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CONTAMINATION OF INDUSTRIAL CITY ATMOSPHERIC AIR AS AN ACTUAL ECOLOGICAL AND HYGIENIC PROBLEM

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Abstract. The article presents the results of a complex ecological and hygienic evaluation of atmospheric air quality of one of the most industrialized Ukrainian cities - Dnepropetrovsk. It is revealed, that dust, nitrogen dioxide, hydrogen sulfide, carbon monoxide, formaldehyde, phenol, ammonia and phenol are the main air pollutants of the city by the multiplicity of the hygienic standards (1.1-10.3 MPC). In accordance with an air pollution index the level of Dnepropetrovsk air pollution is characterized as high (API=11.02). Such situation, together with the identified pronounced processes of biological summation of pollutants negative influence (C_{CA}=3.77) may cause the increased risk of ecologically dependent diseases.

Key words: air pollution, negative influence, air quality, excess, hygienic standards.

I. Introduction.

Today atmospheric air is undergoing intensive technogenic pollution, which takes a global character almost in all countries of Europe, including our country [1]. Social and ecological situation, that has evolved in Ukraine in the recent years has led to deterioration of population's health and demographic situation in general. It should be emphasized that a complicated, unfavorable and in some regions even acute ecological situation has formed in Ukraine. Only 15.3% of the population live in

conditions of a low level of contamination, 52.8% - of moderate, 24.3% - of high and 7.6% - of a very high level of contamination [2].

Air pollution - a priority risk factor for health, because aerogenic way of harmful factors intake traditionally belongs to the most dangerous for humans [3, 4]. Usually the negative impact of xenobiotics on the human organism is complex, through all life-supporting environments, but most of all it is caused by aerogenic component. Such a situation is associated with a wide spectrum of pollutants in the atmospheric air and possibility of their high entering into organism due to a large volume of air consumption, their direct access into the blood, human is inability to individually control air quality. These circumstances give importance and informativity of studing of air pollutants impact on human health and substantiate it as a classic hygienic approach in evidence-based preventive medicine [5, 6, 7].

Unfortunately, despite the active implementation of air rehabilitation programs, a number of environmental protection measures that contribute to reducing harmful emissions, economic issues, disconnected work of various departments, absence of state strategy of information and analytical providing of management decisions led to the deterioration of chemical monitoring component [2, 4]. In such conditions, only improving quantitative defining of substances in the air, calculation of their average daily and annual concentrations, creating of a single network of information exchange about pollution and the exposed population, definition of risk to public health will allow to improve ecological and hygienic monitoring of air quality as an important part of a complex of preventive measures to preserve population's health [5, 6, 7, 8, 9].

II. Formulation of the problem.

The aim of research - complex ecological and hygienic evaluation of atmospheric air quality of Dnepropetrovsk - one of the most developed industrial city in Ukraine.

Materials and methods. Hygienic analysis of content of basic contaminants (dust, sulfur dioxide, nitrogen dioxide, carbon monoxide) and specific contaminants (hydrogen sulfide, phenol, ammonia, formaldehyde, benzopyrene, lead, cadmium,

manganese, chromium, nickel, copper, zinc) by average daily and maximum single concentration in the air of residential zone of Dnepropetrovsk for the period of 2006-2010 years was done.

Evaluation of air pollution was carriedout by values of actual pollutant content, ratio of exceeding the maximum permissible concentration (MPC), percentage of non-standard samples according to [10], and background levels for unpolluted areas.

In addition, the analysis of air pollution level by total air pollution index (API) was calculated by the formula [5, 10]:

$$In = \sum_{i=1}^{n} I_i = \sum_{i=1}^{n} (x_i/MPL_i)\, C_i, \qquad (1)$$

where In - index of air pollution by 5 priority pollutants, dimensionless value; X_i - average annual concentration of the corresponding substance; C_i – coefficient, which takes into account class of unsafety substance. Evaluation of results was conducted according to the existing classification [5].

Due to the simultaneous presence in the air of the following pollutants - sulfur dioxide, carbon monoxide, nitrogen dioxide and phenol, for which biological effect of summation is estimated [10], the coefficient of the combined action of these substances (C_{CA}) by the sum of their ratio MPC excess, which should not exceed 1, was calculated.

The results are processed by traditional methods of variation statistics using licenced statistical programs Statgraphics and Statistica 10.

III. Results and discussion.

Based on the results of previous studies [1, 8, 11] it was found that in the city of Dnipropetrovsk there was formed a complicated industrial complex, which in conditions of irrational infrastructure and growing powerful urbanization of the city forms a high level of pollution. It should be emphasized that diffuse location in the city of residential zone of industrial facilities, irrational location of the motorway network and complicated relief within the sanitary protection zones create unfavorable conditions for dispersion of atmospheric contaminants and as a

consequence - the formation of high levels of contamination of superficial atmospheric layer.

The most active pollutants of the city atmosphere are the industrial enterprises of metallurgy, metalworking, chemical industry. Their total number is more than 200, they have 7,5 thousand stationary sources of air emissions, of them 6600 sources (89%) - organized. Motor transport makes a significant contribution into the total air pollution in cities - 40% of all emissions [11, 12].

The foregoing creates an extremely complicated ecological situation in the city, being confirmed by the results of the research. Thus in general for five years follow-up (Table 1) the average daily values of formaldehyde, nitrogen dioxide, dust and benzopyrene in the air were 0.009±0.00002 mg/m^3, 0.08±0.001 mg/m^3, 0.25±0.003 mg/m^3 and 1.1±0.18•10^{-6} mg/m^3 respectively, exceeding the existing hygiene standards by 3.0, 2.0, 1.7 and 1.1 times; this puts the above-mentioned substances into the rank of major air pollutants in Dnepropetrovsk. At the same time the excess of the MPC for these pollutants was observed in 55.5-100% of the samples, which characterizes the level of air pollution by this indicator as very dangerous and unacceptable. The content of ammonia in an average over 5 years of observation, was 0.039±0.0004 mg/m^3, which practically corresponds to the standard value. Nevertheless in 25% of samples ammonia content exceeded hygienic standards, which also characterized the state of air pollution by this compound as very dangerous. The remaining pollutants were determined at concentrations within 0.12-0.9 MPC, although excess hygienic standards was observed in 3.3-23.3% of samples. Only the content of sulfur dioxide and hydrogen sulfide in all studied samples did not exceed the established MPC.

Regarding the maximum single concentrations, their values for all studied pollutants constituted 0.03-10.3 MPC. The highest ratio of MPC exceeding is typical for hydrogen sulfide - 0.082 mg/m^3 (10.3 MPC), carbon monoxide - 30.0 mg/m^3 (6.0 MPC), dust - 2.0 mg/m^3 (4.0 MPC), phenol - 0.034 mg/m^3 (3.4 MPC); this correlates with relevant percentage of the most significant non-standard samples - 75-100% and characterizes the degree of air pollution with pollutants as unacceptable and very

dangerous. At the same time, despite the fact that the multiplicity of maximum permissible concentration of nitrogen dioxide occupies 5 rank place, the excess of hygienic standards was observed in 91.7% of samples. Only the content of sulfur dioxide practically corresponded to hygienical requirements over the whole period of observation.

Table 1

The content of pollutants in the air of Dnepropetrovsk (2006-2010 years)

Contaminants, mg/m^3	Indicators					
	the average daily concentration	share of MPC	% of samples exceeding the MPC	the maximum single concentration	share of MPC	% of samples exceeding the MPC
dust	0.25±0.003	1.7	98.3	2.0	4.0	90.0
SO_2	0.0059±0.0006	0.12	0	0.55	1.1	1.7
CO	2.24±0.018	0.75	3.3	30.0	6.0	91.7
NO_2	0.08±0.001	2.0	100	0.17	2.0	91.7
H_2S	0.0026±0.00007	0.33	0	0.082	10.3	100
phenol	0.0027±0.00004	0.9	23.3	0.034	3.4	75.0
NH_3	0.039±0.0004	0.98	25.0	0.34	1.7	11.7
formaldehyde	0.009±0.00002	3.0	93.3	0.098	2.8	28.3
benzopyrene ($\bullet 10^{-6}$)	1.3±0.18	1.3	55.0	-	-	-

Comparison of data regarding the number of samples exceeding the MPC by basic and specific pollutants revealed an interesting feature about the content of carbon monoxide and hydrogen sulfide in the air. The average annual daily concentration of these pollutants meet hygiene requirements, while their maximum single concentration almost in all investigated samples exceeds MPC. This fact perhaps testifies to the shortcomings of regulation of their content in the air and requires revision of existing standards for the harmonization of existing standards of the average daily and the maximum single concentration.

Summary results of studies of heavy metals content in the air of residential zone over the period of 2006-2010, are presented in Table 2. These results indicate that the superficial layer of residential area of Dnepropetrovsk is determined by such metals as lead, cadmium, iron, manganese, copper, nickel, chromium and zinc. Their concentrations over the period of observation ranged from 0.005 mcg/m^3 for

chromium, to 0.087 mcg/m^3 for copper and on average do not exceed the respective MPC. However, content of most heavy metals with the exception of manganese and chromium in the air of Dnepropetrovsk is 2.4-30.0 times higher than background levels for uncontaminated areas confirming their technogenic origin [12].

Table 2

Average annual concentration of heavy metals in the air of Dnepropetrovsk (2006-2010 years), M±m

Metals	Indicators, mcg/m^3				
	actual content	MPC *	background concentrations	MPC, Russia**	MPC, WHO**
lead	0.028±0.0037	0.3	0.008-0.05	0.3	0.5-1.0
cadmium	0.006±0.0013	0.3	0.0002	0.2	1.0
manganese	0.053±0.007	1.0	0.013	1.0	1.0
chromium	0.005±0.0012	1.5	0.006	1.0	1.0
nickel	0.012±0.0036	1.0	0.005	0.2	1.0
copper	0.094±0.018	2.0	-	-	-
zinc	0.073±0.013	50.0	0.023	-	-
iron	0.072±0.012	4.0	-	-	-

Notes:* - SSR-201-97 [10]; ** - Sanitary norms. The Complete Reference. – M.: Eksmo, 2006. – P. 30-33 [13].

For a comprehensive hygienic analysis of air pollution it is important to estimate the dynamics of changes over the time. Thus, during the years 2006-2010 in the superficial layer of the city atmosphere was observed an increase of dust concentration by 1.4 times, phenol - 1.8 times ($p<0.001$), reduction of carbon monoxide by 1.3 times ($p<0.01$) (Figure 1, 2) and the relative stability of other pollutants content. To our opinion sustained growth of suspended parts content in the air may be caused both by increase in the intensity of traffic flows, that leads to increase of the amortization of the roadway and tires and increase of intensity of construction and restoration work in the city.

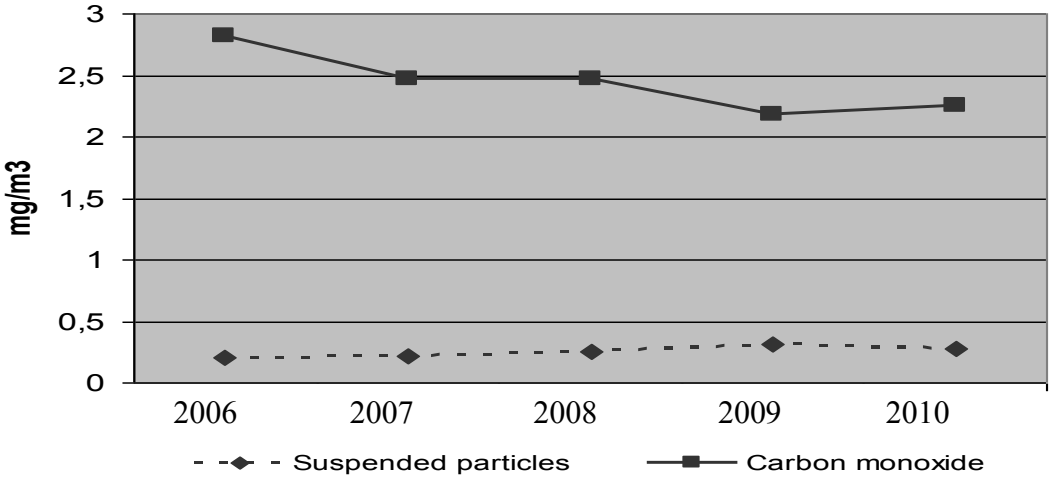

Fig. 1. Dynamics of changes of average annual concentrations of suspended particles and carbon monoxide in the air of Dnepropetrovsk

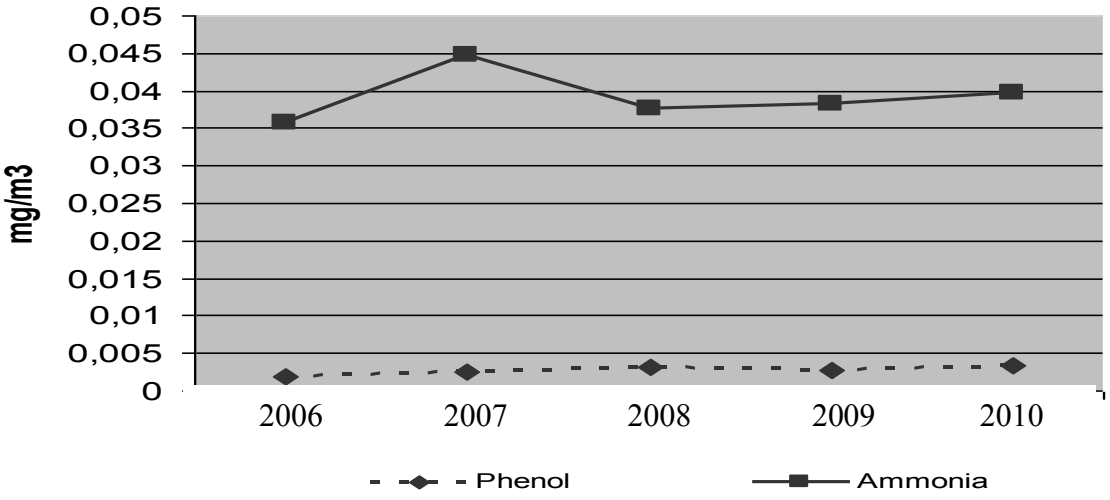

Fig. 2. Dynamics of changes of average annual concentrations of phenol and ammonia in the air of Dnepropetrovsk

At the same time reduction of carbon monoxide content may be associated with reduction of emissions of metallurgical enterprises and usage of more qualitative automobile fuel. As for the dynamics of the content of HM in Dnepropetrovsk air, then there was a slight increase of concentrations of almost all heavy metals, except cadmium and manganese. However, these changes are not reliable.

Air pollution index as an integral indicator of air pollution, was calculated by us by the average concentration of five most priority pollutants - formaldehyde, nitrogen dioxide, dust, benzopyrene and ammonia. During the analyzed period API was within

9,19-13,52 (Fig. 3), that characterizes the level of air pollution in Dnipropetrovsk as high (averaging API=11.02). Our results coincide with other studies [14], according

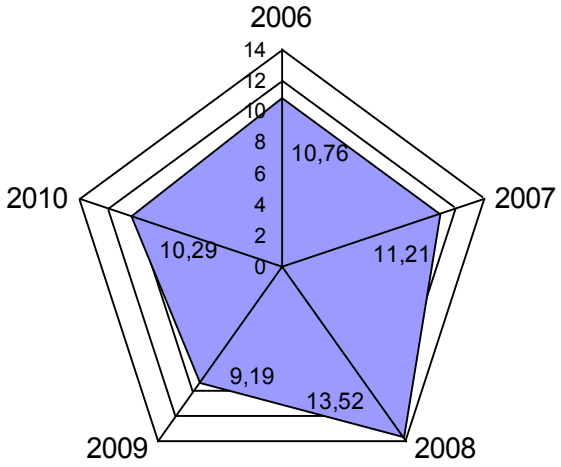

Fig.3. Index of air pollution of Dnepropetrovsk

to which the quality of air in Dnipropetrovsk ranks 14th among the most polluted cities in Ukraine. As the API is calculated by the average concentration of pollutants, it may serve as an indicator of chronic action of technogenic pollution of the city on public health [5] and used in the development of prognostic models.

Coefficient of the combined action (C_{CA}) at the simultaneous presence of sulfur dioxide, carbon monoxide, nitrogen dioxide and phenol in the air of Dnepropetrovsk is 3.77, which considerably exceeds the regulated value ($C_{CA} \leq 1$) and testifies to a potential danger of combination of these toxicants in the existing concentrations to the health of inhabitants.

Thus, the results of the research testify that anthropogenic contamination of the environment of Dnepropetrovsk is varied and intense. For a number of pollutants exceeding of hygienic standards is determined both by average annual concentration and maximum single concentration. At the same time their simultaneous presence creates an increased and long-term technogenic load on the organism of residents, this increases the risk to human health, especially on its hypersensitive strata - pregnant women, children and the elderly [1].

IV.Conclusions

1. At the territory of Dnepropetrovsk a complicated industrial complex is formed, which causes pollution of superficial atmospheric layer with basic and specific

pollutants - dust, sulfur dioxide and nitrogen oxides, carbon monoxide, hydrogen sulfide, ammonia, phenol, formaldehyde, benzopyrene, heavy metals within the limits of 0.12-3.0 MPC by the average annual concentration and 0.03-10.3 MPC by the maximum single concentration.

2. Major air pollutants of Dnepropetrovsk, with the mean exceeding MPC and percentage of non-standard samples are dust, nitrogen dioxide, formaldehyde, phenol and ammonia (1.1-3.0 MPC by the average annual concentration), as well as dust, hydrogen sulfide, carbon monoxide, phenol (3.4-10.3 MPC by the maximum single concentration). The level of air pollution, according to these indexes is very dangerous and unacceptable.

3. Concentrations of heavy metals in the atmosphere of the city meet hygiene requirements, although they are 2.4-30.0 times higher than background levels for uncontaminated areas, confirming their technogenic origin.

4. In the dynamics of time there is a relative stability of contents of the most pollutants in the air of Dnepropetrovsk. Exception is 1.3 times decrease of carbon monoxide content with increase of concentrations of dust and ammonia by 1.4-1.8 times.

5. The level of air pollution in the city of Dnepropetrovsk by integral indicator is characterized as high (API=11.02), which, along with the pronounced processes of biological summation of the pollutants negative impact (C_{CA} = 3.77), may cause a potential danger to the health of city residents and cause the increased risk of ecologically dependent diseases.

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