International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-1, October, 2019

Medical and Ecological Assessment of the Formation of the Carcinogenic Risk from Air Pollution in Megacities

Saida Olegovna Apsaliamova, Bella Olegovna Khashir, Olege Zachirievich Khuazh, Aleksandr Viktorovich Stygun

Abstract*: Air pollution is considered to be the most dangerous by the extent of negative effects, since urban pollution with some compounds has already become irreversible, and entails negative changes in the health of the population. In this regard, the importance of scientific-methodical support for monitoring, integrated assessment of air pollution, and determining the level of medical and ecological, including carcinogenic, risk for individual territories increases. The article is aimed at determining and comparing the level of carcinogenic risk in a megacity due to the chemical carcinogens entering the organism with the atmospheric air and the air in residential and public buildings. The article discusses theoretical approaches to studying the effect of environmental factors on human health, including the risk of oncology diseases. Based on the analysis of the scientific literature and the data about the presence of carcinogenic substances indoors and outside, the problem of medical and ecological assessment of carcinogenic risk formation due to air pollution in megacities has been analyzed.

***Keywords*: medical and ecological assessment, risk of cancer, carcinogenic compounds, atmospheric air, the air in closed premises.**

I. INTRODUCTION

Among the factors that determine the incidence rate, the share of the state of the environment is approximately 20 % [1]. At the same time, given the current environmental load caused by the influence of environmental and professional production factors in combination with stress and mental overload, all this, according to the WHO, causes most diseases, up to 70 – 80 % [2]. Social factors and environmental factors act not separately but in combination with the biological ones (including hereditary), which determines the dependence of human incidence rate on the effect of the environment in which humans are located, as well as the genotype and the biological laws of development.

Revised Manuscript Received on October 30, 2019.
* Correspondence Author
Saida Olegovna Apsaliamova*, Kuban State Medical University, Krasnodar, Russia.
Bella Olegovna Khashir, Kuban State Technological University, Krasnodar, Russia.
Olege Zachirievich Khuazh, Kuban State Technological University, Krasnodar, Russia.
Aleksandr Viktorovich Stygun, Kuban State Technological University, Krasnodar, Russia.

Adding determination of the exact contribution of a particular factor into the etiology of the disease is often quite challenging since over 200 genes that control human susceptibility to diseases are associated with the effect of the environmental factors [3].

In recent years, anthropogenic load on the environment in many regions of the country has been dangerous to health [2]. Depending on the intensity of the influence of environmental factors on the health, the zones of the emergency environmental situation and the zones of ecological disaster are delineated. The ecological state in these areas is assessed on a set of indicators, in particular, the incidence rate in adults and children, the mortality rate, the incidence of birth defects, genetic disorders, and immune system disorders, the concentration of toxic substances in various biological fluids of the human organism.

The dependence of health on the state of the environment can be determined by certain indicators. For instance, a quantitative indicator of population health in the area of environmental monitoring is the health index. Under the condition of complete environment safety, the generalized health index is approximately 65 – 70 % [4]. The integral indicator of health is the adaptive capacity of the human organism. For a person not adapted to the fluctuations of the abiotic factors, the typical symptoms are the changes in his/her physical and mental health.

For assessing the relationship between the environment and the health of the population, and for creating relevant information systems, the WHO European Center for the Environment and Health recommends the following main groups of indicators: the health status (the mortality rate, the incidence rate, the prevalence of diseases); the physical environment (state and effect indicators) – availability of housing, the quality of drinking water and air, radiation, noise; the working conditions (the effect of these factors on the organism); health protection (regulatory food products quality assurance); and the health services [5]..

II. LITERATURE REVIEW

In recent years, several studies devoted to analyzing the health of the population of Russia and its dependence on the environment have been made. In domestic scientific literature, the issues of the effect of the environmental factors on human health, including the risk of oncology diseases, have been addressed in several publications in the fields of hygiene, toxicology, ecology, and epidemiology.

For instance, the scientific research performed by B. B. Prokhorov et al. reveals the genetic aftereffects of the changes in the human environment on the process of population reproduction in Russia [6]. Domestic researchers in the field of medical ecology have considered the issues of ecology and human health [7].

Domestic scientists in the field of medical ecology divide the diseases associated with environmental factors into two groups:

1) the environmentally dependent diseases are those of the nonspecific nature occurring on the background of the changes in the environment. With that, the environmental factors trigger the pathogenetic mechanisms of the disease and complicate its course. As a consequence, the overall incidence rate increases along with cardiovascular, oncology, endocrine, pediatric diseases incidence rate, pregnancy pathologies, disorders in fetal development, etc.;

2) environmentally determined are the diseases of specific nature, when the environmental factor is an etiological factor of the disease (endemic diseases, natural focal diseases, infections, diseases caused by harmful chemicals, radiation, and biological allergens) [8].

According to researchers, the leading role in the etiology and pathogenesis of the diseases is played by the heredity and the state of the environment [9, 10]. Harmful chemical factors contribute to the emergence of new mutations, which is the cause of oncology and other diseases. In particular, the total number of diseases associated with genetic changes, pregnancy disorders, and development defects has increased several times within the last years [11].

Scientific studies have found a strong relationship between the environmental pollution and the frequency of prematurity, developmental defects in children, chromosomal disorders, allergic disorders, anemia, mental retardation, abnormal behavior of children, and their physical development. Children that live in the zones of the ecological disaster have congenital malformations, recurrent bronchitis, allergic diseases, nephropathy, decreased intelligence quotient (IQ), bronchial asthma, immunodeficiency, endocrine disorders, neuropsychic diseases, oncopathology, etc. [12].

Recently, a lot of attention has been paid to the quality of the air environment in closed premises. Scientists and hygienists are more and more inclined to think that the air indoors is the main factor that influences forming population health and can cause the development of ecologically-dependent diseases.

By the results of the research performed by scientists from various countries, the concentrations of chemical compounds in the air of residential premises are higher than the similar indicators of air pollution by 25 – 62 % [13, 14], and in some works, excessive levels of toxic chemical compounds are noted in the air in closed premises, which are 1.4 – 4 times higher than in the air outdoors [15]. For example, it is indoors that people get 40 – 60 % of the annual dosage of benzo(a)pyrene [16].

A significant part of the chemical compounds found in the air of residential premises belongs to the class of carcinogens. It is, therefore, possible to assume appropriate growth of the aerogenic carcinogenic load on humans and, consequently, increased risk of forming the ecology-dependent part of cancer incidence rate, which was found before only upon the action of carcinogens contained in the atmospheric air. This is confirmed by the results of the epidemiological studies of foreign scientists. They prove that living in certain conditions (e.g., the use of stove heating and cooking on the open fire) increases the number of cases of lung and larynx cancer [17]. Experts also point to the fact that burning solid fuels indoors leads to high levels of air pollution, which increases the risk of lung cancer, which is additionally promoted by the low level of ventilation in the residential premises [18].

With that, the composition and concentration of the chemical compounds in the air of residential areas depend on their concentrations in the air outdoors, and the presence of internal sources of pollution. People spend almost 75 % of their time indoors, where the air environment even in the case of low concentrations of harmful substances can seriously affect the well-being and health of the residents due to the prolonged exposure.

After introducing into the hygienic practice of the risk assessment methodology, Y.D. Gubernsky studied the effect of carcinogenic compounds in the air of enclosed spaces of various social purposes on public health. He studied the chemical compounds that entered the air indoors from polymeric materials, food products, and household chemicals. By the results of these studies it was found that the total contribution of chemical air pollution in residential and public buildings in the formation of the risk for humans might reach 80 – 95 % [19, 20].

The hypothesis of the study is as follows: the methodology of assessing the carcinogenic risk is a great management tool for the practical medicine authorities, which allows developing the required hygiene recommendations.

III. METHODS

A. General desciption

The study used analytical and mathematical research methods.

The theoretical aspects of the problem of medical-ecological assessing the formation of carcinogenic risk from air pollution in megacities were studied through analyzing the scientific literature on the problem.

In the practical part of the study, the level of carcinogenic load on the organism was identified based on the eight carcinogenic substances (benzo(a)pyrene, nitrosodiethylamine, NDMA, formaldehyde and benzene, as well as heavy metals, such as cadmium, nickel, chromium), which were determined according to the FSBI "Central Territorial Administration for Hydrometeorological and Environmental Monitoring" (Central AHEM) (Moscow).

The choice of the stated carcinogens was determined, first, by the fact that they were common to the air indoors and outdoors, and second, by the fact that most of them were (by definition of the WHO experts) indicators of air quality in residential premises.

The entire study concerned the South-Eastern district of Moscow, covering six administrative districts.

The inhalation load of chemical carcinogens, and the resulting individual and total carcinogenic risks were calculated according to the recommendations of domestic and foreign researchers [11, 12].

Also, the study used the method of the expert survey for analyzing the approaches to solving the problem of the carcinogenic risk from air pollution in megacities.

The respondents to the online survey were 21 experts, of which 12 people were from the FSBI Central AHEM, and nine persons were from the FSBI Centre of Strategic Planning of the Ministry of Healthcare of the Russian Federation.

B. Algorithm

In the first phase of the study, the scientific literature on the problem of carcinogenic risk from air pollution of megacities was studied.

The second phase of the study involved the qualitative and quantitative study of the carcinogenic risk of air pollution in closed areas and the air outdoors in megacities, as well as expert interviews on the implementation of possible approaches to solving the problem of the carcinogenic risk from air pollution in megacities.

C. Flow chart

IV. RESULTS

The summarized results of parallel sampling according to the FSBI Central AHEM showed the presence of a spectrum of carcinogenic substances indoors and outdoors due to the natural air exchange and ventilation (Table 1).

Table 1. The content of carcinogenic compounds in the air outdoors and indoors (the average daily concentrations)

Carcinogenic compounds	Atmospheric air	The air in dwelling premises	The air in public premises
Benzopyrene, ng/m^3	2.1 ± 0.9	2.81 ± 1.1	3.96 ± 0.34
NDMA, ng/m^3	19.7 ± 0.2	36.36 ± 0.9	48.42 ± 1.77
NDEA, ng/m^3	5.78 ± 0.11	12.84 ± 2.1	16.86 ± 2.14
Benzene, ng/m^3	0.018 ± 0.002	0.035 ± 0.001	0.22 ± 0.01
Formaldehyde, mg/ m^3	0.006 ± 0.0012	0.0081 ± 0.001	0.021 ± 0.009
Cadmium, mg/ m^3	0.0002	0.0002	0.0008
Nickel, mg/ m^3	0.0006	0.0003	0.00006
Chromium, mg/ m^3	0.0006	0.00004	0.000010

Based on the obtained data and taking into account the duration of a person exposure to a particular microenvironment (atmospheric air of populated areas, residential and public buildings), and the average duration of human life, the total inhaled dosage entering the human body, and the resulting individual and total carcinogenic risks were determined [11, 12].

The analysis showed the presence of certain fluctuations of the risks, depending on the location of the dwelling building. The greatest contribution, according to experts, in the formation of the risk is made by carcinogenic heavy metals, while the least contribution is made by benzopyrene and formaldehyde, although these two substances in quantitative terms exceed the permissible hygienic standards the most. According to the international classification, the risk caused by benzo(a)pyrene can be regarded as the minimum, by nickel and formaldehyde — as allowable. With the acceptable level of the risk, as specified by the experts, these compounds are to be monitored, and additional measures for their reduction are to be planned.

According to the obtained data, for cadmium, chromium, NDMA and NDEA, the carcinogenic risk of exposure is categorized by experts as "alarming", which requires constant monitoring of the levels of these compounds in the air in the dwelling buildings, identifying the sources of emission into the atmospheric air and, eventually, into closed premises, developing and implementing scheduled health activities.

The data in Table 2 (for the six administrative districts) allow ranking the compounds in the air indoors and determining the most carcinogenically dangerous ones by the magnitude of the carcinogenic risk index.

Table 2. The carcinogenic risk from the air in dwelling houses

District	The carcinogenic risk from exposure to the compounds								
	Benzo-pyrene	NDMA	NDEA	benzene	Formaldehyde	cadmium	nickel	chromium	Σ
Zhulebino	1.5 x10^{-6}	2.3x10^{-4}	2.6x10^{-4}	1.2x10^{-4}	3.5x10^{-5}	1.1x10^{-4}	4.5x10^{-5}	3.6x10^{-4}	1.2x10^{-3}
Kapotnya	1.0x10^{-6}	1.7x10^{-4}	1.9x10^{-4}	1.0x10^{-4}	1.8x10^{-5}	0.7x10^{-4}	5.4x10^{-5}	3.1x10^{-4}	9.1x10^{-4}
Kuzminki	0.9x10^{-6}	1.9x10^{-4}	1.2x10^{-4}	0.9x10^{-4}	1.5x10^{-5}	0.7x10^{-4}	4.1x10^{-5}	2.7x10^{-4}	8.0x10^{-4}
Leforto vo	1.6x10^{-6}	2.4x10^{-4}	3.3x10^{-4}	1.4x10^{-4}	4.5x10^{-5}	1.2x10^{-4}	2.7x10^{-5}	0.9x10^{-4}	1.0x10^{-3}
Lyublino	0.9x10^{-6}	1.4x10^{-4}	1.4x10^{-4}	0.8x10^{-4}	1.9x10^{-5}	1.0x10^{-4}	5.4x10^{-5}	2.3x10^{-4}	7.6x10^{-4}
Pechatniki	0.9x10^{-6}	1.5x10^{-4}	1.3x10^{-4}	0.8x10^{-4}	1.7x10^{-5}	0.7x10^{-4}	0.9x10^{-5}	2.7x10^{-4}	7.3x10^{-4}
In the case of concentration at the level of MPC	0.4x10^{-6}	2.6x10^{-4}	2.4x10^{-4}	2.9x10^{-4}	1.5x10^{-5}	2.0x10^{-4}	9.0x10^{-5}	6.8x10^{-3}	7.8x10^{-3}

Determination of the sources of their ingress into the air of dwelling houses, according to experts, will make it possible to substantiate the measures to reduce their harmful effects on the organism.

Assessing the total carcinogenic risk to the health of the population, which is created by the studied compounds inside dwelling houses (Table 2), experts state that its level in most apartments is considered to be alarming (7.3 – 9.1x10-4), approaching high level. That is, the existing level of air pollution in dwelling houses with carcinogenic compounds cannot be considered safe for the health of the residents.

For comparison, the carcinogenic risk due to the pollution of the atmospheric air and the air in public premises was calculated; the results are shown in Table 3.

Table 3. The carcinogenic risk from the pollution of the atmospheric air and the air in public premises

Carcinogenic compounds	The air in public premises		Atmospheric air of the city	
	concentration, mg/m^3	carcinogenic risk	concentration, mg/m^3	carcinogenic risk
Benzopyrene	3.96x10^{-6}	0.4x10^{-6}	3.7x10^{-6}	1.2x10^{-6}
NDMA	32.42x10^{-6}	5.2x10^{-5}	5.9x10^{-6}	2.3x10^{-5}
NDEA	14.86x10^{-6}	7.3x10^{-5}	3.2x10^{-6}	3.8x10^{-5}
Benzene	0.092	8.1x10^{-5}	0.01	2.1 x10^{-5}
Formaldehyde	0.011	1.7x10^{-5}	0.004	1.5x10^{-5}
Cadmium	0.00017	3.5x10^{-5}	0.00010	5.0x10^{-5}
Nickel	0.00050	1.4x10^{-5}	0.00010	0.7x10^{-5}
Chromium	0.00007	9.6x10^{-5}	0.00002	6.7x10^{-5}
Σ		3.7x10^{-4}		2.2x10^{-4}

According to experts involved in the survey, given the time of exposure to particular microenvironment, these data show higher risk for the population of a megacity from carcinogenic substances in public premises, compared to the risk from the atmospheric air. As to the risk assessment for each substance, experts explain that the same patterns remain that were described in studying the pollution of dwelling houses.

Considering the data about carcinogenic risks separately for the atmospheric air and the air in public and residential buildings, experts emphasize that they are all components of the total aerogenic load. It was, therefore, important to provide a comparative risk assessment for each human environment (Table 4).

Table 4. The shares of the contributions of specific human microenvironments in the formation of the carcinogenic risk

Human environment	carcinogenic risk	
	risk x 10^{-4}	the share of contribution, %
The air in dwelling premises	7.3	55.3
The air in public premises	3.7	28.0
Atmospheric air	2.2	16.7

According to the calculations, the greatest contribution in the total formation of the aerogenic carcinogenic risk is created by the air in dwelling houses, the share of which exceeds 55.0 % of the contribution of all microenvironments, and the total contribution of closed premises reaches 83.0 %.

V. DISCUSSION

Thus, the provided materials, according to experts, show the necessity of developing and adopting various preventive (constructive, planning) measures aimed at reducing the pollution of the air environment in dwelling houses. Despite the influence of the outside air on the air quality indoors, the behavior and the lifestyle of tenants is of considerable importance in this process. According to one of the respondents (Kirill N.), "in particular, this should include the manner of using the gas stoves that burn natural gas, and smoking in the room". One should also consider, as stated by the experts, the fact that the leading factor that affects the state of air pollution is the efficiency of inflow exhaust ventilation.

Another aspect to consider, according to experts, is the following. The concentrations of some carcinogens (in particular, chromium, cadmium, and benzene) in the air in dwelling houses was less than their MPCs. However, the carcinogenic risk of their effect, as evidenced by relevant indicators, is considered alarming. This circumstance, according to experts, is evidence of the fact that the MPCs of some carcinogens, as determined by the toxicological symptoms of hazard, do not meet the adopted levels of safety for humans, and do not consider long-term consequences. A need arises for revising the existing regulatory framework concerning the possible risks.

Experts point out that only 60 % of the chemical substances are subjected to monitoring, while the rest remain without the attention of the regulators. Therefore, experts recommend assessing the air pollution by the data of modeling the pollutants in the surface layer of the atmosphere, as an alternative to the monitoring activities. This approach will provide an opportunity to

– determine the average concentrations of the pollutants in the emissions from industrial enterprises in the atmospheric air for a certain period (1 hour, 24 hours, month, year);

– calculate the exposure for adults and children based on the negative effect of all priority pollutants, which allows us to assess the full range of emissions;

– assess the risk to the health of the population in the case of acute and chronic inhalation exposure; and

– analyze the contributions of individual sources of emission in the formation of the risk areas for maintaining the measures for maintaining public health.

According to experts, environmental risk assessment suggests the likelihood of groups of people falling under the influence of various levels of pathogenic effects, and these and other adverse effects occurring in these persons. These elements correspond to the main aspects of risk analysis — analysis of their impact and analysis of the effects.

Identification of the risk factors requires identifying the relations between the events and the evidence of them not being accidental, being sustainable, and being the precursor of the disease. The obtained data are analyzed for their compliance with the characteristics of causality (the strength of statistical relationships, consistency, specificity, coincidence with the general biological ideas about the etiology and the pathogenesis of the disease, etc.).

To determine the risk of exposure to chemical pollutants, as stated by experts, it is important to determine the relationship between the dosage and the effect. For this purpose, various experimental and mathematical models are used. However, most of them are based on the data obtained during experiments on animals, which complicates their extrapolation to humans.

Since the mechanisms of harmful factors effect on the health of the population are very difficult to trace, the experts turned their attention to analyzing the effects observed in the health status of the population. From these positions, the interviewed experts consider the risk as the probability of negative effects in a certain part of the population (5 %, 20 % risk). This method of risk assessment can be itemized for the effect (for example, the risk of the onset of a particular disease, the risk of the onset of premature death, etc.).

The study has proven that the methodology of assessing the carcinogenic risk is a great management tool for the practical medicine authorities, which allows developing hygienic recommendations in resolving the following issues:

– substantiation of the sanitary protection zones, which allows the determination of the possible effect (for instrumental measurements) and the zones with the unacceptable levels of risk for the population during the sanitary-epidemiological expertise;

– providing hygienic recommendations and adopting adequate architectural solutions in designing industrial facilities according to the requirements of the sanitary legislation;

– substantiation of the efficiency of the nature protection actions that allow identifying the main sources of pollution and assessing their contribution to the total pollution at the stage of risk management; and

– assessing the harm to the health of the population living in the high-risk zones to develop preventive measures.

VI. CONCLUSION

At the end of the study, the following conclusions may be drawn.

1. The hazard degree of the components of aerogenic carcinogenic risk may be presented as follows: the air in dwelling houses → the air in public buildings → the atmospheric air in a megacity.

2. The most dangerous substances in the process of forming the carcinogenic risk are benzene, chromium VI and nitrosamines, which are the products of exogenous synthesis of nitrogen-containing compounds, where the leading role is played by nitrogen oxides.

3. Preventing the aerogenic carcinogenic load on the population requires developing and implementing the measures aimed at improving the microclimate indoors.

The results of the study have confirmed the hypothesis that the methodology of assessing the carcinogenic risk is a great management tool for the practical medicine authorities, which allows developing the required hygiene recommendations.

REFERENCES

1. Y.M. Rogatnev, V.N. Scherba, O.S. Nazarova, T.A. Filippova, O.N. Dolmatova, "Spatio-Temporal Zoning of the Urban Lands' Functioning for Ensuring the Sustainable Development of the City", Journal of Environmental Management and Tourism, 10(1), 2019, pp. 210-219.
2. A.I. Finogenov, A.V. Popov, "Concept of Planning Development of Coastal Resort Settlements under Conditions of Complex Relief", Journal of Environmental Management and Tourism, 10(1), 2019, pp. 135-139.
3. T.S. Borisova, "Valeologiya" [Valeology]: textbook. Minsk: Vysheishaya Shkola, 2018, p. 352.
4. K.O. Nurgaliyeva, A.U. Amirova, A.S. Nurtazinova, « The Green Economy in Market-Oriented Countries: The Case of Kazakhstan», Journal of Environmental Management and Tourism, 9(5), 2019, pp. 1019-1029.
5. Health 2020: Basics of the European policy and strategy for the twenty-first century. The World Health Organization. 2013. Available: http://www.euro.who.int/__data/assets/pdf_file/0017/215432/Health2020-Long-Rus.pdf
6. B.B. Prokhorov, E.I. Ivanova, D.I. Shmakov, E.M. Shcherbakova, "Mediko-demograficheskoe prognozirovanie" [Medical and demographic forecasting]. Moscow: MAX Press, 2011, pp. 360.
7. V.M. Gilnutdinov, L.K. Kazantseva, T.O. Tagaeva, K.S. Kugaevskaya, "Vliyanie zagryazneniya okruzhayushchei sredy na zdorove naseleniya regionov Rossii" [The effect of environmental pollution on the health of the population in regions of Russia]. Region: Economics and sociology, 1, 2013, pp. 209 – 228.
8. V.I. Kharitonov. "Zadachi gigieny i ekologii primenitelno k probleme ekologicheski obuslovlennoi zabolevaemosti" [The tasks of hygiene and ecology applied to the issue of environment-related morbidity]. Russian medical-biological Bulletin n.a. Academician I. P. Pavlov, 2, 2015, pp. 137–145.
9. M. Kazakov, V. Gladilin, A. Mirokhina, E. Drannikova, G. Narozhnaya, "System Diagnostics and Monitoring of Socio-Economic and Tourist Potential of Peripheral Territories of the Region", Journal of Environmental Management and Tourism, 9(2), 2018, pp. 283-290.
10. A.A. Chebotareva, V.E. Chebotarev, E.I. Danilina, "Transport and Logistics in a Modern Metropolis: New Opportunities", International Journal of Recent Technology and Engineering, 8(1), 2019, pp. 2247-2251.
11. K. Tripathy, T. Nanda, O.V. Sudharani, "The Influence of Environmental and Genetic Factors on Various Disorders and Diseases", Journal of Genetic Syndromes & Gene Therapy, 11, 2011. Available: https://www.longdom.org/open-access/the-influence-of-environmental-and-genetic-factors-on-various-disorders-and-diseases-2157-7412.S11-001.pdf
12. D. Rojas-Rueda, "Environmental Burden of Childhood Disease in Europe", International Journal of Environmental Research and Public Health, 16(6), 2019. https://www.ncbi.nlm.nih.gov/pubmed/30917598
13. D. Castro, K. Slezakova, C. Delerue-Matos, M.C. Alvim-Ferraz, S. Morais, M.C. Pereira, "Polycyclic Aromatic Hydrocarbons in Gas and Particulate Phases of Indoor Environments Influenced by Tobacco Smoke: Levels, Phase Distributions, and Health Risks". Atmospheric Environment, 45(10), 2011, pp. 1799-1808.
14. U. Franck, O. Herbarth, S. Röder, U. Schlink, M. Borte, U. Diez, U. Krämer, I. Lehmann, "Respiratory Effects of Indoor Particles in Young Children are Size Dependent", Science of the Total Environment, 409(9), 2011, pp. 1621- 1631
15. N.V. Nikiforova, A.A. Kokoulina, S.Y. Zagorodnov, "Otsenka zagryaznennosti vozdukha zhilykh pomeshchenii formaldegidom v usloviyakh primeneniya polimersoderzhashchikh stroitelnykh i otdelochnykh materialov" [Assessment of dwelling houses air pollution with formaldehyde in the conditions of using of polymer-containing building materials]. Hygiene and sanitation, 95(1), 2016, pp. 28 – 32.
16. L.R. Zaripova, A.V. Ivanov, E.A. Tafeeva, "Vnutrizhilishchnaya sreda i zdorovye naseleniya" [Environment in dwelling houses and the health of the population]. Modern issues of science and education, 5, 2015. Available: http://www.science-education.ru/ru/article/view?id=22081
17. C. Chen, B. Zhao, "Review of Relationship between Indoor and Outdoor Particles: I/O ratio", Infiltration Factor and Penetration Factor. Atmospheric Environment, 45(2), 2011, pp. 275-288.
18. R. Goyal, M. Khare, "Indoor Air Pollution and Health Effects", Air Pollution – Health and Environmental Impacts, 2010, pp. 109-134.
19. Y.D. Gubernsky, S.M. Novikov, N.V. Kalinina, V.A. Matsyuk, "Otsenka riska vozdeistviya na zdorovye naseleniya khimicheskikh veshchestv, zagryaznyayushchikh vozdukh zhiloi sredy" [Assessment of the risk of the impact of the chemicals polluting the air of the residential environment on health]. Hygiene and sanitation, 6, 2006, pp. 27 – 37.
20. Y.D. Gubernsky, N.V. Kalinina, E.B. Gaponova. "Gigienicheskaya kharakteristika khimicheskogo zagryazneniya vozdushnoi sredy zhilykh i obshchestvennykh zdanii" [Hygienic characteristic of chemical pollution of the air environment in residential and public buildings]. Proceedings of the plenary session "Methodological issues of examining, evaluating and regulating the chemical environmental pollution and its impact on the health of the population. Moscow, 2015, pp. 102 – 105.