ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Research Of Interannual And Intra-Annual Atmospheric Boundary Layer Dispersion Variability Parameters In The NPP Site Vicinity.

Fedor F. Bryukhan*.

Moscow State University of Civil Engineering, Yaroslavskoe sh. 26, Moscow 129337, Russia.

ABSTRACT

The threat to human health is largely determined by the level of air pollution with chemical and radioactive components. Therefore, identification of the pollutants dispersion conditions in the atmospheric boundary layer (ABL) is of great importance in establishing the engineering protection of territories. In many respects, it concerns the nuclear power plants (NPPs) siting areas where automated radiation monitoring systems are installed. In particular, the ABL monitoring is carried out in such areas. When analyzing and predicting the radiation situation in the NPP site vicinities, it is essential to determine the variability of atmospheric dispersion parameters over time. This research is aimed at assessing the interannual and intra-annual atmospheric dispersion parameters variability in the NPP siting areas based on the monitoring data. Taking the Belorussian NPP as an example, the relative interannual stability of the main average annual atmospheric dispersion parameters (vertical temperature gradient, wind speed and direction) was revealed during the 2015-2018 observation period. At the same time, the average seasonal values of the dispersion parameters are characterized by significant fluctuations thereof during the annual course. The prospects of the ABL status monitoring for other potentially hazardous industrial facilities, such as thermal power plants and chemical plants, are also noted.

Keywords: air pollution, atmospheric dispersion, radiation safety, environmental safety, nuclear power plant, monitoring, atmospheric boundary layer.

https://doi.org/10.33887/rjpbcs/2020.11.1.6

Corresponding author

INTRODUCTION

It is known that the extent of air pollution significantly affects human health [1, 2]. In turn, atmospheric pollution, both chemical and radioactive, depends on the conditions of atmospheric dispersion, which is a combination of the transport of polluting agents by directed air flow (wind) and turbulent diffusion [3, 4]. Therefore, a comprehensive study of atmospheric pollution is crucial for environmental applications. In particular, the dispersion parameters of the atmospheric boundary layer (ABL) that extends from the ground surface to the heights of about 1 km determine the conditions of the radionuclide dispersion and are therefore important in assessing the NPP radiation safety and developing engineering protection of NPPs. In this regard, the ABL status monitoring is envisaged at the key stages of the NPP life cycle (during construction, operation and decommissioning) [3, 4].

The main tasks of such monitoring are as follows:

- to determine the ABL dispersion characteristics that are required for the NPP radiation safety assessment;
- to predict and reveal the trends in fluctuations of these characteristics over time;
- to develop recommendations aimed at mitigating the adverse impact of NPPs on human health and the environment.

Currently, in the world practice and in Russia, the ABL status monitoring is usually carried out by means of acoustic and radio-acoustic sounding of the atmosphere with the help of sodars (SODAR) and RASS systems [5-7]. Combined measurement systems consisting of sodars and RASS allow remote recording of vertical profiles of the wind vector and temperature in the lower atmospheric layer extending to the heights of 600-1000 m [8-10].

This research is aimed at assessing interannual and intra-annual variability of atmospheric dispersion parameters in the areas of NPP siting, and the ABL monitoring data in the Belorussian NPP site vicinity are used as an example. This article contains the data observed over the last 4 full years (from 2015 to 2018) and obtained by experts from the Scientific & Industrial Association Gidrotekhproekt and the Moscow State University of Civil Engineering. The climatic regime of atmospheric dispersion in this area was studied earlier in the framework of engineering surveys using radiosonde observations [11].

METHODOLOGY

The SODAR/RASS-based monitoring system provides for continuous measurement of the following ABL parameters:

- air temperature;
- wind speed and direction;
- air turbulence characteristics.

Sodars are the systems for remote measurement of the turbulence structure and vertical wind profiles in the lower atmospheric layers. To detect atmospheric inhomogeneities due to atmospheric turbulence, sodars use acoustic waves. The reflected acoustic signal is processed by the built-in software and the resulting values of the intensity and frequency shift are used to determine the wind speed and direction, as well as turbulence characteristics.

The essence of the radio-acoustic method of sounding the atmosphere is that the RASS systems emit electromagnetic waves, which are reflected from atmospheric inhomogeneities created by acoustic waves during the operation of sodars. Along their propagation, these waves create periodic fluctuations in the dielectric permittivity of the air, which are able to scatter electromagnetic waves with a coherent addition of dissipated energy. Electromagnetic radiation reflected from such a structure of inhomogeneities is received by the RASS antenna. From the received signal, it is possible to determine the speed of sound at various heights, and therefore the air temperature. Processing of received signals and calculation of vertical temperature profiles is carried out using the software built into the RASS system.

Using the described system, which includes a data processing subsystem, automatic registration and accumulation of measurement results is also carried out [4]. This subsystem maintains a database and calculates a set of ABL dispersion characteristics using a specially developed set of software.

In August 2014, measuring equipment was mounted and installed at a weather station located 4.5 km northeast of the Belorussian NPP site. Upon completion of the equipment adjustment and commissioning, continuous monitoring of the ABL state was launched which is going on to date. The ABL parameters are automatically measured and recorded every 10 minutes.

The data processing subsystem manages the measurement results, archives them, vertically interpolates the temperature and the wind vector, as well as calculates the ABL statistical characteristics, the key of which include the following:

- average air temperature at various heights;
- repeatability of atmospheric stability classes;
- average values of the vertical temperature gradient in the vertical layers;
- characteristics of surface and elevated temperature inversions;
- statistical characteristics of the wind;
- a set of joint repeatability values of atmospheric stability classes, wind speeds and directions.

Calculation of the ABL characteristics is carried out with data averaging over fixed periods (current months, seasons and years). The results of the ABL parameter calculations accumulated over the last 4 full years make it possible to identify the specific features of interannual and intra-annual changes in the ABL dispersion characteristics.

RESULTS AND DISCUSSION

The main ABL dispersion parameters include a vertical gradient of air temperature, atmospheric stability classes, modulus and direction of the wind vector. Interannual changes in these characteristics averaged over the current years are presented in tables 1 and 2.

According to table 1, the vertical temperature gradient is positive throughout the entire study period and varies in the range of 1.29-1.63 ºC/100 m. Such fluctuations in the temperature gradient with height characterize a high degree of the ABL atmospheric turbulence and facilitate the dispersion of radionuclides. The following notation of atmospheric stability classes is used in table 1: A – extremely unstable, B – moderately unstable, C – weakly unstable, D – neutral, E – weakly stable, and F – stable. As follows from table 1, throughout the entire observation period, the prevailing classes are B, C, and D characteristic of favorable dispersion conditions. Adverse stability classes (E and F) are observed quite rarely, and their total repeatability does not exceed 12 %.

The data from table 2 show that the wind vector modulus varies mainly within 1-4 m/s while it rapidly grows with height. At the same time, interannual fluctuations of the wind speed are insignificant and amount to about 1 m/s, which is equal to the measurement accuracy of the wind speed. According to the results presented in table 2, the west-south-west direction prevailed throughout the period of 2015-2018.

Thus, the relative stability of the main average annual characteristics of atmospheric dispersion is noted.

At the same time, as follows from table 3, significant variability of the average seasonal characteristics of atmospheric dispersion is noted in the annual course. According to the results shown in this table, the air temperature gradient in the 0-300 m layer is positive and has its maximum in the winter months and the minimum – in the summer months. The total repeatability of adverse atmospheric stability classes (E and F) increases from winter to summer from 4.5 to 11.3 %. In the transitional seasons (in spring and autumn), it is about 7 %. As for the wind, a significant rise in its speed with height and a relatively stable direction are typical of all seasons. In the annual course, there is a noticeable weakening of the wind speed from the winter to the spring and summer months. Along with this, the wind direction is characterized by relative stability.

Table 1: Interannual changes in the average annual values of the air temperature vertical gradient in the layer of 0-300 m and the repeatability of atmospheric stability classes

Годы	Temperature gradient, ^{0}C/100 m	Repeatability of atmospheric stability classes, %					
		A	B	C	D	E	F
2015	1.29	8.5	21.2	23.8	39.4	4.4	2.7
2016	1.30	7.4	21.2	21.9	41.4	5.1	3.0
2017	1.63	10.7	23.6	22.8	37.0	3.6	2.4
2018	1.49	11.1	24.2	20.7	35.5	5.0	3.6

Table 2: Interannual changes in the modulus and direction of the average annual values of the wind vector at various heights in the ABL

Годы	Modulus of the wind vector, m/s				Direction of the wind vector, degrees			
	0 m	100 m	200 m	300 m	0 m	100 m	200 m	300 m
2015	1.3	1.6	1.8	2.4	234	240	242	243
2016	1.0	1.2	1.6	2.7	231	236	237	238
2017	1.7	2.0	2.8	3.9	230	234	237	238
2018	0.9	1.1	1.7	2.7	224	224	226	230

Table 3: The annual course of the seasonal atmospheric dispersion characteristics averaged over the period of 2015-2018

ABL dispersion characteristics	Seasons			
	Winter	Spring	Summer	Autumn
Temperature gradient in the 0-300 m layer, ºC/100 m	2.05	1.52	0.81	1.32
Repeatability of stability classes, %:				
A	13.3	9.9	7.4	7.1
B	21.8	26.2	21.0	21.1
C	25.4	22.7	18.8	22.3
D	35.0	34.2	41.5	42.5
E	2.7	4.3	6.5	4.6
F	1.8	2.7	4.8	2.4
Wind vector modulus at ABL heights, m/s:				
0	1.9	0.8	1.4	1.3
100 m	2.4	0.9	1.7	1.6
200 m	3.1	1.1	2.2	2.3
300 m	3.9	1.7	3.0	3.4
Wind vector direction, degrees:				
0	219	248	272	216
100 m	221	254	274	230
200 m	228	245	271	214
300 m	230	236	262	222

The experience of using SODAR and RASS systems in various countries demonstrates that they are an effective means of obtaining initial data for assessing the current and time-averaged characteristics of atmospheric dispersion near NPPs. It is important to note that similar studies have obvious prospects for assessing atmospheric air pollution in the technogenic impact zones of other environmentally hazardous industrial facilities, for example, thermal power plants and chemical enterprises.

CONCLUSION

Based on the remote sensing data of the atmosphere in the Belorussian NPP site vicinity, the interannual and intra-annual ABL dispersion variability was assessed.

The state of the lower, 0-300 m atmospheric layer is characterized by a positive air temperature gradient that reflects a high degree of the ABL turbulence. The repeatability of adverse atmospheric stability classes is insignificant and does not exceed 12 %.

A certain interannual stability of the main average annual characteristics of atmospheric dispersion (vertical gradient of temperature, wind speed and direction) was revealed throughout the 2015-2018 observation period. Along with this, the average seasonal values of the dispersion parameters are characterized by significant changes over the annual course.

There is also the prospect of monitoring the state of ABL for other potentially hazardous industrial facilities, such as thermal power plants and chemical plants. It is noted that the ABL status monitoring is also promising for other potentially hazardous industrial facilities, such as thermal power plants and chemical enterprises.

REFERENCES

[1] Ghorani-Azam A, Riahi-Zanjani B, Balali-Mood MJ. Journal of Research in Medical Sciences 2016; 21:65..
[2] Turner MC, Krewski D, Diver R et al. Environmental Health Perspectives 2015; 125(8):087013.
[3] Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances to the Environment. Safety Report no 19. Vienna, IAEA, 2001, 216 pp.
[4] Bryukhan FF. Atomic Energy 2017; 122:69-74.
[5] Bradley S. Atmospheric Acoustic Remote Sensing: Principles and Applications. New York, CRC Press, 2008, 265 pp.
[6] Emeis S. Atmospheric and Oceanographic Sciences Library 2011; 40:184.
[7] Novitskii MA, Mazurin NF, Kulizhnikova LK et al. Russian Meteorology and Hydrology 2011; 36:693-699.
[8] Hennemuth B, Peters G, Kirtzel H-J. Atmospheric Measurement Techniques 2012; 5:1399-1408.
[9] Bruykhan FF, Vinogradov AYu, Lavrusevich AA. Industrial and Civil Engineering 2015; 2:51-54.
[10] The METEK Radio Acoustic Sounding System. Elmshorn (Germany), METEK, 2013, 25 pp.
[11] Bryukhan AF. Investigation of the Atmospheric Dispersion for Nuclear Power Plants Siting. Proceedings of the 5-th International Research and Practice Conference "European Science and Technology", Munich (Germany), 2013, 1:345-350.