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CARCINOGENIC SUBSTANCES IN THE ATMOSPHERIC AIR OF DNIPRO CITY AND RISK TO THE POPULATION

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Abstract. Carcinogenic substances in the atmospheric air of Dnipro city and risk to the population. Serdiuk A.M., Chernychenko I.O., Lytvychenko O.M., Babii V.F.,Kondratenko O.Ye., Hlavachek D.O. *The objective – to study the dynamic changes for the health risk of the population of the industrial center in accordance with the state of atmospheric air pollution with carcinogenic compounds. The assessment of the state of atmospheric air pollution was carried out by us based on the results of physicochemical analysis of samples taken in places attached to the locations of stationary posts of state monitoring. The concentration of identified substances was determined by conventional methods: spectral-luminescent and gas chromatographic. Heavy metal concentrations were determined using data from the Central Geophysical Observatory of the Ministry of Emergency Situations. The calculation of the inhalation load of chemical carcinogens and the risks associated with them (non-carcinogenic and carcinogenic) was carried out in accordance with domestic guidelines. The assessment of dynamic changes in the nature of atmospheric air pollution with a complex of carcinogenic substances was made 5 of them are constantly recorded at levels exceeding hygienic standards. When compared with the reference concentrations, all compounds are characterized by high coefficients, indicating the likelihood of their effect on the body's immune system, respiratory organs, malformations, etc. A high individual carcinogenic risk of the effect of chromium VI and nitrosamines was determined. A total carcinogenic risk is formed at levels of 2.5 – 3.9×10^{-3}, which should be considered as high; this requires development and implementation of preventive measures. On the territory of the industrial center, a high level of air pollution with increased carcinogenic and non-carcinogenic risk is stably registered.*

Реферат. Канцерогенные вещества в атмосферном воздухе г. Днепр и риск для населения. Сердюк А.М., Черниченко И.А., Литвиченко О.Н., Бабий В.Ф., Кондратенко Е.Е., Главачек Д.А. *Цель работы - изучение динамических изменений риска для здоровья населения промышленного центра в соответствии с состоянием загрязнения атмосферного воздуха канцерогенными соединениями. Оценка состояния загрязнения атмосферного воздуха проводилась нами по ретроспективным данным результатов физико-химического анализа проб, отобранных в местах, привязанных к пунктам расположения стационарных постов государственного мониторинга. Определение концентраций идентифицированных веществ проводилось спектрально-люминесцентным и газохроматографическим методами. Концентрации тяжелых металлов определялись по данным Центральной геофизической обсерватории Министерства по чрезвычайным ситуациям. Расчет ингаляционной нагрузки химических канцерогенов и обусловленного ими риска (неканцерогенного и канцерогенного) проводился в соответствии с отечественными методическими рекомендациями. Дана оценка динамических изменений характера загрязнения атмосферного воздуха комплексом канцерогенных веществ, 5 из которых постоянно регистрируются на уровнях, превышающих гигиенические нормативы. При сравнении с референтными концентрациями все соединения характеризуются высокими коэффициентами опасности, указывающими на вероятность их влияния на иммунную систему организма, органы дыхания, пороки развития и т.п. Определен высокий индивидуальный канцерогенный риск влияния хрома VI и нитрозаминов. Суммарный канцерогенный риск для населения формируется на уровнях 2,5 – 3,9×10^{-3} и квалифицируется как высокий, что требует разработки и внедрения профилактических мероприятий. На территории промышленного центра стабильно регистрируется высокий уровень загрязнения атмосферного воздуха с повышенным канцерогенным и неканцерогенным риском.*

The danger of air pollution to human health is no longer in doubt. However, the methods and criteria for assessing the negative impact continue to be the subject of discussion in the scientific literature [6, 7, 8, 9]. Until now, the state of the air environment is mainly assessed using hygienic indicators – maximum allowable concentration (MAC), total pollution indicators, etc. And, perhaps, this is enough to address environmental issues, and reasonable criteria are adequate.

However, in our opinion, this is not enough when it comes to human health and the need to determine the role of environmental factors in the formation of morbidity. To address this issue, risk indicators are more adequate - carcinogenic and non-carcinogenic [1, 5].

The aim of the work is to study the dynamic changes in the risk for the health of the population of the industrial center in accordance with the state of air pollution with carcinogenic compounds.

MATERIALS AND METHODS OF RESEARCH

Observations of the state of air pollution in the city of Dnipro, on the territory of which a number of powerful enterprises (ferrous metallurgy, coke chemistry, chemistry, etc.) operate with emissions that are included in the list of carcinogens directly to humans [3], were conducted by retrospective analysis of our own research and data obtained during the monitoring by the Central Geophysical Observatory of the Ministry of Emergencies of Ukraine.

Hazard assessment and identification of risks for the population caused by the identified air pollution of cities were carried out according to the international methodological approaches tested by us [2, 4].

RESULTS AND DISCUSSION

Analyzing the obtained data on the state of air pollution in the city of Dnipro, we can identify a number of features.

First of all, it should be noted the stable nature of the content of a complex of chemicals with proven carcinogenic properties in the air of the city.

Second, the quantitative parameters of the identified compounds during the almost a twenty-years' observation period are marked by fluctuations, which is associated with the intensity of industrial development (Table 1).

Table 1

Mean daily concentration of priority carcinogenic substances in atmospheric air of the city of Dnipro, mcg/m ^{3}

Compounds	Years of observation						
	2000	2003	2006	2009	2012	2015	2018
B*a*P	0.0036	0.0035	0.0052	0.0069	0.0061	0.0067	0.006
NDMA	0.048	0.057	0.061	0.063	0.069	0.058	0.054
NDEA	0.019	0.021	0.024	0.024	0.025	0.026	0.026
Cadmium	0.029	0.040	0.055	0.051	0.060	0.059	0.059
Nickel	0.07	0.11	0.10	0.11	0.12	0.11	0.12
Lead	0.270	0.350	0.290	0.290	0.340	0.350	0.380
Chromium VI	0.072	0.126	0.115	0.110	0.130	0.120	0.120
Formaldehyde, mg/m^3	0.0049	0.0068	0.0063	0.0069	0.0080	0.0070	0.0080

At the same time, noting the presence of chemical factors in the air and comparing their content with the maximum allowable concentration, it is possible to state only the degree of its pollution, and health hazards remain open. Answers to the latter can be obtained by comparing the determined concentrations with the indicators of reference concentrations (RfC), which, in contrast to the

MAC, were justified taking into account the effect of the compound on the human body. In addition, the calculated coefficients (HQ) and hazard indices (HI) characterize non-carcinogenic risk in both individual and total indicators and allow to identify and predict critical organs and systems where negative effects are likely to occur (Table 2).

Table 2

Criterion assessment of atmospheric air pollution in the city of Dnipro

Chemical compounds	Ratio of MAC excess					Ratio of RfC, (HQ) excess				
	MAC, mcg/m^3	year of observation				RfC, mcg/m^3	year of observation			
		2000	2006	2012	2018		2000	2006	2012	2018
B*a*P	0.001	3.6	5.0	6.0	6.0	0.001	3.6	5.0	6.0	6.0
NDMA	0.050	0.96	1.22	1.38	1.08	0.050	0.96	1.22	1.38	1.08
NDEA	0.015	1.26	1.6	1.66	1.7	0.015	1.26	1.6	1.66	1.7
Cadmium	0.3	0.09	0.18	0.20	0.19	0.02	1.45	2.75	3.0	2.95
Nickel	1.0	0.07	0.10	0.12	0.12	0.05	1.4	2.0	2.4	2.4
Lead	0.3	0.9	0.96	1.13	1.27	0.5	0.54	0.58	0.68	0.76
Chromium VI	1.5	0.048	0.07	0.086	0.08	0.1	0.72	1.1	1.3	1.2
Formaldehyde mg/m^3	3.0	1.6	2.00	2.66	2.7	3.0	1.6	2.00	2.66	2.66
∑		8.53	11.13	14.53	13.21		11.53	16.25	19.08	18.75

The analysis of the level of danger caused by air pollution in the city of Dnipro by carcinogenic compounds can be illustrated by the example of data obtained in 2018 (Table 3). Based on the fact that the hazard index, which determines the permissible levels, should not be higher than "1", then, according to table 3, all test substances, except for lead, are characterized by an inflated HQ. According to the international classification scale, the risk factor for the concentration of PD is defined as high (HQ=6.0), the rest of the compounds – alert (1.20-2.95), which requires the introduction of appropriate preventive measures for each level.

In general, the total level of non-carcinogenic risk of the studied compounds is 18.75 and includes the risk of damage to various organs and systems. Among somatic diseases, the danger of probable damage to the respiratory organs (HI=9.21), elevated levels of congenital malformations (HI=6.76), kidneys (HI=7.69), etc. is noteworthy. But of particular concern is the likelihood of dysfunction of the immune system (HI=11.06), changes in which can contribute to the development of various pathologies, and especially cancer. The latter is confirmed by indicators of the probable carcinogenic risk caused by the identified compounds (Table 4).

As can be seen from the table, the proportion of separate substances in the formation of carcinogenic risk is different. The most dangerous are nitrosamines and chromium VI, the individual risk of which is considered to be alarming; the carcinogenic risk of other substances is within acceptable limits. However, given that certain carcinogenic compounds are in the vast majority of substances of

unidirectional action on the effects on individual critical organs and systems, a more objective criterion for evaluation is the total risk indicator. The total carcinogenic risk for the population of Dnipro during the observation period is in the range of 2.5-3.9 cases of cancer per 1000 population and is considered according to the international classification [2] as high, which requires the development and implementation of precautionary measures.

Table 3

Assessment of carcinogenic risk for population of the city of Dnipro due to pollution of atmospheric air

Chemical compound	Mean daily average concentration of mcg/m^3	Reference concentrations of RfC, mcg/m^3	HQ	Critical organs and systems
B*a*P	0.006	0.001	6.0	Immune system, cancer, congenital defects
NDMA + NDEA	0.054+0.026	0.05+0.015	2.78	Kidneys, liver
Cadmium	0.059	0.02	2.95	Kidneys, cancer, respiratory organs, hormonal system
Nickel	0.12	0.05	2.4	Blood, respiratory organs, immune system, CNS, cancer
Lead	0.38	0.5	0.76	CNS, blood, congenital defects, kidneys, reproductive system
Chromium VI	0.12	0.1	1.20	Respiratory organs, cancer, liver,kidneys
Formaldehyde	0.008	0.003	2.66	Respiratory organs, immune system

Total risk, HI				
	HI total	18.75	HI blood	3.16
	HI respiratory organs	9.21	HI liver	2.78
	HI immune system	11.06	HI hormonal system	2.95
	HI congenital defects	6.76	HI CNS	3.16
	HI kidneys	7.69	HI reproductive system	0.76
	HI cancer	12.55		

Thus, the above data indicate a danger to the health of the population of Dnipro air pollution with carcinogenic compounds. In addition, it should be noted that in real conditions the degree of danger is somewhat higher, as the exposure dose of chemical carcinogens due to atmospheric air is only about 20%, and the main inhalation load in residential is (55.0%) and public non-industrial premises – (28.0%) [1]. However, in all cases, the primary link in the chain of formation of the inhalation load of chemical carcinogens on the body is polluted air, the struggle for the purification of which should be a priority for environmental services.

Table 4

Characteristics of carcinogenic risk due to pollution of atmospheric air of the city of Dnipro

Compounds	Years of observation						
	2000	2003	2006	2009	2012	2015	2018
B*a*P	4.0×10^{-6}	3.9×10^{-6}	5.8×10^{-6}	7.7×10^{-6}	6.8×10^{-6}	7.5×10^{-6}	6.6×10^{-6}
NDMA	6.7×10^{-4}	7.9×10^{-4}	8.5×10^{-4}	8.8×10^{-4}	9.7×10^{-4}	8.1×10^{-4}	7.6×10^{-4}
NDEA	8.2×10^{-4}	9.0×10^{-4}	10.3×10^{-4}	10.3×10^{-4}	10.7×10^{-4}	11.1×10^{-4}	9.9×10^{-4}
mg/m3	5.2×10^{-5}	7.2×10^{-5}	9.9×10^{-5}	11.0×10^{-5}	10.8×10^{-5}	10.6×10^{-5}	10.6×10^{-5}
Nickel	1.7×10^{-5}	2.6×10^{-5}	2.4×10^{-5}	2.8×10^{-5}	2.9×10^{-5}	2.8×10^{-5}	2.9×10^{-5}
Lead	3.2×10^{-6}	4.2×10^{-6}	3.5×10^{-6}	3.5×10^{-6}	4.1×10^{-6}	4.2×10^{-6}	4.6×10^{-6}
Chromium VI	8.6×10^{-4}	15.1×10^{-4}	13.8×10^{-4}	13.2×10^{-4}	15.6×10^{-4}	14.4×10^{-4}	14.4×10^{-4}
Formaldehyde, mg/m3	6.4×10^{-5}	8.9×10^{-5}	8.3×10^{-5}	9.1×10^{-5}	10.5×10^{-5}	9.2×10^{-5}	10.5×10^{-5}
Σ	2.5×10^{-3}	3.4×10^{-3}	3.5×10^{-3}	3.5×10^{-3}	3.9×10^{-3}	3.6×10^{-3}	3.4×10^{-3}

CONCLUSIONS

1. Highly active carcinogenic compounds are stably registered on the territory of the city of Dnipro, the priority of which are polycyclic aromatic hydrocarbons, nitrosamines and heavy metals.

2. Most dangerous substances in the process of formation of carcinogenic risk for the population are chromium VI and nitrosamines, which are products of exogenous synthesis from nitrogen-containing compounds, where nitrogen oxides play a leading role.

3. To control the state of air pollution, it is recommended to focus on the MAC indicators, and when determining the risk to human health – on the reference concentrations and indicators of non-carcinogenic and carcinogenic risk.

Conflict of interest. The authors declare no conflict of interest.

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