Development of measures to protect the population and prevent pollution based on the study of the radiation background of the object

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Abstract. In the modern world, the energy of the atom is used in industry, medicine and other spheres of human activity. However, the usage of radioactive substances can have a negative impact on the environment, the health of workers and the public. Therefore, it is important to keep a close watch on the radiation situation in the immediate vicinity of facilities where radioactive substances are used or stored. These can be nuclear power plants and industrial enterprises, as well as areas with a naturally elevated background radiation level. In this paper, a study of the background radiation of the object of possible radioactive contamination – Gatchina Palace in Gatchina, Leningrad region was carried out. On the basis of measurements made, we have performed the calculation of the annual radiation doses of staff and tourists, as well as issued recommendations to ensure the radiation safety of employees and visitors of the Gatchina Palace.

1 Introduction

Employees and visitors of various institutions and enterprises are often unaware of the hidden threats that may await them [1]. The radiation background of the premises can become a hidden threat, and often it differs sharply in different places of the same building. In the conditions of continuous creation and improvement of methods of use of radioactive materials, it is especially important to provide measures to protect people from ionizing radiation [2-5]. Its' effects cause chronic and acute diseases, as well as genetic effects [6]. However, the effects of radiation depend on the dose. Human exposure to different doses of radiation is determined by dosimetric characteristics [7].

Taking into account the impact of different doses on a person, their permissible values are established, which differ in the population and workers of radiation hazardous facilities. In case of exceeding the permissible values of doses at any facility, continuous monitoring of radioactivity indicators is necessary; the program of such monitoring is developed by Spanish scientists in the framework of the study of the content of uranium and plutonium [8-9]. It is also important to develop measures to protect employees and the public from radiation. In Russia dosimetric values are established according to the Federal law "On radiation safety of the population" of 09.01.1996 N 3-FL [10]. It can be used to compare the state of the background radiation of an object with the established norms. The aim of this work is to study the background of the Gatchina Palace, located in Gatchina, Leningrad region.

Every day in the off-season to take time to visit the Gatchina Palace from 100 to 400 people during the season – from 300 to 650. Employees spend 8 hours in the Palace.

Facing the Gatchina Palace – Pudost stone is characterized by the ability of accumulation of the dose, as most of the limestone that creates the background radiation [11].

In the course of the study such tasks as dose rate measurement using the measuring device "Ecologist" and the calculation of the annual dose for different groups of employees. On the basis of measurements and calculations as a result of the work developed measures to ensure the safety of the population and employees.

A similar study was conducted in Poland in Wroclaw: the measurement of radon level using a Geiger counter in different rooms allowed to calculate the annual effective dose rate [12].

2 Methods

To carry out the study, the influence of atmospheric emissions from nuclear power plants in Russia and Europe was studied in this work, since they have a tangible impact on the General background radiation background along with its natural sources [13-14]. It turned out that the Leningrad region and Gatchina are radon dangerous. Radon is a heavy gas, the product of the decay of heavier elements such as radium [15-16]. Special maps of radon, thorium, uranium and other radioactive elements are created for such areas [17-18].

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The study of the radiation background in the premises of the Gatchina Palace was carried out by measuring the dose rate. Twenty-fold measurement was carried out in such areas as kitchen and Arsenal square, chapel and courtyard.

Dose rates can be estimated in different ways [19-20]. To summarize the results of the measurements in this study, we used the distribution laws of random variables of the measured values of dose rate. Mathematical expectation, variance, standard deviation and normal distribution law were chosen as the main evaluation characteristics. Such characteristics are used in the theory of reliability and allow to find the optimal distribution of random variables, in this study – dose rates [21].

On the basis of the results of the study concluded on the state of the background radiation in the Gatchina Palace and developed recommendations for the protection of personnel from the background radiation.

3 Results

As a result of the measurement, 20 values were obtained for each room of the Gatchina Palace (Table 1).

At the end of the measurements for each type of the surveyed space, calculate the average dose rate $\bar{P}_i$ and the standard deviation S_i using equations:

$$\bar{P}_i = \frac{1}{N_i} \sum_{n=1}^{N_i} P_{ni} \quad (1)$$

$$S_i = \left(\frac{1}{N_i - 1} \sum_{n=1}^{N_i} (P_{ni} - \bar{P})^2 \right)^{\frac{1}{2}} \quad (2)$$

P_{ni} - the result of the n-th measurement of dose rate in the i-th location; N_i - the total number of measurements in the i-th location.

The standard deviation values for all rooms were calculated using the equation (2) (see Table 3).

During the work, based on the calculation of the left and right boundaries in the MathCad environment, it was concluded that the number of measurements equal to 20 is sufficient to carry out a reliable measurement. Calculations based on measured physical or chemical parameters are often performed using the MathCad software package [22].

The final step was the calculation of the dose received per year for the three selected groups of people (see Table 4).

The calculations were carried out with the following assumptions: tourists spend 2 hours in the Gatchina Palace, the frequency of visits is 1 time per year; guides spend 8 hours per day 5 days a week in the premises; working staff conducting restoration work, spends all day in the walls and surroundings of the Gatchina Palace.

Table 1. Values of dose rates, Mr/h.

	Kitchen square of the 1-st floor	Kitchen square of the 2-nd floor	Chapel	Inner court	Arsenal square of the 1-st floor	Arsenal square of the 2-nd floor
1	8	10	14	8	10	10
2	11	14	10	10	8	12
3	17	12	11	12	13	14
4	14	13	12	10	11	10
...	...	...	...	...	...	...
20	24	18	12	16	18	16

Table 2. Calculated dose rates.

Kitchen square of the 1-st floor	Kitchen square of the 2-nd floor	Chapel	Inner court	Arsenal square of the 1-st floor	Arsenal square of the 2-nd floor
13.5 mR/h	14 mR/h	11.5 mR/h	13 mR/h	14.2 mR/h	13.6 mR/h

Table 3. Standard deviation from the obtained data.

	Kitchen square of the 1-st floor	Kitchen square of the 2-nd floor	Chapel	Inner court	Arsenal square of the 1-st floor	Arsenal square of the 2-nd floor
1	1.13157	1.26578	1.34473	1.10526	1.27631	1.2421
2	1.28947	1.47631	1.13421	1.21052	1.17105	1.34736
3	1.60526	1.37105	1.18684	1.31578	1.43421	1.45263
4	1.44736	1.42368	1.23947	1.21052	1.32894	1.2421
...	...	...	...	...	...	...
20	1.97368	1.68684	1.23947	1.52631	1.69736	1.55789

Table 4. The resulting dose rate of three groups of staff.

The point of the research	Dose accumulated by tourists, mSv	Dose accumulated by guides, mSv	Dose accumulated by employees, mSv
1	0.022950	44.4150	-
2	0.019635	37.9995	-
3	0.023885	46.2245	-
4	0.242250	46.8825	-
5	0.022100	42.7700	738.27
6	0.231200	44.7400	-
The total cumulative dose, mSv	0.135915	263.0355	738.27

4 Conclusion

The study measured the dose rates at the Gatchina Palace and determined the accumulated doses for tourists, guides and workers. It was found that the accumulated dose does not exceed the allowable annual dose, but close to the limit value. In this regard, it is necessary to introduce measures to protect workers from the effects of radioactive contamination. The first and most necessary measure is to provide jobs with permanent residence away from the territory of the Gatchina Palace. The second, no less important measure is to increase the vacation of workers and the provision of free vouchers to sanatoriums and dispensaries.

The radiation situation in such areas is quite changeable. This is due not only to the work of the nearest nuclear power plants (for example, Leningrad NPP), but also to the consequences of radiation accidents that occurred earlier [23-24]. Accurate and up-to-date data on the contamination of a particular area are needed to ensure the safety of the population and personnel. This means that it is advisable to introduce a modern system for monitoring radiation indicators [25-26]. Such systems consist of virtual maps of radiation pollution areas [27-29]. These areas can vary in different areas in size or composition and volume of pollutants in accordance with the data constantly measuring radioactive indicators devices.

The development of technologies for monitoring radioactive contamination is as necessary as the development of public protection measures [30].

References

1. A. Byzov, S. Efremof, F. Gomazov WASTE 2018 10-13 (2018)
2. Z. Carr, M. Maeda, D. Oughton, W. Weiss Rad. Prot. Dos. **182** 112-119 (2018)
3. A. Tumanov IOP Eart. and Env. Sc. **272** (2019)
4. N.A. Politaeva, L.N. Olshanskaya, F.A. Ovchinnikov, S.V. Sverguzova IOP Eart. and Env. Sc. **288** (2019)
5. L. Olshanskaya, N. Politaeva, E. Tatarinceva, E. Danilova, A. Tareeva IOP Eart. and Env. **288** (2019)
6. I. Obodovski *Fundamentals of radiation and chemical safety* (Frankfurt: Elsevier Inc., 2015)
7. J.F. Barquinero, P. Puig Trends in Math. **7** 67-70 (2017)
8. C. Sancho, R. García-Tenorio J. Env. Rad. **203** 55-70 (2019)
9. G. Ciotoli, M. Voltaggio, P. Tuccimei, M. Soligo, A. Pasculli, S.E. Beaubien, S. Bigi J. Env.Rad. **166** 355-375 (2017)
10. Федеральный закон «О радиационной безопасности населения» от 09.01.1996 N 3-ФЗ
11. D. Chiper, C. Cimpeanu, C. Barna, S. Ilie Rom. J. Ph. **63** 808 (2018)
12. D.E. Tchorz-Trzeciakiewicz, S.R. Olszewski Sc.Tot. Env. **667** 511-521 (2019)
13. M. Zhukovsky, A. Vasilyev, A. Ekinin, M. Vasyanovich, M. Pyshkina, M. Semenov, E. Murashova, I. Kapustin RAD Conf. Proc. **2** 126-131 (2017)
14. A.P. Byzov, A.I. Shershneva, M.A. Ens WASTE 2018 49-51 (2018)
15. A. Luca, M. Sahagia, A. Antohe, R. Ioan, L. Șerbina, C. Ivan J. Rad. Nuc. Chem. **311** 1075-1079 (2017)
16. M. Sahagia, A. Luca, A. Antohe, C. Ivan, R. Ioan, B. Neacsu Rom. Rep. Ph. **58** S230-42 (2013)
17. C. Lucchetti, A. Briganti, M. Castelluccio, G. Galli, S. Santilli, M. Soligo, P. Tuccimei J. Env. Rad. **202** 41-50 (2019)
18. E.J. Mekongtso Nguelem, M. Moyo Ndontchueng, O. Motapon Spring. **5** 1253 (2016)
19. P. Bangotra, R. Mehra, R. Jakhu, P. Pandit, M. Prasad Sc. Rep. **9** 2515 (2019)
20. R.C. Ramola, M. Prasad, T. Kandari, P. Pant, P. Bossew, R. Mishra, S. Tokonami Sc.Rep. **6** 31061 (2016)
21. M. Szymkowiak Dec. Con. **196** 3-10 (2020)
22. D. Khan, A. Khan, I. Khan, F. Ali, F. Karim, I. Tlili Sc. Rep. **9** (2019)
23. D.A. Terentjev Ph. At. Nuc. **81** 1499-05 (2018)
24. S.F. Goncharov, G.M. Avetisov Med. Rad. Rad. Saf. **63** 74-82 (2018)
25. V. Burlov, A. Andreev, F. Gomazov MATEC Web of Conf. **193** 02038 (2018)
26. V. Abramov, I.Aleshin, V. Burlov, A. Chusov, E. Istomin, M. Shilin, A. Sokolov IBIMA 2019 7053-7061 (2019)
27. S.A. Maskevich, M.G. Germenchuk Mat. Sc. Eng. **487** (2019)

28. B. Burghela, A. Țenter, A. Cucos, T. Dicu, M. Moldovan, B. Papp, K. Szacsvai, T. Neda, L. Suci, A. Lupulescu, C. Malos, S. Florică, C. Baci, C. Sainz Sc. Tot. Env. **669** 887-892 (2019)
29. E. Istomin, V. Abramov, V. Burlov, A. Sokolov, N. Popov SGEM **17** 859-866 (2017)
30. V.E. Privalov, V.G. Shemanin J. of Opt. Tech. **84** 289-293 (2017)