UDC 612-06
DOI: 10.21668/health.risk/2020.4.05.eng

Read online

Research article

TRENDS DETECTED IN CHILDREN'S HEALTH AND THEIR RELATION WITH BASIC AEROGENIC RISK FACTORS UNDER EXPOSURE TO SPECIFIC AMBIENT AIR CONTAMINATION CAUSED BY METALLURGIC AND WOOD-PROCESSING ENTERPRISES

M.A. Zemlyanova[1], A.N. Perezhogin[2], Yu.V. Koldibekova[1]

[1]Federal Scientific Center for Medical and Preventive Health Risk Management Technologies,
82 Monastyrskaya Str., Perm, 614045, Russian Federation
[2]Irkutsk Antiplague Research Institute of Siberia and Far East awarded by the Labour Red Banner,
78 Trilissera Str., Irkutsk, 664047, Russian Federation

Industrial objects including metallurgic and wood-processing enterprises that emit hazardous chemicals into ambient air are often located within or close to residential areas; it results in poorer ambient air quality and health disorders caused by it, first of all, among children.

Our research objects were chemicals contents in ambient air in a residential area exposed to emissions from metallurgic and wood-processing enterprises (the test territory) and in an area where there were no such productions (the reference territory), and primary morbidity among children in both of them.

We determined priority chemical risk factors basing on hygienic assessment of ambient air quality and calculation of risks that non-carcinogenic effects would occur in organs and systems of children who lived in a zone exposed to the given industrial objects. These factors included aluminum oxide, particulate matter, phenol, and gaseous fluorides and their contents were up to 5.0 times higher than permissible levels. We detected negative trends in primary morbidity among children and established authentic models showing dependence between a probable growth in morbidity as per respiratory diseases, diseases of the nervous system, gastric diseases, diseases of the musculoskeletal system and connective tissue, and diseases of the urogenital system and total doses of chemicals under aerogenic exposure. All the above mentioned indicates that poor ambient air quality in a residential area can make for a growth in related morbidity as per the given nosologies.

Established and parameterized cause-and-effect relations allow predicting negative responses in critical organs and systems (as per the given nosologies) of exposed children. It provides scientific substantiation for developing relevant prevention activities aimed at reducing and preventing negative consequences for health of children living in regions where large metallurgic and wood-processing enterprises are located.

Key words: *chemical factors in ambient air, ambient air contamination, industrial objects, metallurgic and wood-processing enterprises, non-carcinogenic risks, aerogenic risk factors, critical organs and systems, primary morbidity among children.*

When industrial objects including metallurgic and wood-processing enterprises are located within residential areas or close to them, it often results in poorer quality of ambient air and occurrence of related health disorders especially among children [1]. We analyzed research works both by domestic and foreign researchers and revealed that it was not a rare case when the greatest part of a city population lived in zones exposed to chemical emissions and there were various negative responses regarding their health [2–7]. Prior-

Marina A. Zemlyanova – Doctor of Medical Sciences, Chief Researcher acting as the Head of the Department for Biochemical and Cytogenetic Diagnostic Techniques (e-mail: zem@fcrisk.ru; tel.: +7 (342) 236-39-30; ORCID: http://orcid.org/0000-0002-8013-9613).

Aleksei N. Perezhogin – Head of the Department for Sanitary Protection on a Territory and Monitoring (e-mail: mail@38.rospotrebnadzor.ru; tel.: +7 (3952) 24-33-67; ORCID: https://orcid.org/0000-0002-5678-468X).

Yuliya V. Koldibekova – Candidate of Biological Sciences, Senior researcher acting as the Head of the Laboratory for Metabolism and Pharmacokinetics at the Department for Biochemical and Cytogenetic Diagnostic Techniques (e-mail: koldibekova@fcrisk.ru; tel.: +7 (342) 237-18-15; ORCID: http://orcid.org/0000-0002-3924-4526).

ity substances that create extremely high ambient air contamination in some regions where the above mentioned industries are located are nickel, copper, di-aluminum trioxide, chromium (VI), aromatic hydrocarbons, fluorides and gaseous fluorides (components that often occur in emissions from metallurgic enterprises) as well as particulate matter, methanol, phenol, etc. (components that often occur in emissions from wood-processing enterprises). All the above-mentioned substances predominantly belong to the 1–2 hazard categories and produce tropic effects on the respiratory organs, cardiovascular, musculoskeletal, nervous and endocrine systems, kidneys, and digestive organs[1] [8–12].

In some RF regions where metallurgic and wood-processing enterprises are located population morbidity with respiratory diseases is caused by ambient air being contaminated with specific chemical compounds typical for such productions. Lipetsk region, Irkutsk region, Sverdlovsk region, Krasnoyarsk region, and some others are among territories where morbidity with respiratory diseases is high; these diseases are of allergic nature, involve lymphproliferative processes, and are caused by aerogenic exposure to chemical factors which are typical for the above-mentioned industries[2]. Apart from respiratory diseases, diseases of the circulatory system are also widespread. Primary morbidity with cardiovascular diseases, predominantly functional cardiopathy, was shown to be authentically higher among people living in residential areas where particulate matter concentrations in ambient air were above hygienic standards than among people living in reference areas where hygienic standards were not violated [13]. The gastrointestinal tract is also a target organ, especially when it comes down to children, in people exposed to ambient air being contaminated with specific chemicals. Morbidity with gastric diseases among children living in contaminated areas is usually 2–4 times higher than it is in areas where there are no such industrial objects outlined above [14]. Thus, children exposed to aromatic hydrocarbons more frequently suffer from inflammatory-dystrophic diseases of the gastrointestinal tract such as chronic gastritis and gastroduodenitis. Such substances as phenol and ethylbenzene have hepatotoxic properties and are able to produce direct effects on cellular structures via doing damage to membrane hepatocytes transportation, distorting biological processes in liver cells, and freeing their own metabolites out of them [15]. Diseases that involve functional disorders in the central nervous system and endocrine system are more frequent among children living in industrially developed regions than among children living on reference territories [16]. A basic mechanism for effects produced by aerotechnogenic chemical risk factors on the hormone, nervous, and immune system is activation or suppression of hypothalamo-pituitary-adrenal axis that can result in hormonal imbalance [17, 18]. Neuroendocrine impacts on the immune system functioning are related to the nervous system being able to perform direct or indirect control over various hormones secretion; they are also related to «inverse» influence exerted by hormones on neuromediators [18, 19]. When certain chemicals (chromium, lead, phenol, copper oxide, etc.) are introduced with ambient air via inhalation, there is an increase in morbidity with diseases of the kidneys. Being nephrotoxic, these substances can both directly influence renal parenchyma or exert indirect impacts via changes in hemodynamics and acid-base balance in the internal environment [20]. Renal functional disorders occur as a decrease in glomerular filtration, tubular reabsorption inhibition, and weaker renal plasma flow[3]. Analy-

[1] HS 2.1.6.3492-17. Maximum permissible concentrations (MPC) of contaminants in ambient air in urban and rural settlements. KODEKS: an electronic fund for legal and reference documentation. Available at: http://docs.cntd.ru/document/556185926 (03.11.2020) (in Russian).

[2] On sanitary-epidemiologic welfare of the population in the Russian Federation in 2019: The State Report. Moscow, The federal Service for Surveillance over Consumer Rights Protection and Human Well-being Publ., 2020, 299 p. (in Russian).

[3] Pathological kidney physiology: a manual. In: E.N. Kuchuk, F.I. Vismont eds. Minsk, BSMU Publ., 2011, 41 p. (in Russian).

sis of morbidity among children who lived in residential area exposed to emissions from both metallurgic and wood-processing enterprises revealed that primary morbidity with diseases of the musculoskeletal system was up to 2.0 times higher among them than on average in the country [21]. Given all the above mentioned, we can conclude that in such areas there is elevated risk of disability among children and poorer life quality.

Therefore, all these data indicate that chemical factors that are components in emissions form metallurgic and wood-processing enterprises make a significant contribution into ambient air contamination and increased prevalence of diseases associated with it practically as per all basic nosology categories.

Our research goal was to reveal and assess trends in occurring health disorders and their relations with basic aerogenic risk factors given specific ambient air contamination by metallurgic and wood-processing enterprises.

Data and methods. Our research objects were chemicals contents in ambient air and primary morbidity among children living on a territory where metallurgic and wood-processing enterprises were located (the test territory) and children living on a territory without such enterprises (the reference territory).

Ambient air samples were taken on the examined territories at seven observation points and analyzed during 2014–2017 by experts from the Center for Hygiene and Epidemiology. Obtained results were assessed via analyzing contents of the examined chemical components and their conformity with hygienic standards fixed by the HS 2.1.6.3492-17.

Health risks for children under chronic inhalation exposure to chemical factors were assessed in accordance with the Guide on health risk assessment under exposure to chemicals that pollute the environment involving calculation of hazard quotient and hazard index (HQ, HI) that were determined taking into account organs and systems being critical under aerogenic exposure[4].

Our initial data for analyzing morbidity among children were taken from state statistical reports such as Form No. 12 «Data on a number of diseases registered among patients living on a territory where a medical organization renders its services» over 2014–2018. To analyze morbidity among children living on the test and reference territories basing on data obtained from state statistical reports, we calculated primary morbidity in each analyzed year and calculated average values over the whole observation period (2014–2018). Data on morbidity are given as a number of disease cases per 1,000 people from a corresponding age group. To describe dynamics of morbidity, we calculated its growth (decrease) rates in 2018 against 2014 (in %).

Mathematical modeling within «a dose of a chemical inhaled with ambient air – morbidity among children» system was performed basing on data on population applying for medical aid in 2014–2018.

Results and discussion. We performed hygienic assessment of ambient air quality in residential areas influenced by metallurgic and wood-processing enterprises as per data provided by the Center for Hygiene and Epidemiology over 2014–2017. The assessment revealed that hygienic standards were violated as per contents of certain chemicals in ambient air such as aluminum and its compounds (up to 2.00 average daily MPC); particulate matter (up to 3.01 average daily MPC); phenol (up to 1.1 average daily MPC), gaseous fluorides (up to 1.7 average daily MPC) (Table 1).

Over the same period, ambient air in residential areas on the reference territory contained particulate matter in concentrations that were up to 1.2 times higher than hygienic standards. Hygienic standards on the reference territory were not violated as per aluminum, benzene, phenol, manganese, nickel, chromium, lead and its compounds, and fluorides.

[4] G 2.1.10.1920-04. Guide on health risk assessment under exposure to chemicals that pollute the environment. Moscow, The Federal Center of the State Sanitary Epidemiologic Surveillance, RF Public Healthcare Ministry Publ., 2004, 143 p. (in Russian).

Table 1

Average contaminants concentrations in ambient air in residential areas influenced by metallurgic and wood-processing enterprises detected at observation posts belonging to the Center for Hygiene and Epidemiology in 2014–2017, shares of MPCav.d.

A chemical	MPCav.d., mg/m^3	2014	2015	2016	2017	Average over 2014–2017
Aluminum and its compounds	0.01	–	–	2.00	–	2.00
Benzene	0.1	–	–	–	–	–
Particulate matter	0.15	–	–	3.01	–	3.01
Phenol	0.006	0.21	1.50	1.59	–	1.10
Manganese	0.001	–	–	0.07	–	0.07
Methanol	0.5	–	–	0.01	–	0.01
Nickel	0.001	–	–	0.03	–	0.03
lead	0.0003	–	–	0.33	–	0.33
Poorly soluble non-organic fluorides	0.03	–	–	0.06	–	0.06
Gaseous fluorides	0.005	0.74	1.55	2.89	–	1.73
Chromium $^{6+}$	0.0015	–	–	0.01	–	0.01

Table 2

Hazard quotients (HQ) and hazard indexes (HI) under chronic inhalation exposure for children living on a territory exposed to metallurgic and wood-processing enterprises

No.	Chemical	Hazard quotient (HQ)									
		Blood and blood-forming organs	Cardiovascular system	Nervous system	Respiratory organs	Reproductive system	Hormone system	Kidneys	Liver	Immune system	Skeletal system
1.	Aluminum and its compounds	–*	–*	5.4	5.4	–*	–*	–*	–*	–*	5,4
2.	Benzene	0.41	0.41	0.41	–*	0.41	–*	–*	–*	0.41	–*
3.	Particulate matter	–*	5.3	–*	5.3	–*	–*	–*	–*	–*	–*
4.	Manganese	–*	–*	1.8	1.8	–*	–*	–*	–*	–*	–*
5.	Nickel oxide	2.0	-*	2.0	2.0	-*	-*	-*	-*	2.0	
6.	Lead and its compounds	0.26	–*	0.26	–*	0.26	0.26	0.26	–*	–*	–*
7.	Phenol	–*	0.98	0.98	0.98	–*	–*	0.98	0.98	–*	–*
8.	Poorly soluble fluorides	–*	–*	–*	0.18	–*	–*	–*	–*	–*	0,18
9.	Gaseous fluorides	–*	–*	–*	1.98	–*	–*	–*	–*	–*	1,98
10.	Chromium (VI)	–*	–*	–*	0.2	–*	–*	0.2	0.2	–*	–*
Hazard index (HI)		**2,67**	**6.69**	**10.86**	**17.84**	0.67	0.26	**1.44**	**1.18**	**2.41**	**7.56**

Note: 1 * means a substance does not influence a critical system under such introduction (when inhaled).

We assessed non-carcinogenic risks of diseases caused by aerogenic exposure to chemicals; the assessment revealed hazard quotients being higher than permissible levels (HQ > 1) for children living on the test territory as regards aluminum and its compounds (HQ = 5.4), particulate matter (HQ = 5.3), manganese (HQ = 1.8), nickel oxide (HQ = 2.0), and gaseous fluorides (HQ = 1.98) (Table 2).

We established that hazard indexes for children exceeded their permissible levels under chronic inhalation exposure to chemicals regarding the respiratory organs (17.8 times), nervous system (10.9 times), skeletal

and cardiovascular systems (6.7–7.6 times), blood and blood-forming organs and immune system (2.4–2.7 times), kidneys and liver (1.2–1.4 times).

Basic contributions into intolerable non-carcinogenic risks of respiratory diseases were made by aluminum (30.2 %), particulate matter (29.7 %), nickel oxide (11.2 %), and gaseous fluorides (11.0 %); diseases of the nervous system, aluminum (49.7 %), nickel (18.4 %), and manganese (16.6 %); blood and blood-forming organs, nickel oxide (74.9 %); immune system, nickel oxide (82.9 %); cardiovascular system, particulate matter (79.2 %); skeletal system, aluminum (71.4 %), and gaseous fluorides (26.2 %). We didn't establish any hazard quotients exceeding their hygienic standards as per aluminum, manganese, nickel, and gaseous fluorides on the reference territory when assessing chronic aerogenic exposure.

The existing aerogenic exposure that occurs due to increased contents of emissions from metallurgic and wood-processing enterprises in ambient air can make for a growth in morbidity with the diseases of respiratory organs, digestive organs, musculoskeletal system and connective tissue, and genitourinary system. It is confirmed by analysis of primary morbidity dynamics among children in 2014–2018 as per certain nosologies (Table 3).

Overall, primary morbidity among children living on the test territory changed insignificantly over the analyzed period; however, there was significant growth as per certain nosologies. Thus, growth in primary morbidity among children over 5 analyzed years was established for the following nosologies: diseases of the digestive organs (118.18 %); diseases of the musculoskeletal system and connective tissue (43.58 %); diseases of the genitourinary system (44.97 %).

We analyzed primary morbidity among children as per specific nosologies; the analysis revealed the greatest growth as per the following ones: osteopathy and chondropathy (190.06 %); glomerular, tubulointerstitial kidney diseases, other diseases of the kidneys and ureter (71.72 %). The greatest decrease rates were revealed for chronic bronchitis, unspecified bronchitis and emphysema (73.33 %); asthma (52.38 %).

Comparative analysis of primary morbidity revealed that average primary morbidity among children was 2.2–41.9 times higher practically as per all nosologic groups on the test territory than on the reference one. Endocrine diseases were the only exclusion from the comparison as there were no such diseases detected among children living on the reference territory.

Table 3

Primary morbidity among children (aged 0–14) living on the test territory influenced by metallurgic and wood-processing enterprises taken as per basic nosologic categories over 2014–2018

Nosologic category (as per ICD-10)	Test territory		Reference territory	
	Average value over 2014–2018	Growth rate against 2014, %	Average value over 2014–2018	Growth rate against 2014, %
J00-J99 Diseases of the respiratory system	2,370.35	–54.97	1,094.18	2.1
K00-K93 Diseases of the digestive system	174.62	118.18	64.78	–47.7
M00-M99 Diseases of the musculoskeletal system and connective tissue	50.22	43.58	1.2	–
G00-G99 Diseases of the nervous system	40.61	–1.09	5.93	179.5
N00-N99 Diseases of the genitourinary system	54.98	44.97	5.60	–100.0
E00-E90 Endocrine, nutritional, and metabolic diseases	30.84	9.27	–	–

Table 4

Parameters used in models showing «a dose of a chemical from the environment – morbidity among children» dependence (as per data provided by the Regional Fund for Obligatory Medical Insurance over 2014–2018)

Nosology group	A chemical contained in ambient air	Model parameters				
		b_0	b_1	F	R^2	p
Diseases of the respiratory system	Nickel	–0.023	6,938.462	72.2	0.29	0.0001
Diseases of the nervous system	Lead	–4.639	17,177.6	143.2	0.52	0.0001
	Manganese	–3.058	0.867	19.1	0.16	0.0001
Diseases of the musculoskeletal system and connective tissue	Gaseous fluorides	–3.241	71.353	18.3	0.14	0.0001
Diseases of the genitourinary system	Lead	–3.094	6,078.919	52.9	0.28	0.0001
	Phenol	–2.824	31.241	70.2	0.31	0.0001

We built a mathematic model showing «exposure – response» dependence; it allowed us to establish the following authentic direct cause-and-effect relations: an increase in morbidity with «Diseases of the respiratory organs» and total doses of nickel ($R^2 = 0.29$; $b_0 = –0.023$; $b_1 = 6{,}938.462$; $p = 0.0001$); «Diseases of the nervous system» and total doses of manganese and lead ($R^2 = 0.16–0.56$; $–3.058 \le b_0 \ge –4.639$; $0.867 \le b_1 \ge 17{,}177.6$; $p = 0.0001$); «Diseases of the musculoskeletal system and connective tissue» and total doses of gaseous fluorides ($R^2 = 0.14$; $b_0 = –3.241$; $b_1 = 71.353$; $p = 0.0001$); «Diseases of the genitourinary system» and total doses of lead and phenol ($R^2 = 0.28–0.31$; $–2.824 \le b_0 \ge –3.094$; $31.241 \le b_1 \ge 6{,}078.919$; $p = 0.0001$) (Table 4).

Conclusion. We analyzed the results obtained via hygienic assessment of ambient air quality and non-carcinogenic risks of diseases occurrence in critical organs and systems of children who lived on a territory exposed to metallurgic and wood-processing enterprises. The analysis allowed establishing priority chemical risk factors (di-aluminum trioxide, particulate matter, phenol, and gaseous fluorides) that were up to 5 times higher than their permissible levels. Unfavorable hygienic situation involving poor ambient air quality in residential areas can lead to a growth in associated morbidity with diseases of the musculoskeletal system and genitourinary system; this conclusion is confirmed by a growth in primary morbidity among children as per these nosologies and authentic cause-and-effect relations between probabilities of growth in morbidity and total doses of chemicals under aerogenic exposure.

Despite there is a descending trend in primary morbidity with diseases of the respiratory system and nervous system over the analyzed period, we established a relation between an increase in morbidity and risk factors (nickel, manganese, and lead). Obtained dependence can indicate that a prognosis is unfavorable as these diseases can develop among children in future.

Therefore, established and parameterized cause-and-effect relations allow predicting negative responses in critical organs and systems (as per specific nosologic groups) among exposed children. These results can be used for developing scientifically substantiated and relevant prevention activities aimed at reducing and preventing negative consequences for health of children living in regions where both metallurgic and wood-processing enterprises are located.

Funding. The research was not granted any sponsor support.

Conflict of interests. The authors declare there is no any conflict of interests.

References

1. Vekovshinina S.A., Kleyn S.V., Zhdanova-Zaplesvichko I.G., Chetverkina K.V. The quality of environment and risk to health of the population residing under the exposure to emissions from colored metallurgy enterprises and wood processing industry. *Gigiena i sanitaria*, 2018, vol. 97, no. 1, pp. 16–20 (in Russian).

2. Onishchenko G.G., Novikov S.M., Rakhmanin Yu.A., Avaliani S.L., Bushtueva K.A. Osnovy otsenki riska dlya zdorov'ya naseleniya pri vozdeistvii khimicheskikh veshchestv, zagryaznya-yushchikh okruzhayushchuyu sredu [Basics of health risk assessment under exposure to chemicals that pollute the environment]. Moscow, NII ECh i GOS Publ., 2002, 408 p. (in Russian).

3. Mamyrbaev A.A.., Sakebaeva L.D., Sabyrakhmetova V.M., Karashova G.I., Shayakhmetova K.N., Umarova G.A. Assessment of risk of non-carcinogenic effects due to the pollution of atmospheric air in residential areas of Uralsk city. *Meditsinskii zhurnal Zapadnogo Kazakhstana*, 2016, vol. 49, no. 1, pp. 82–88 (in Russian).

4. Klyuev N.N., Yakovenko L.M. «Dirty» cities in Russia: factors determining air pollution. *Vestnik Rossiiskogo universiteta druzhby narodov. Seriya: Ekologiya i bezopasnost' zhiznedeyatel'nosti*, 2018, vol. 26, no. 2, pp. 237–250 (in Russian).

5. Beelen R., Raaschou-Nielsen O., Stafoggia M., Andersen Z.J. Effects of long-term exposure to air pollution on natural-cause mortality: an analysis of 22 European cohorts within the multicentre ESCAPE project. *Lancet,* 2014, vol. 383, no. 9919, pp. 785–795. DOI: 10.1016/S0140-6736(13)62158-3

6. Air pollution and child health: prescribing clean air. *World Health Organization,* 2018. Available at: https://www.who.int/ceh/publications/air-pollution-child-health/en/ (10.03.2020).

7. Götschi T., Heinrich J., Sunyer J., Künzli N. Long-term effects of ambient air pollution on lung function: a review. *Epidemiology*, 2008, vol. 19, no. 5, pp. 690–701. DOI: 10.1097/EDE.0b013e318181650f

8. Toxicological profile for manganese: U.S. Department of Health and Human Services. Atlanta, Agency for Toxic Substances and Disease Registry (ATSDR), U.S. Public Health Service Publ., 2012, 556 p.

9. Toxicological Profile for Nikel: U.S. Department of Health and Human Services. Atlanta, Agency for Toxic Substances and Disease Registry Division of Toxicology and Environmental Medicine Publ., 2005, 351 p.

10. Toxicological profile for aluminum: U.S. Department of Health and Human Services. Atlanta, Agency for Toxic Substances and Disease Registry (ATSDR), U.S. Public Health Service Publ., 2008, 357 p.

11. Draft Toxicological Profile for Chromium: U.S. Department of Health and Human Services. Atlanta, Agency for Toxic Substances and Disease Registry Division of Toxicology and Environmental Medicine Publ., 2008, 610 p.

12. Toxicological Profile for fluorides, hydrogen fluoride, and fluorine: U.S. Department of Health and Human Services. Atlanta, Agency for Toxic Substances and Disease Registry Division of Toxicology and Environmental Medicine Publ., 2003, 404 p.

13. Petrov S.B. Ecological and epidemiological estimation of influence of suspended matters in atmospheric air on development of circulatory system diseases. *Ekologiya cheloveka*, 2011, no. 2, pp. 3–7 (in Russian).

14. Makosko A.A., Matesheva A.V. Prevalence trends of environment-related diseases due to the anthropogenic air pollution. *Innovatsii*, 2012, vol. 168, no. 10, pp. 98–105 (in Russian).

15. Myshkin V.A., Bakirov A.B., Repina E.F. Hepatotoxic substances and contemporary trends of hepatotoxic effects correction. *Meditsinskii vestnik Bashkortostana*, 2011, vol. 6, no. 6, pp. 131–136 (in Russian).

16. Baranov A.A., Al'bitskii V.Yu., Ivanova A.A., Terletskaya R.N., Kosova S.A. Trends and the health status of the child population of the Russian Federation. *Rossiiskii pediatricheskii zhurnal*, 2012, no. 6, pp. 4–9 (in Russian).

17. Kim E.A., Cheong H.-K., Joo K.-D., Shin J.-H., Lee J.S., Choi S.-B., Kang D.M. Effect of manganese exposure on the neuroendocrine system in welders. *Neuro Toxicology*, 2007, vol. 28, no. 2, pp. 263–269. DOI: 10.1016/j.neuro.2006.07.013

18. Dietert R.R. Developmental immunotoxicology: Focus on health risks. *Chem. Res. Toxicol.*, 2009, vol. 22, no. 1, pp. 17–23. DOI: 10.1021/tx800198m

19. Dolgikh O.V., Alikina I.N., Gusel'nikov M.A. Assessment of immune status in children with functional respiratory system disorders, living in aerogenic aluminium exposure zone. *Permskii meditsinskii zhurnal*, 2019, vol. 36, no. 5, pp. 44–51 (in Russian).

20. Yagmurov O.D., Petrov L.V. Morphology of acute exogenous nephrotoxic injures. *Nefrologiya*, 2011, vol. 15, no. 1, pp. 27–31 (in Russian).

21. Ustinova O.Yu., Valina S.L., Shtina I.E., Kobyakova O.A., Makarova V.G. Features of children's morbidity living in area of influence enterprises for alumina production. *Zdorov'e naseleniya i sreda obitaniya*, 2019, no. 1, pp. 18–23 (in Russian).

Zemlyanova M.A., Perezhogin A.N., Koldibekova Yu.V. Trends detected in children's health and their relation with basic aerogenic risk factors under exposure to specific ambient air contamination caused by metallurgic and wood-processing enterprises. Health Risk Analysis, 2020, no. 4, pp. 47–54. DOI: 10.21668/health.risk/2020.4.05.eng

Received: 30.09.2020
Accepted: 03.12.2020
Published: 30.12.2020