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ASSESSMENT OF CARCINOGENIC HEALTH RISK FOR POPULATION LIVING IN MONOCITIES AND RURAL SETTLEMENTS

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Our research goal was to perform assessment of carcinogenic health risk for population living in monocities and rural settlements in Orenburg region including both total and individual carcinogenic risk assessment. We assessed carcinogenic health risks for population living in cities with industrial enterprises as economic bases (Novotroitsk and Mednogorsk) and rural settlements (Oktyabrskiy, Ilekskiy, and Tyul'ganskiy districts) in Orenburg region. Exposure assessment was based on the data obtained via laboratory research of environmental objects over 2005–2013 (1,265 atmospheric air samples and 1,897 drinking water samples). We determined total carcinogenic risks for population on each territory under multi-environment impacts exerted by chemicals; a share of each chemical in risk formation was also identified. The results we obtained allow us to make a conclusion that monocities' areas are unfavorable in terms of carcinogenic effects on population health. We detected priority carcinogens for each territory in order to work out practical recommendations on lowering carcinogenic risks and on possibility of delayed effects evolvement. Carcinogenic risk caused by chemicals contained in drinking water both in monocities and rural settlements was considered to be acceptable; however, it was 1.5-2 times higher for monocities population. Overall, chromium took the leading role among carcinogens in monocities air; benzene and arsenic occupied the same place in rural settlements air. Chromium, benzpyrene, and arsenic were priority carcinogens contained in drinking water in rural settlements. Our research proves the necessity to work our practical recommendations on lowering carcinogenic risks and on possibility of delayed effects evolvement on regional level.

Key words: total carcinogenic risk, individual carcinogenic risk, multi-environment impact, chemicals, environmental factors.

In contemporary context, public health depends greatly upon actual assurance of rights to a safe living environment and prevention of diseases. According to the World Health Organization (WHO), the highest contribution to population health is made by a group of factors consolidated by the concept of "external environment", which includes numerous elements that pollute air, water, soil, food [7-9, 15].

In recent decades, high prevalence of malignant neoplasms is a challenging issue for the population of Orenburg region, especially for the population in monocities [1, 2, 11].

Studying the effects of environmental factors on population health is one of the central focuses among other challenges in environmental hygiene. Medical significance of this issue is determined by the need for timely prevention of negative changes in health status associated with the action of environmental factors, their timely correction, which is the basis for primary prevention of diseases [12].

According to WHO, air pollution is the most important specific environmental health risk factor in the European Region [14, 15]. Particular attention should be paid to assessment and prevention of the delayed effects of

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pollutants on public health data [8]. When assessing risks their complex and combined routes of exposure must be taken into account.

In prevention of delayed effects, assessment of carcinogenic health risk is still very important, which in turn allows early identification of risk factors and working out a package of measures for their elimination. At the same time, a differentiated approach should be considered, with priority risk factors identified for each territory [3, 4, 13].

Risk assessment activities open up new opportunities to analyze multi-environment impacts and integrated chemicals intake with maximum consideration to the multiple sources, routes and ways of influence, different spectra of emerging effects.

Among the industrial cities of the region, the largest total carcinogenic risk from exposure to atmospheric air pollution was registered in Novotroitsk, then in Orsk, Mednogorsk and Orenburg. The highest share to carcinogenic effects risk in Mednogorsk, Novotroitsk and Orsk is made by the content of chromium oxide (+6) in atmospheric air (share in the total risk of 87, 82 and 69% respectively). In Orenburg, the largest share (57%) is made by benzene content in the atmospheric air [5]. Sanitary and hygienic rating for the Orenburg region territory in terms of total carcinogenic risk for 2015 showed the highest risk levels exceeding the acceptable ones ($1.0E-10-4$ – $1.0E-10-6$) on 27 territories of the region: in Abdulino, Ponomarevo, Saraktash, Tyul'ganskiy, Oktyabrskiy, Ilekkiy, Matveyevskiy, Aleksandrovskiy, Perevolotskiy, Kuvandykkiy, Belyaevskiy, Tashlinskiy, Sorochinskiy, Krasnogvardeyskiy, Gay, Novoorsk, Novosergievskiy, Sakmara, Adamovskiy, Kvarkenskiy, Yasnenskiy districts, Orenburg city, as well as in Svetlinskoye, Sharlykkiy, Grachevskiy, Orenburgskiy, Pervomaiskiy areas [5]. It should be noted that in the large industrial cities (Orenburg, Orsk), there is a tendency to reducing risk, while in monocities (Mednogorsk, Novotroitsk), there is an increase in carcinogenic and non-carcinogenic risks to the population health.

The earlier comparative reviews on risk assessment in monocities and rural settlements

of Orenburg region argue for the urgency of the problem.

Given the wide prevalence of carcinogens in environmental objects, an assessment of their complex impact is of particular interest.

Materials and methods. In order to identify the degree of exposure to pollutants contained in atmospheric air and drinking water, being carcinogenic to humans according to the classification of the International Agency for Research on Cancer (IARC), we assessed carcinogenic health risks for population living in cities with industrial enterprises as economic bases (Novotroitsk, Mednogorsk), and rural settlements (Oktyabrskiy, Ilekkiy and Tyul'ganskiy districts). The assessment of carcinogenic risks to public health was carried out in compliance with the "Guidelines for assessment of public health risk from exposure to chemicals that pollute habitat" [4, 6, 10]. We studied the laboratory reports on environmental objects for the last 5 years. A total of 1,245 samples of atmospheric air and 1,897 samples of drinking water were analyzed.

We studied data of the Regional Information Fund for Socio-Hygienic Monitoring at the FBHI "Center for Hygiene and Epidemiology in Orenburg region", official statistical data forms of territorial body of the Federal State Statistics Service for Orenburg region, and data of the FGA "Orenburg Center for Hydrometeorology and Environmental Monitoring" for 2005-2013. Among the atmospheric air components studied at the fixed stations of "Orenburg Center for Hydrometeorology and Environmental Monitoring" (branch of FSBI "Hydrometeorology and Environmental Monitoring for Volga Region"), 8 pollutants (formaldehyde, benzo (a) pyrene, benzene, ethylbenzene, lead, chromium oxide (+6), nickel and cadmium) have carcinogenic properties; 15 carcinogens (benzo (a) pyrene, benzene, arsenic, nickel, lead, chrome, 2,4-D, chloroform, carbon tetrachloride, 1,2-dichloroethane, tetrachlorethylene, bromide dichloromethane, dibromochloromethane, bromoform, and trichlorethylene) were detected in drinking water. When assessing exposure, we used incidence factors of substances'

concentrations in various media. In the atmospheric air (29,440 samples) and the drinking water from the centralized water supply systems (6,521 samples), we assessed mean concentrations of substances subject to a long-term dynamic surveillance within the framework of socio-hygienic monitoring.

Results and discussion. When identifying hazard, it was found that the major origins of environmental pollution in Novotroitsk were the large enterprises of metallurgical industry, construction and food industries (LLC "Novotroitsk Construction Materials Plant "Argo", JSC "Ural Steel", JSC "Cement Plant", JSC "Novotroitsk Silicate Materials Plant", JSC "Novotroitsk Chromium Compounds Plant", LLC "Novotroitsk Meat Processing Plant", Novotroitsk Branch of OJSC "Uralektroremont Concern", JSC "Novotroitsk Bread Products Plant", LLC "Moloko"). In the city of Mednogorsk, the main origins of pollution are JSC "Mednogorsk Copper and Sulfur Plant", JSC "Mednogorsk Elektrotechnical Plant "Uralektro", cogeneration plant of Mednogorsk and LLC "Mednogorsk Brick Plant".

In the rural settlements territory, the main origins of environmental pollution are road transport, heat power and food industry enterprises, and agricultural companies.

Mednogorsk is located on the territory of 0.4 thousand km², the population for the period under study: 29.78 thousand people. Persons who have not reached working age make up 25% of the population, 60% are persons of working age and 15% - are over working age.

The area of Novotroitsk is 0.4 th. km², the population is 100.94 thousand people. According to the review of the population structure, 21% are older than the working age, 64% are in the working age, and 15% of the population – are under the working age.

Ilekskiy district has an area of 3.6 th. km², the average population: 23.89 thousand people. When studying the population structure, it was found that 23% were people under the working age, 52% were of the working age, 25% - older the working age.

Oktyabrskiy and Tyul'ganskiy districts occupy an area of 2.7 and 1.9 thousand km², respectively. The population for the period under study made 22.59 and 23.46 thousand people, respectively.

Data analysis on carcinogens found in the atmospheric air of Mednogorsk showed that the highest individual carcinogenic risks are made by chromium compounds (2.8×10^{-3} , share in the total carcinogenic risk 35.3%). The total life-long carcinogenic risk as a result of exposure to air pollutants is 3.31×10^{-3} , which is considered as unacceptable (Table 1).

In Novotroitsk, the highest individual carcinogenic risk was established for chromium (4.31×10^{-3} , 92.7%). For Novotroitsk, the total carcinogenic risk from carcinogens contained in the atmospheric air makes 4.65×10^{-3} , which is regarded as unacceptable carcinogenic risk (see Table 1).

The carcinogenic effect assessment for Oktyabrskiy district showed that the highest individual carcinogens risk in the atmospheric air was of chrome (6.2×10^{-4} , 46%) and arsenic (6.1×10^{-4} , 45%), which made 91% of the total carcinogenic risk equaling to 1.35×10^{-3} (Table 2).

In Ilekskiy district, the maximum share (82%) to the total carcinogenic risk accounts for chromium (ICR 4.15×10^{-3}). The total carcinogenic risk made 5.1×10^{-3} , which is evaluated as the unacceptable carcinogenic risk.

The highest individual carcinogenic risk from substances in the atmospheric air in Oktyabrskiy district was established for arsenic (1.3×10^{-3} , 78.5%). The second rank was for benzene (1.4×10^{-4} , 9%). The total carcinogenic risk for Oktyabrskiy district made 1.6×10^{-3} .

Analysis of carcinogenic risk from exposure to chemicals contained in drinking water showed that the maximum individual carcinogenic risk for the city of Mednogorsk was established for arsenic (3.8×10^{-4} , 59.1%) and chromium (2.2×10^{-4} , 33.5%). The total carcinogenic risk from chemicals contained in drinking water for Mednogorsk made 6.44×10^{-4} (Table 3).

Table 1

Life-long carcinogenic risk from exposure to chemicals in ambient air

Chemical Substance	Mednogorsk city		Novoroitsk city	
	ICR	Share, %	ICR	Share, %
Formaldehyde	1,15E-04	14,5	1,35E-04	2,90
Benz (a) pyrene	3,65E-07	0,0	1,58E-07	0,00
Benzene	1,14E-04	14,4	1,26E-05	0,27
Ethylbenzene	4,59E-06	0,6	3,85E-06	0,08
Styrene	1,55E-06	0,2	2,68E-06	0,06
Chromium	2,8E-03	35,3	4,31E-03	92,71
Lead	9,56E-07	0,1	0	0,00
Arsenic	1,04E-04	13,3	0	0,00
Soot	7,38E-05	9,3	1,74E-04	3,74
Nickel	1,34E-05	1,7	0	0,00
Cobalt	5,22E-05	6,6	0	0,00
Cadmium	2,00E-05	2,5	0	0,00
Chloroform	3,10E-06	0,4	8,00E-08	0,00
Carbon tetrachloride	8,44E-06	1,1	1,03E-05	0,22
Total risk	3,31E-03		4,65E-03	

Table 2

Life-long carcinogenic risk from exposure to chemicals in ambient air

Chemical Substance	Tyul'gansky district		Ilekskiy district		Oktyabrskiy district	
	ICR	Share, %	ICR	Share, %	ICR	Share, %
Formaldehyde	3,55E-05	2,63	9,05E-05	1,78	3,26E-05	2,04
Benz (a) pyrene	1E-07	0,01	4,46E-07	0,01	8,25E-08	0,01
Benzene	3,46E-06	0,26	7,12E-04	14,04	0,00014	8,74
Ethylbenzene	3,34E-07	0,02	0	0,00	2,24E-06	0,14
Styrene	3,96E-07	0,03	0	0,00	3,89E-07	0,02
Chromium	6,2E-04	45,94	4,146E-03	81,7	1,87E-05	1,17
Lead	1,72E-07	0,01	1,89E-06	0,04	1,89E-06	0,12
Arsenic	6,13E-04	45,39	0	0,00	1,3E-03	78,46
Soot	1,95E-05	1,45	0	0,00	2,91E-05	1,82
Nickel	4,07E-05	3,02	2,84E-06	0,06	2,43E-06	0,15
Cobalt	4,87E-06	0,36	2,67E-05	0,53	8,88E-05	5,55
Cadmium	2,66E-06	0,20	9,23E-05	1,8	0,000012	0,75
Chloroform	5,67E-06	0,42	0	0,00	2,12E-06	0,13
Carbon tetrachloride	3,61E-06	0,27	0	0,00	1,44E-05	0,90
Total risk	1,35E-03		5,1E-03		1,6E-03	

Table 3

Carcinogenic risk from exposure to chemicals in drinking water

Chemical Substance	Mednogorsk city		Novoroitsk city	
	ICR	Share, %	ICR	Share, %
Arsenic	3,8E-04	59,1	2,14E-04	61,85
Lead	4,32E-06	0,67	2,39E-06	0,69
Chromium	2,16E-04	33,5	1,2E-04	34,6
Beryllium	0	0,00	0	0,00
Cadmium	0	0,00	0	0,00
2.4 D	8,686E-07	0,13	0	0,00
Benz (a) pyrene	9,91E-06	1,54	0	0,00
Benzol	8,486E-06	1,32	0	0,00
Chloroform	2,242E-07	0,03	2,28E-06	0,66

End of Table 3

Chemical Substance	Mednogorsk city		Novoroitsk city	
	ICR	Share, %	ICR	Share, %
Carbon tetrachloride	1,931E-06	0,30	3,87E-06	1,12
1,2-Dichloroethane	1,04E-05	1,62	0	0,00
Tetrachlorethylene	9,509E-07	0,15	0	0,00
Bromodichloromethane	2,645E-06	0,41	2,42E-06	0,70
Dibromochloromethane	6,56E-06	1,02	1,09E-06	0,31
Bromoform	2,483E-07	0,04	1,08E-07	0,03
Ethynyl trichloride	4,086E-07	0,06	7,14E-09	0,00
DDT	9,714E-07	0,15	0	0,00
Total risk	6,44E-04		3,46E-04	

Table 4

Carcinogenic risk from exposure to chemicals in drinking water

Chemical Substance	Ilekskiy district		Oktyabrskiy district		Tyul'gansky district	
	ICR	Share, %	ICR	Share, %	ICR	Share, %
Arsenic	2,11E-04	35,4	8,16E-05	36,6	1,34E-04	72
Lead	4,05E-07	0,07	0	0	2,84E-06	1,5
Chromium	1,58E-04	26,5	4,8E-05	21,5	1,91E-05	10,3
Beryllium	2,46E-05	4,1	3,93E-06	1,76	8,49E-06	4,56
Cadmium	9,46E-06	1,6	2,93E-05	13,2	9,05E-07	0,49
2,4 D	1,04E-06	0,18	1,65E-07	0,07	0	0
Benz (a) pyrene	1,74E-04	29,2	4,92E-05	22,1	1,49E-05	8
Benzol	0	0	4,62E-07	0,21	0	0
Chloroform	9,3E-08	0,016	7,94E-08	0,036	3,49E-08	0,019
Carbon tetrachloride	1,98E-06	0,33	1E-06	0,45	2,79E-07	0,15
1,2-Dichloroethane	1,16E-05	1,9	5,85E-06	2,6	1,63E-06	0,87
Tetrachlorethylene	0	0	5,46E-07	0,25	3,4E-06	1,8
Bromodichloromethane	1,26E-06	0,21	6,38E-07	0,29	1,77E-07	0,095
Dibromochloromethane	2,13E-06	0,36	1,08E-06	0,48	3E-07	0,16
Bromoform	2,01E-07	0,034	1,02E-07	0,046	2,82E-08	0,015
Ethynyl trichloride	4,19E-07	0,07	2,04E-07	0,09	0	0
DDT	0	0	6,94E-07	0,31	0	0
Total risk	5,95E-04		2,23E-04		1,86E-04	

When assessing the carcinogenic risk in Novoroitsk, it was found that the highest individual carcinogenic risk was in arsenic (2.14×10^{-4} , 61.9%) and chromium (1.2×10^{-4} , 34.6%).

The total carcinogenic risk in Novoroitsk made 3.46×10^{-4} , which is regarded as the unacceptable carcinogenic risk to population (Table 3).

The assessment of carcinogenic risk in the Ilekskiy district territory showed that the highest individual carcinogenic risk was established for arsenic (2.11×10^{-4} , 35.4%), benz (a) pyrene (1.74×10^{-4} , 29.2%); chromium (1.58×10^{-4} , 26.5%). The total carcinogenic risk makes 5.95×10^{-4} (Table 4).

In the analysis of carcinogenic risk in Oktyabrskiy district, the highest individual carcinogenic risk was found in arsenic (8.16×10^{-5} , 36.6%), benz (a) pyrene (4.92×10^{-5} , 22.1%) and chromium (4.8×10^{-5} , 21.5%). The total carcinogenic risk equals to 2.23×10^{-4} (see Table 4).

In Tyul'gansky district, the highest individual risk was established for arsenic (1.34×10^{-4} , 72.0%) and chromium (1.91×10^{-5} , 10.3%). The total carcinogenic risk makes 1.86×10^{-4} (see Table 4).

In the analysis of the population risk, the highest population carcinogenic risk from exposure to air pollutants and drinking water was detected in Novoroitsk. The lowest population

risk from carcinogens in atmospheric air was typical for Tyul'ganskiy district; from pollutants in drinking water – for Oktyabrskiy district (Table 5).

Table 5

Population carcinogenic risk

Parameter	Tyul'ganskiy district	Ilekanskiy district	Oktyabrskiy district	Mednogorsk city	Novorossiysk city
Air	31,7	121,8	36,1	98,6	469,4
Water	14,0	5,3	4,2	19,2	34,9

The basic origin for uncertainties is related to incomplete information about all the polluting chemical carcinogens. When assessing the exposure, uncertainty is associated with the specifics of environmental monitoring, since such control takes place only over the priority pollutants identified for the entire territory of Orenburg region.

In determining carcinogenic risk of atmospheric air, the uncertainty is due to the fact that to assess risks we use concentrations obtained from the values of the maximum one-time concentrations, which is especially typical for sampling route sites. This affects overestimation of the total risk value.

It should be noted that when detecting arsenic in drinking water, sensitivity of the applied technique is higher than the reference level, which can lead to reassessment of individual risk, nevertheless, in the comparative analysis of territories under study, using the results is allowable.

Uncertainty in the present work is also related to conventionality of the selected exposure scenario, which does not fully take into account the specific aspects in daily activity of the population belonging to different age and sex groups, in particular, the time that the potentially exposed population stays in the territory under study.

Therefore, the obtained values of risk parameters in this paper can be considered as relative. The most accurate results in assessing the effect of environmental hazards to health can be really established only in the properly scheduled and targeted epidemiological studies, reducing the uncertainty levels (if possible) by using analytical and la-

boratory data, and developing scenarios that are closest to real situations.

Conclusions. Thus, as a result of risk assessment in monocities and rural settlements, it was found that the total carcinogenic risk from exposure to chemicals in the air is considered as unacceptable. Such risk requires urgent curative measures.

Carcinogenic risk of chemicals contained in drinking water, both in monocities, and rural settlements, is considered as acceptable, but for monocities it is 1.5-2.0 times higher.

Chromium took the leading role among carcinogens in the atmospheric air of monocities, for rural settlements these were arsenic and benzene.

Among carcinogens contained in drinking water, for rural settlements, chrome and benz(a)pyrene took the leading place, for monocities – arsenic.

The present research is practically important for optimizing and improving the SHM (sanitary and hygienic monitoring) system at the regional level in order to improve data collection system. It is necessary to work out regional programs and activities in assessment of economic damage to public health due to environment pollution.

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