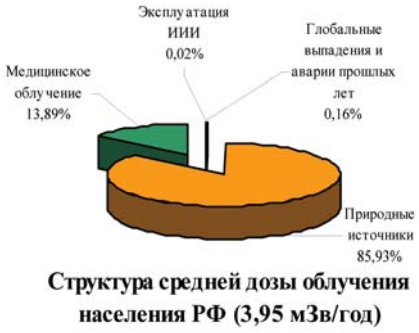

Figure 2. Structure of the mean radiation dose of the Russian population from all SIR

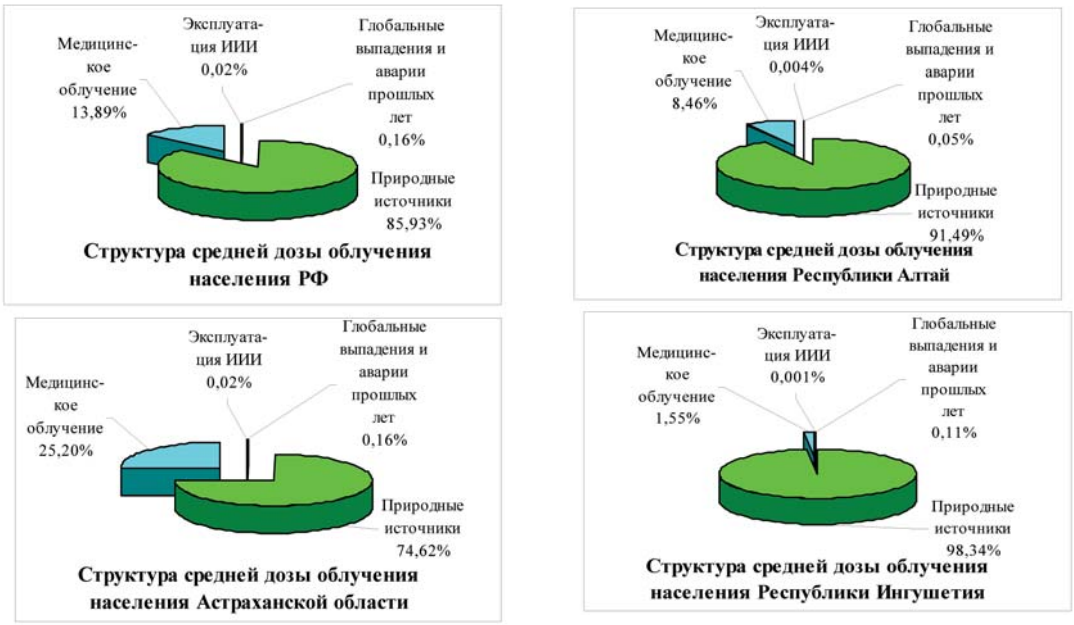

Figure 3. Comparative characteristics of the population dose structure in different constituent territories of the Russian Federation due to various SIR

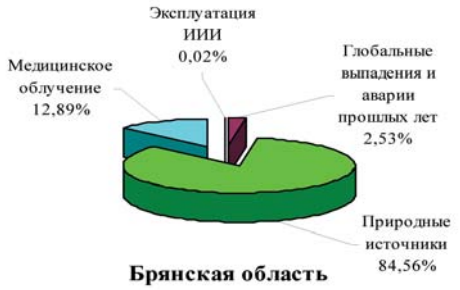

Figure 4. Structure of the population doses in Bryansk region from various SIR.

Figure 5. The structure of the mean dose for the Russian Federation from natural sources of ionizing radiation

For each subject of the Russian Federation, the contribution of different natural radiation sources to the total dose is different. As an illustration of the contribution of natural sources to the total dose of the population we provide the structure of the average Russian Federation dose, as well as the structure of public exposure in the constituent territories with the highest (Altai Republic) and lowest (Astrakhan region) doses. Doses from food, drinking water and external exposure in different regions vary slightly. Doses from radon in different regions vary considerably, and radon especially determines the level of the public exposure.

According to the Radiation-hygienic passport of the Russian Federation for 2012, [3] and «Doses of the population of the Russian Federation for 2012» reference book, [4], the mean annual effective dose of the public in the Republic of Altai from natural sources is 9,63 mSv/year and is the highest in the Russian Federation. Also elevated (5.0 to 10.0 mSv/year) average dose of the public from the natural radiation sources are observed in the Jewish Autonomous oblast (6,8 mSv/year), the Republic of Tyva (5,2 mSv/year), Stavropol oblast (5,63 mSv/year) and the Zabaykalsky Krai (6,29 mSv/year). In all these regions, the reason for the increased exposure is the high concentration of radon in indoor air.

There are identified more than 50 places of residence of the public on the territory of 17 constituent territories of the Russian Federation with a population varying from a few dozen to several thousand people with average dose more than 10 mSv/year. Thus, the average dose of inhabitants of Baley, Zabaykalsky Krai, only due to radon in the indoor air are about 13 mSv/year, reaching up to 100 mSv/year for the inhabitants of individual houses or apartments.

According to the Radiation-hygienic passports doses from natural sources for about 1 million people exceed 10 mSv/year, and for about 10 million people the doses exceed 5 mSv/year.

Thus, currently in the Russian Federation:

• a scientifically based system of data collection of all the components of the natural exposure of the public is created, on the basis of which an objective picture of the manifestation of natural radiation sources in separate constituent territories of the Russian Federation and in the entire country is received;

Figure 6. Annual effective doses of the public from natural sources in different regions of the Russian Federation

• particular residential areas in the territories of several constituent territories of the Russian Federation with elevated and high levels of exposure from natural sources are identified;

• science-based regulatory and methodological base for the regulation of radiation safety of the public exposed to natural sources of radiation in industrial and municipal conditions is developed and created.

Currently, local targeted programs for reduction of public exposure to radon are being developed or implemented in the several subjects of the Russian Federation (the Altai Republic, St. Petersburg, Leningrad region, Zabaykalsky Krai).. However, they do not have sufficient funding, scientific and methodological support, leading to their low efficiency. To implement an effective system for reduction the levels of the public exposure from natural sources, it is necessary to develop a national target program, which should include the following directions:

1. Improvement of the regulatory and methodological support of the state system of radiation safety regulation in terms of limiting the exposure of the public of the Russian Federation from natural sources.

2. Organization of the detailed radiation surveys of residential and public buildings in the areas of the potential and identified radon hazard.

3. Creation and assurance of the infrastructure for radon mitigation activities in the residential and public buildings with identified exceedance of the permissible levels of radon or gamma radiation dose rate from natural radionuclides.

4. Assurance of the compliance with the set standards of the industrial exposure from natural sources.

5. Evaluation of the effects of excessive exposure from natural sources on human health.

We continue work on ensuring the radiation safety of the inhabitants of the territories contaminated due to the accident at the Chernobyl NPP.

Currently, in all the 14 affected regions of the Russian Federation drinking water, baby food in kindergartens and schools, all food products in sales networks comply with the hygienic standards. In 12 regions of the Russian Federation (excluding the Bryansk and Kaluga regions) all agricultural food products, including those produced in local farms, comply with the hygienic standards [10].

At the same time, in two regions- Bryansk and Kaluga – food (milk) produced in private farms, as well as natural food products (berries, mushrooms, fish, game) – still often do not comply with relevant ^{137}Cs standards.

As on 2012, in 321 settlements of the Bryansk region and in two settlements of the Kaluga region, the dose to the critical group of the public exceeds 1 mSv/year [10, 11]. According to forecast made by the Research Institute of Radiation Hygiene, in 70 years after the accident at the Chernobyl NPP, in 2056, in four settlements of the Bryansk region, the mean annual public dose from the Chernobyl fallout will still exceed 1 mSv.. Thus, it would be necessary to ensure radiation safety of the public in the contaminated areas after the accident at the Chernobyl NPP for more than one decade.

Currently, the attention of professionals and public is attracted to the development of the radiation situation at "Fukushima-1" NPP in Japan.

The accident at the nuclear power plant "Fukushima-1" was assigned the highest, 7th level, according to the international classification, which allowed us to refer it to the manmade disaster comparable to the Chernobyl accident, and by some estimates, even exceeding the Chernobyl accident by the discharge.

Giant discharges of radionuclides into the Pacific Ocean during the acute phase of the accident at the NPP "Fukushima" and the subsequent period, continuing to the present, led to radioactive contamination of the ocean area close to the NPP "Fukushima".

At the end of July, 2013 the Japanese government officially admitted that radioactively contaminated water continues to leak from the emergency cooling systems of reactors of the "Fukushima-1" into the Pacific Ocean. According to the TEPCO company, up to 300 tons of radioactively contaminated water was leaking into the Pacific Ocean every day. Such contamination of the waters of the Pacific Ocean with radionuclides does not remain traceless.

For timely detection of radionuclide transport by air and waterways, as well as in order to prevent the importation of contaminated commodities into the Russian territory in other ways, since the first hours of the Fukushima accident radiation monitoring was organized by the executive authorities of the Russian Federation, which included:

– control of dose rate of the gamma radiation;

– control of the content of artificial radionuclides in the atmospheric air;

– control of the soil surface activity, vegetation and local food products, which consumption is a potential source of the human intake of radionuclides (milk, leafy vegetables, mushrooms, fish, seafood);

– control of the artificial radionuclides in sea water and aquatic biota (fish, shellfish, algae);

– control of the surface contamination of vehicles coming from Japan (airplanes, helicopters, ships) and cargoes;

– control of artificial radionuclides in food products and raw materials imported from Japan;

– control of radioactive contamination of passengers and their baggage arriving from Japan,.

To assess the potential threat of the Fukushima accident and to clarify the areas and possible levels of radioactive contamination in the Far East region and the Pacific Ocean near the borders of Russia, Russian Geographic Society organized and conducted 3 marine scientific expeditions, and Rospotrebnadzor conducted six terrestrial expeditions on Sakhalin and the Kuril Islands. A detailed analysis of the results of the research expeditions is presented in our publications [12-16].

Results of the comprehensive studies have shown that the accident at the "Fukushima-1" NPP did not lead to a significant radioactive contamination of Russia and the coastal waters. Maximum levels of soil surface contamination with cesium-137 on the Kuril Islands and Sakhalin are much lower than the levels from global fallouts. The level of additional radiation exposure to the public does not exceed 10 μSv per year, corresponding to a negligible level of radiation risk in accordance with NRB-99/2009.

No radioactive contamination of fish or seafood caught in the Pacific Ocean near the borders of Russia was identified. However, the ongoing discharges of the radioactive substances from Fukushima NPP to the Pacific Ocean and the ability of living organisms to accumulate radionuclides through the food chain requires continuous radiation monitoring of marine resources in the Far East coast of Russia. There are important reasons for that.

According to the first marine expedition carried out under the auspices of the Russian geographical society in April – May 2011, elevated levels of caesium radionuclides in sea water were identified in the Pacific Ocean, about 400 km East of Fukushima(Fig. 7).

According to Ken O. Buesseler [17], the content of cesium radionuclides in benthic fish caught in 2011-2012 in the coastal zone of the Fukushima Prefecture exceeded the permissible level of 100 Bq/kg in almost half of the samples. In a few cases the content of cesium above the specified limits in fish was identified in the neighboring to Fukushima prefectures Ibaraki and Miyagi, which is clearly evident from the data presented in Fig. 8. High levels of cesium were identified in other environmental groups of fish – pelagic, neuston, freshwater.

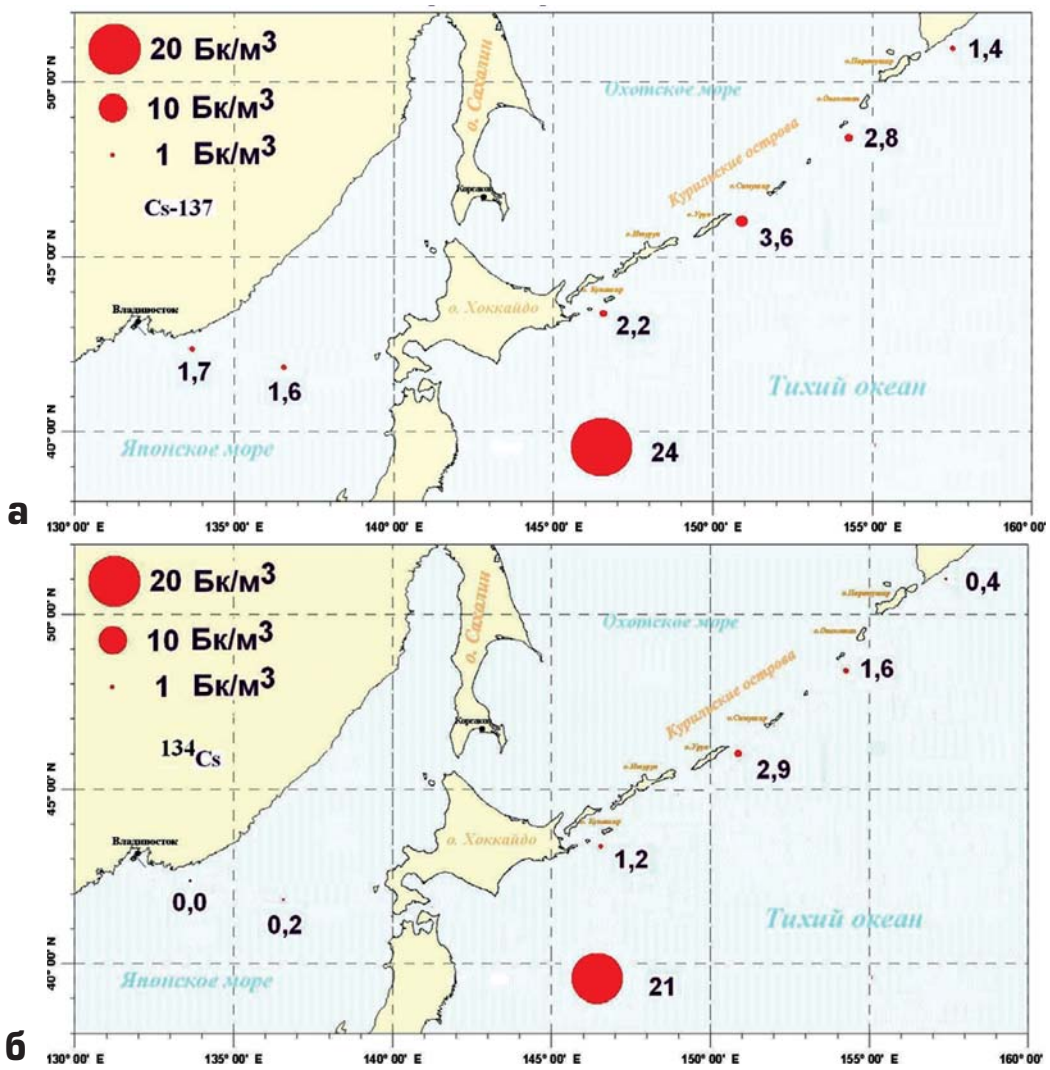

Figure 7. Spatial distribution of 137Cs (a) and 134Cs (b) in the surface waters of the Pacific Ocean in April 24 to May 6, 2011 period.

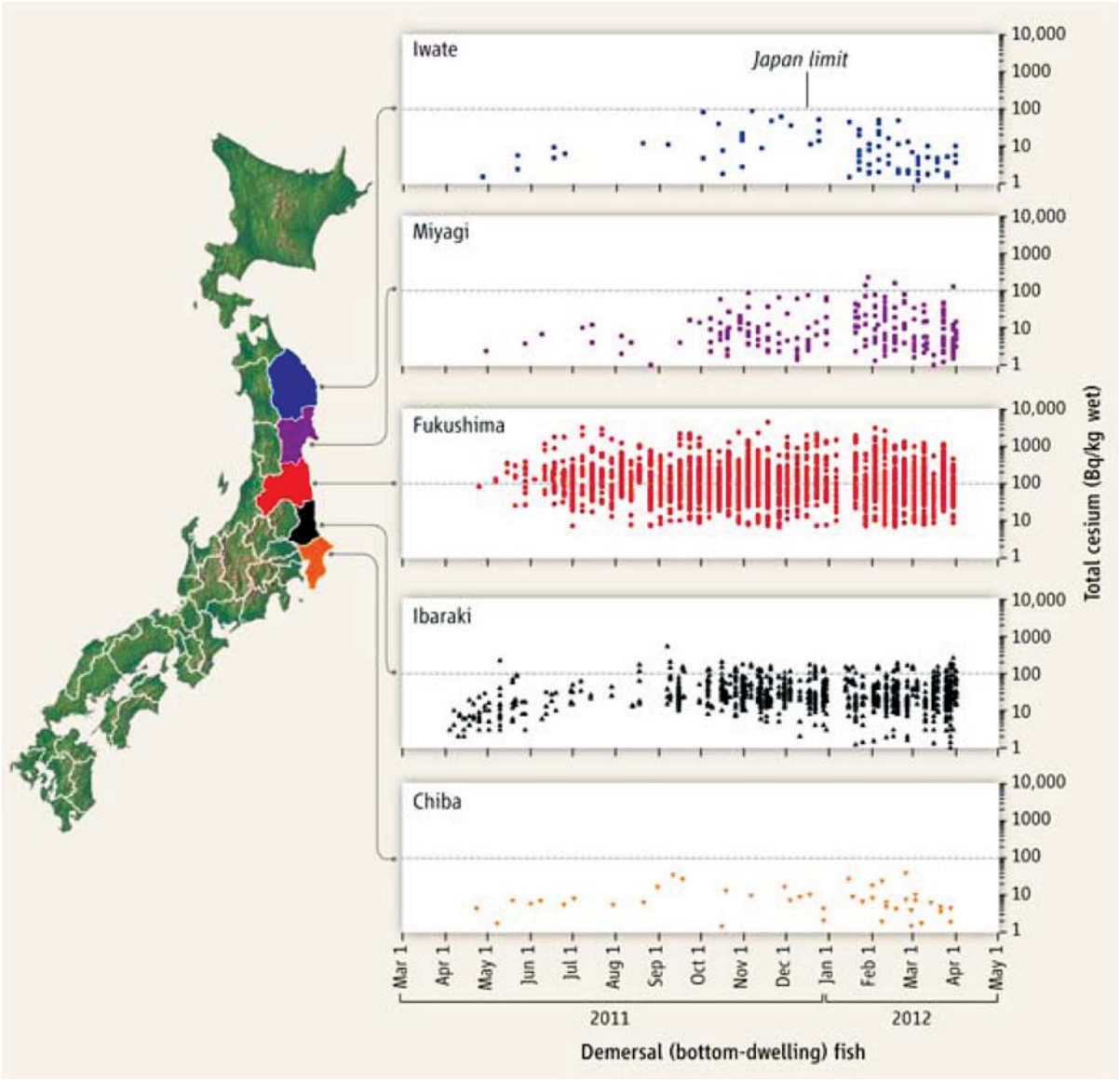

Figure 8. Levels of cesium radionuclide contamination in the benthic fish caught in different areas of the East coast of Japan [17]

Radiation safety and radiation terrorism counteraction during international sports events held in Russia in recent years (XXVII World Summer Universiade, Kazan, 2013, XXII Olympic and XI Paralympic Winter Games, Sochi, 2014) required significant effort and resources of authorities responsible for this activity.

Radiation safety of the Olympic and Paralympic Games in Sochi and the Summer Universiade in Kazan, Russia, was provided by the FSB, the Russian Ministry of Defense, Ministry of Internal Affairs of Russia, Rosatom, Office of the President of the Russian Federation; Rospotrebnadzor, FMBA of Russia and Rosgidromet agencies

The basic requirements to ensure the safety of the Olympic Games are described in the text of the Olympic Charter, and the goals and objectives of public health and hygiene agencies are reviewed in detail in the Technical Manual for health services (IOC, June 2007) [18, 19].

The main objectives to counter the nuclear and radiation terrorism during the sporting events in Kazan and Sochi were to prevent the theft of radioactive materials and radiation sources on radiation objects, preventing unauthorized delivery of radiation sources and their use for terrorist objectives in the Universiade and the Olympic Games venues.

The main objectives of Rospotrebnadzor on ensuring the sanitary and epidemiological welfare (in terms of Radiation Safety) of the participants and guests of the Universiade, the Olympic and Paralympic Games, and the population of Kazan and Sochi cities were as follows

- strengthening the sanitary inspection at the designated area for the construction of venues in the process of construction and commissioning,
- monitoring and evaluation of the radiation situation in the area of competition,

• identification and assessment of the content of radionuclides in the environment at the control points of Kazan and Sochi, in food and drinking water at all Universiade and the Olympic Games venues, and in the cities Kazan and Sochi, as well as

• participation in all activities to combat radiological terrorism.

During the preparation and carrying out of the games Departments of the Radiation protection of the FBUZ "Center for Hygiene and Epidemiology in the Republic of Tatarstan" and FBUZ "Center for Hygiene and Epidemiology in the Krasnodar Krai" supported by the radiological groups of the Saint-Petersburg Research Institute of Radiation Hygiene after Professor P.V.Ramzaev held the radiation survey of more than 120 venues, which included thousands of measurements of the β-radiation dose rate, radon concentration in the air, activity of radionuclides in food, drinking water, building materials, environmental objects.

Coordinated work of all executive authorities allowed for provision of stable radiation environment and prevention the radiation incidents during the Universiade in Kazan, the Olympic and Paralympic Games in Sochi.

The organization experience of radiation safety of the Summer Universiade in Kazan, 2013, was analyzed and published in papers and monographs [20-22]. There is an ongoing analysis of the materials on the sanitary and epidemiological welfare of the participants and guests of the Olympic and Paralympic Games in Sochi and in the near future all aggregate materials will be published.

Thus, the important tasks for improving the radiation safety of the population in the Russian Federation at the present stage are:

- Improving the emergency response of executive authorities based on the experience of eliminating of the consequences of the Chernobyl and "Fukushima-1" accidents, and on the basis of the international recommendations; radiation safety of the inhabitants living in the contaminated areas; improving the system of radiation-hygienic certification and the quality of Radiation-Hygienic Passportization;

- Processing and analysis of collected unique data on the radiation safety of the public in large-scale sports events;

- Harmonization of national regulations and methodologies of radiation safety in accordance with the requirements of the WTO, the Customs Union and the Eurasian Economic Community;

- Improving the hardware and methodological provision of the radiological laboratories to execute the current tasks and emergency response;

- Training and improving the qualification of specialists.

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